

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Mathematical expressions for reliability, availability, maintainability and maintenance support terms

Expressions mathématiques pour les termes de fiabilité, de disponibilité, de maintenabilité et de logistique de maintenance

IEC 61703:2016

<https://ecommerce.sist.si/catalog/standards/sist/3566e7a2-70bf-48ab-b63c-c268a8b6eec5/iec-61703-2016>



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2016 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Mathematical expressions for reliability, availability, maintainability and maintenance support terms

Expressions mathématiques pour les termes de fiabilité, de disponibilité, de maintenabilité et de logistique de maintenance

IEC 61703:2016

<https://ecommerce.sist.si/catalog/standards/sist/3566e7a2-70bf-48ab-b63c-c268a8b6eec5/iec-61703-2016>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 03.120.30; 21.020

ISBN 978-2-8322-3558-4

Warning! Make sure that you obtained this publication from an authorized distributor. Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.
--

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references.....	10
3 Terms and definitions	10
4 Glossary of symbols and abbreviations	13
4.1 General.....	13
4.2 Acronyms used in this standard	13
4.3 Symbols used in this standard	15
5 General models and assumptions	18
5.1 Constituents of up and down times	18
5.2 Introduction to models and assumptions	19
5.3 State-transition approach	20
5.4 Model and assumptions for non-repairable individual items	22
5.5 Assumptions and model for repairable individual items.....	23
5.5.1 Assumption for repairable individual items	23
5.5.2 Instantaneous repair	24
5.5.3 Non-instantaneous repair	25
5.6 Continuously operating items (COI) versus intermittently operating individual items (IOI).....	26
6 Mathematical models and expressions	27
6.1 Systems.....	27
6.1.1 General	27
6.1.2 Availability related expressions	29
6.1.3 Reliability related expressions	36
6.1.4 Mean operating time between failures [192-05-13] and mean time between failures.....	40
6.1.5 Instantaneous failure rate [192-05-06] and conditional failure intensity (Vesely failure rate).....	41
6.1.6 Failure density and unconditional failure intensity [192-05-08].....	44
6.1.7 Comparison of $\lambda(t)$, $\lambda_V(t)$, $z(t)$ and $f(t)$ for high and small MTTRs	47
6.1.8 Restoration related expressions	47
6.2 Non-repairable individual items.....	49
6.2.1 General	49
6.2.2 Instantaneous availability [192-08-01].....	50
6.2.3 Reliability [192-05-05]	50
6.2.4 Instantaneous failure rate [192-05-06]	51
6.2.5 Mean failure rate [192-05-07]	52
6.2.6 Mean operating time to failure [192-05-11].....	53
6.3 Repairable individual items with zero time to restoration	54
6.3.1 General	54
6.3.2 Reliability [192-05-05]	54
6.3.3 Instantaneous failure intensity [192-05-08].....	56
6.3.4 Asymptotic failure intensity [192-05-10]	58
6.3.5 Mean failure intensity [192-05-09].....	59
6.3.6 Mean time between failures (see 3.3)	60

6.3.7	Mean operating time to failure [192-05-11].....	60
6.3.8	Mean operating time between failures [192-05-13]	61
6.3.9	Instantaneous availability [192-08-01], mean availability [192-08-05] and asymptotic availability [192-08-07]	61
6.3.10	Mean up time [192-08-09]	61
6.4	Repairable individual items with non-zero time to restoration.....	62
6.4.1	General	62
6.4.2	Reliability [192-05-05]	62
6.4.3	Instantaneous failure intensity [192-05-08].....	64
6.4.4	Asymptotic failure intensity [192-05-10]	67
6.4.5	Mean failure intensity [192-05-09].....	68
6.4.6	Mean operating time to failure [192-05-11].....	69
6.4.7	Mean time between failures (see 3.3)	70
6.4.8	Mean operating time between failures [192-05-13]	71
6.4.9	Instantaneous availability [192-08-01].....	71
6.4.10	Instantaneous unavailability [192-08-04].....	73
6.4.11	Mean availability [192-08-05].....	74
6.4.12	Mean unavailability [192-08-06].....	76
6.4.13	Asymptotic availability [192-08-07]	78
6.4.14	Asymptotic unavailability [192-08-08].....	78
6.4.15	Mean up time [192-08-09]	79
6.4.16	Mean down time [192-08-10]	81
6.4.17	Maintainability [192-07-01]	82
6.4.18	Instantaneous repair rate [192-07-20].....	84
6.4.19	Mean repair time [192-07-21]	86
6.4.20	Mean active corrective maintenance time [192-07-22]	87
6.4.21	Mean time to restoration [192-07-23]	88
6.4.22	Mean administrative delay [192-07-26]	89
6.4.23	Mean logistic delay [192-07-27].....	90
Annex A (informative)	Performance aspects and descriptors	91
Annex B (informative)	Summary of measures related to time to failure	92
Annex C (informative)	Comparison of some dependability measures for continuously operating items.....	95
Bibliography		97
Figure 1 – Constituents of up time		18
Figure 2 – Constituents of down time.....		19
Figure 3 – Acronyms related to failure times		19
Figure 4 – Simple state-transition diagram.....		21
Figure 5 – Sample realization (chronogram) related to the system in Figure 4		22
Figure 6 – State-transition diagram of a non-repairable individual item		22
Figure 7 – Sample realization of a non-repairable individual item		23
Figure 8 – State-transition diagram of an instantaneously repairable individual item		24
Figure 9 – Sample realization of a repairable individual item with zero time to restoration		25
Figure 10 – State-transition diagram of a repairable individual item.....		25

Figure 11 – Sample realization of a repairable individual item with non-zero time to restoration	26
Figure 12 – Comparison of an enabled time for a COI and an IOI	26
Figure 13 – Equivalent operating time for IOI items	27
Figure 14 – State-transition graph for a simple redundant system	27
Figure 15 – Markov graph for a simple redundant system	28
Figure 16 – Evolution of the state probabilities related to the Markov model in Figure 15	28
Figure 17 – Evolution of $A(t)$ and $U(t)$ related to the Markov model in Figure 15	29
Figure 18 – Evolution of the $Ast_i(0, t)$ related to the Markov model in Figure 15	31
Figure 19 – Instantaneous availability and mean availability of a periodically tested item	33
Figure 20 – Example of a simple production system	34
Figure 21 – Evolution of $A(t)$ and $K(t)$	35
Figure 22 – Illustration of a system reliable behaviour over $[0, t]$	36
Figure 23 – Illustration of a system reliable behaviour over time interval $[t_1, t_2]$	37
Figure 24 – State-transition and Markov graphs for reliability calculations	37
Figure 25 – Evolution of the state probabilities related to the Markov model in Figure 24	38
Figure 26 – Evolution of $R(t)$ and $F(t)$ related to the Markov model in Figure 24	39
Figure 27 – Evolution of $Ast_i(0, t)$ related to the Markov model in Figure 24	40
Figure 28 – Time between failures versus operating time between failures	40
Figure 29 – Comparison between $\lambda(t)$ and $\lambda_V(t)$ related to the model in Figure 24	43
Figure 30 – Comparison between $z(t)$ and $f(t)$	46
Figure 31 – Comparison of $\lambda(t)$, $\lambda_V(t)$, $z(t)$ and $f(t)$ for high and small values of MTTRs	47
Figure 32 – Illustration of reliable behaviour over $[t_1, t_2]$ for a zero time to restoration individual item	55
Figure 33 – Sample of possible number of failures at the renewal time t	56
Figure 34 – Illustration of reliable behaviour over $[t_1, t_2]$ for a non-zero time to restoration individual item	62
Figure 35 – Evolution of $R(t, t + 1/4)$	64
Figure 36 – Sample of possible number of failures at the renewal time t	64
Figure 37 – Evolution of the failure intensity $z(t)$	66
Figure 38 – Evolution of the mean failure intensity $z(t, t + 1/4)$	69
Figure 39 – Illustration of available behaviour at time t for a non-zero time to restoration individual item	71
Figure 40 – Evolution of the instantaneous availability $A(t)$	73
Figure 41 – Illustration of unavailable behaviour at time t for a non-zero time to restoration individual item	73
Figure 42 – Evolution of the instantaneous unavailability $U(t)$	74
Figure 43 – Evolution of the mean availability $\bar{A}(t, t + 1/4)$	76
Figure 44 – Evolution of the mean unavailability $\bar{U}(t, t + 1/4)$	77
Figure 45 – Sample realization of the individual item state	80
Figure 46 – Plot of the up-time hazard rate function $\lambda_U(t)$	80
Figure 47 – Evolution of the maintainability $M(t, t + 16h)$	84
Figure 48 – Evolution of the lognormal repair rate $\mu(t)$	86

Figure A.1 – Performance aspects and descriptors	91
Table B.1 – Relations among measures related to time to failure of continuously operating items	92
Table B.2 – Summary of characteristics for some continuous probability distributions of time to failure of continuously operating items	93
Table B.3 – Summary of characteristics for some probability distributions of repair time	94
Table C.1 – Comparison of some dependability measures of continuously operating items with constant failure rate λ and restoration rate μ_R	95

SIST Preview
(<https://ecommerce.sist.si>)

[IEC 61703:2016](https://ecommerce.sist.si/catalog/standards/sist/3566e7a2-70bf-48ab-b63c-c268a8b6eec5/iec-61703-2016)

<https://ecommerce.sist.si/catalog/standards/sist/3566e7a2-70bf-48ab-b63c-c268a8b6eec5/iec-61703-2016>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MATHEMATICAL EXPRESSIONS FOR RELIABILITY, AVAILABILITY, MAINTAINABILITY AND MAINTENANCE SUPPORT TERMS

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61703 has been prepared by IEC technical committee 56: Dependability.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

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

- a) standard made as self containing as possible;
- b) item split between individual items and systems;
- c) generalization of the dependability concepts for systems made of several components;
 - introduction of the conditional failure intensity (Vesely failure rate);
 - introduction of the state-transition and the Markovian models;

- generalization of the availability to production availability;
- d) introduction of curves to illustrate the various concepts.

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

FDIS	Report on voting
56/1682/FDIS	56/1693/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.

This International Standard is to be used in conjunction with IEC 60050-192:2015.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

SIST Preview
(<https://ecommerce.sist.si>)

[IEC 61703:2016](#)

<https://ecommerce.sist.si/catalog/standards/sist/3566e7a2-70bf-48ab-b63c-c268a8b6eec5/iec-61703-2016>

INTRODUCTION

IEC 60050-192 provides definitions for dependability and its influencing factors, reliability, availability, maintainability and maintenance support, together with definitions of other related terms commonly used in this field. Some of these terms are measures of specific dependability characteristics, which can be expressed mathematically.

It is important for the users to understand the mathematical meaning of those expressions and how they are established. This is the purpose of the present International Standard which, used in conjunction with IEC 60050-192, provides practical guidance essential for the quantification of those measures. For those requiring further information, for example on detailed statistical methods, reference should be made to the IEC 60605 series [23]¹.

Annex A provides a diagrammatic explanation of the relationships between some basic dependability terms, related random variables, probabilistic descriptors and modifiers.

Annex B provides a summary of measures related to time to failure.

Annex C compares some dependability measures for continuously operating items.

The bibliography gives references for the mathematical basis of this standard, in particular, the mathematical material is based on references [2], [6], [8], [9], [13], [14] and [18]; the renewal theory (renewal and alternating renewal processes) can be found in [6], [8], [9], [10], [11], [13], [15], and [17]; and more advanced treatment of renewal theory can be found in references [1], [3], [12], [16], [19] and [20]. More information on the theory and applications of Markov processes can be found in references [3], [9], [10], [15], [16], [17] and [19].

(<https://ecommerce.sist.si>)

[IEC 61703:2016](#)

<https://ecommerce.sist.si/catalog/standards/sist/3566e7a2-70bf-48ab-b63c-c268a8b6eec5/iec-61703-2016>

¹ Numbers in brackets refer to the Bibliography.

MATHEMATICAL EXPRESSIONS FOR RELIABILITY, AVAILABILITY, MAINTAINABILITY AND MAINTENANCE SUPPORT TERMS

1 Scope

This International Standard provides mathematical expressions for selected reliability, availability, maintainability and maintenance support measures defined in IEC 60050-192:2015. In addition, it introduces some terms not covered in IEC 60050-192:2015. They are related to aspects of the system of item classes (see hereafter).

According to IEC 60050-192:2015, dependability [192-01-22] is the ability of an item to perform as and when required and an item [192-01-01] can be an individual part, component, device, functional unit, equipment, subsystem, or system.

To account for mathematical constraints, this standard splits the items between the individual items considered as a whole (e.g. individual components) and the systems made of several individual items. It provides general considerations for the mathematical expressions for systems as well as individual items but the individual items which are easier to model are analysed in more detail with regards to their repair aspects.

The following item classes are considered separately:

- Systems;
- Individual items:
 - non-repairable [192-01-12];
 - repairable [192-01-11]:
 - i) with zero (or negligible) time to restoration;
 - ii) with non-zero time to restoration.

In order to explain the dependability concepts which can be difficult to understand, keep the standard self-contained and the mathematical formulae as simple as possible, the following basic mathematical models are used in this standard to quantify dependability measures:

- Systems:
 - state-transition models;
 - Markovian models.
- Individual items:
 - random variable (time to failure) for non-repairable items;
 - simple (ordinary) renewal process for repairable items with zero time to restoration;
 - simple (ordinary) alternating renewal process for repairable items with non-zero time to restoration.

The application of each dependability measure is illustrated by means of simple examples.

This standard is mainly applicable to hardware dependability, but many terms and their definitions may be applied to items containing software.

2 Normative references

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

IEC 60050-192:2015, *International electrotechnical vocabulary – Part 192: Dependability* (available at <http://www.electropedia.org>)

ISO 3534-1:2006, *Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-192:2015, ISO 3534-1 and the following apply.

NOTE To facilitate the location of the full definition, the IEC 60050-192 reference for each term is shown [in square brackets] immediately following each term, for example:

mean time to restoration [192-07-23]

The terms and definitions given in Clause 3, which do not appear in IEC 60050-192, are used in order to facilitate the presentation of mathematical expressions of some IEC 60050-192 terms. Some terms have been taken from IEC 60050-192 and modified for the needs of this standard.

3.1

instantaneous restoration intensity

restoration intensity

restoration frequency

$v(t)$

limit, if it exists, of the quotient of the mean number of restorations [192-06-23] of a repairable item [192-01-11] within time interval $[t, t + \Delta t]$, and Δt , when Δt tends to zero, given that the item is as good as new at $t = 0$

$$v(t) = \lim_{\Delta t \rightarrow 0+} \frac{E[N_R(t + \Delta t) - N_R(t) | \text{as good as new at } t = 0]}{\Delta t}$$

where

$N_R(t)$ is the number of restorations in the time interval $[0, t]$;

E denotes the expectation.

Note 1 to entry: The difference between the restoration intensity and the repair rate comes from the conditions: the item is as good as new at time $t = 0$ for the restoration intensity and for the repair rate the repair starts at time $t = 0$. From a mathematical point of view, the restoration intensity is similar to the unconditional failure intensity (see 3.8).

Note 2 to entry: The unit of measurement of instantaneous restoration intensity is the unit of time to the power-1.

3.2

instantaneous repair rate

repair rate

$\mu(t)$

limit, if it exists, of the quotient of the conditional probability that the repair is completed within time interval $[t, t + \Delta t]$ and Δt , when Δt tends to zero, given that the repair started at $t = 0$ and had not been completed before time t

Note 1 to entry: The difference between the restoration intensity and the repair rate comes from the conditions: the item is as good as new at time $t = 0$ for the restoration intensity and for the repair rate the repair starts at time $t = 0$. From a mathematical point of view, the repair rate is similar to the failure rate (see 3.6).

[SOURCE: IEC 60050-192:2015, 192-07-20, modified — Note 1 to entry has been replaced and Note 2 to entry deleted]

3.3

mean time between failures

METBF

expectation of the time which elapses between successive failures

Note 1 to entry: The concept of mean time between failures has been omitted from IEC 60050-192. It was defined in IEC 60050-191 as “the expectation of time between failures”. The definition has been modified to explain the acronym METBF (mean elapsed time between failures) which is used in this standard to avoid any confusion between the mean time between failure (METBF) and the mean operating time between failures (MTBF or MOTBF).

[SOURCE: IEC 60050-191:1990, 191-12-08, modified — acronym and Note 1 to entry added]

3.4

up-time distribution function

function giving, for every value of t , the probability that an up-time will be less than, or equal to, t

Note 1 to entry: If the up-time is (strictly) positive and a continuous random variable, then $F_U(0) = 0$ and

$$F_U(t) = 1 - \exp\left(-\int_0^t \lambda_U(x) dx\right)$$

where

$\lambda_U(t)$ is the instantaneous up-time hazard rate function.

Note 2 to entry: The up-time distribution function is the general up-time distribution valid for both COI (continuously operating item) and IOI (intermittently operating item). For COIs, $F_U(t) = F(t)$

Note 3 to entry: If the up time is exponentially distributed, then

$$F_U(t) = 1 - \exp(-t/MUT)$$

where MUT is the mean up-time.

In this case, the reciprocal of MUT is denoted by λ_U and $\lambda_U = 1/MUT$

3.5

instantaneous up-time hazard rate function

up-time hazard rate function

$\lambda_U(t)$

limit, if it exists, of the quotient of the conditional probability that the up-time will end within time interval $[t, t + \Delta t]$ and Δt , when Δt tends to zero, given that the up-time started at $t = 0$ and had not been finished before time t

Note 1 to entry: The instantaneous up-time hazard rate function is expressed by the formula:

$$\lambda_U(t) = \lim_{\Delta t \rightarrow 0^+} \frac{1}{\Delta t} \frac{F_U(t + \Delta t) - F_U(t)}{1 - F_U(t)} = \frac{f_U(t)}{1 - F_U(t)}$$

where $F_U(t)$ is the up-time distribution function and $f_U(t)$ is the probability density function of the up-time.

Note 2 to entry: $\lambda_U(t)$ is the general hazard rate for the up times valid for both COI and IOI. For COIs, $\lambda_U(t) = \lambda(t)$ (see 3.6).

Note 3 to entry: If the up time is exponentially distributed, then the instantaneous up-time hazard rate function is constant in time and is denoted by λ_U .

Note 4 to entry: The unit of measurement of instantaneous up-time hazard rate function is the unit of time to the power –1.

3.6

instantaneous failure rate failure rate

$\lambda(t)$

limit, if it exists, of the quotient of the conditional probability that the failure of an item occurs within time interval $[t, t + \Delta t]$, by Δt , when Δt tends to zero, given that failure has not occurred within time interval $[0, t]$

Note 1 to entry: The instantaneous failure rate is expressed by the formula:

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

where $F(t)$ and $f(t)$ are, respectively, the distribution function and the probability density at 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 to entry: The restriction to non-repairable items in the definition provided by IEC 60050-192 can be removed to generalize this definition for any kind of items i.e. systems or individual items, repairable or not.

Note 3 to entry: The instantaneous failure rate is the up-time hazard rate for COIs. In this case, $\lambda(t) = \lambda_U(t)$ (see 3.5).

Note 4 to entry: When $\Delta t \rightarrow 0+$, the failure rate is the conditional probability per unit of time that the item fails between t and $t + \Delta t$, given it is in up state all over the time interval $[0, t]$. It is usually assumed that the item is as good as new at time 0.

Note 5 to entry: The instantaneous failure rate may be also expressed by the formula:

$$\lambda(t) = \lim_{\Delta t \rightarrow 0+} \frac{E[N(t + \Delta t) - N(t) | \text{up state over } [0, t]]}{\Delta t}$$

where $N(t)$ is the number of failures in the time interval $[0, t]$, where E denotes the expectation.

This form of the definitions allows comparisons of the failure rate to the conditional failure intensity and to the unconditional failure intensity.

[SOURCE: IEC 60050-192:2015, 192-05-06, modified — generalized to systems with repairable components and Notes to entry added]

3.7

conditional failure intensity Vesely failure rate

$\lambda_V(t)$

limit, if it exists, of the quotient of the mean number of failures of a repairable item within time interval $[t, t + \Delta t]$, by Δt , when Δt tends to zero, given that the item is in up state at time t and as good as new at time 0

Note 1 to entry: The instantaneous failure intensity is expressed by the formula:

$$\lambda_V(t) = \lim_{\Delta t \rightarrow 0+} \frac{E[N(t + \Delta t) - N(t) | \text{up state at } t \text{ and as good as new at time } 0]}{\Delta t}$$

where $N(t)$ is the number of failures in the time interval $[0, t]$, where E denotes the expectation.

Note 2 to entry: When $\Delta t \rightarrow 0+$, the conditional failure intensity is the probability per unit of time that the item fails between t and $t + dt$, given it is in up state at time t and as good as new at time 0. In particular cases (quick restoration of failures), it provides good approximations of the failure rate. This parameter introduced in 1970 by W. E. Vesely [26] is also called Vesely failure rate.

Note 3 to entry: According to the definitions, $\lambda_V(t)$ and $z(t)$ are linked by the formula: $\lambda_V(t) = z(t)/A(t)$. where $A(t)$ is the item instantaneous availability at time t .

3.8**unconditional failure intensity
instantaneous failure intensity
failure intensity
failure frequency** $z(t)$

limit, if it exists, of the quotient of the mean number of failures of a repairable item within time interval $[t, t + \Delta t]$, by Δt , when Δt tends to zero, given that the item is as good as new at time $t = 0$

Note 1 to entry: The instantaneous failure intensity is expressed by the formula:

$$z(t) = \lim_{\Delta t \rightarrow 0+} \frac{E[N(t + \Delta t) - N(t) | \text{as good as new at } t = 0]}{\Delta t}$$

where $N(t)$ is the number of failures in the time interval $[0, t]$, where E denotes the expectation and where the implicit condition that the item is as good as new at time $t = 0$ has been added.

Note 2 to entry: The unconditional failure intensity is the failure intensity as defined in IEC 60050-192:2015 [192-05-08]. It is also sometimes named ROCOF (rate of occurrence of failure).

Note 3 to entry: When $\Delta t \rightarrow 0+$, the unconditional failure intensity is the probability per unit of time that the item fails between t and $t + dt$ given that the item is in up state at time $t = 0$. Here the item may be in any state at time t and this is why the adjective unconditional is used.

Note 4 to entry: According to the definitions, $\lambda_v(t)$ and $z(t)$ are linked by the formula: $z(t) = A(t) \cdot \lambda_v(t)$ where $A(t)$ is the item instantaneous availability at time t .

[SOURCE: IEC 60050-192:2015, 192-05-08, modified — synonyms have been added and the entry has been revised]

3.9**continuously operating item
COI**

item for which operating time [192-02-05] is equal to its enabled time [192-02-17]

3.10**intermittently operating item
IOI**

item for which operating time [192-02-05] is less than its enabled time [192-02-17]

Note 1 to entry: In this case, the enabled time of the item is made of the sum of the times spent in the operating [192-02-04], idle [192-02-14] and standby [192-02-10] states.

4 Glossary of symbols and abbreviations**4.1 General**

The symbols and abbreviations given in Clause 4 are widely used and recommended, however, they are not mandatory. For consistency of presentation, the notation in this document may differ from that used in a referenced document.

4.2 Acronyms used in this standard

Acronym/abbreviation	Meaning
COI	Continuously operating item
IOI	Intermittently operating item
MACMT	Mean active corrective maintenance time, i.e. the expectation of the active corrective maintenance time