

Reliability testing - Compliance tests for constant failure rate and constant failure intensity

This document is a preview generated by EVS

EESTI STANDARDI EESSÕNA

NATIONAL FOREWORD

See Eesti standard EVS-EN 61124:2012 sisaldab Euroopa standardi EN 61124:2012 ingliskeelset teksti.	This Estonian standard EVS-EN 61124:2012 consists of the English text of the European standard EN 61124:2012.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 10.08.2012.	Date of Availability of the European standard is 10.08.2012.
Standard on kättesaadav Eesti Standardikeskusest.	The standard is available from the Estonian Centre for Standardisation.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 03.120.30, 19.020, 21.020

Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardikeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega:
Aru 10, 10317 Tallinn, Eesti; www.evs.ee; telefon 605 5050; e-post info@evs.ee

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation:
Aru 10, 10317 Tallinn, Estonia; www.evs.ee; phone 605 5050; e-mail info@evs.ee

English version

**Reliability testing -
Compliance tests for constant failure rate
and constant failure intensity
(IEC 61124:2012)**

Essais de fiabilité -
Plan d'essais de conformité d'un taux
de défaillance constant et d'une intensité
de défaillance constante
(CEI 61124:2012)

Prüfungen der Funktionsfähigkeit -
Prüfpläne für konstante Ausfallrate
und konstante Ausfalldichte
(IEC 61124:2012)

This European Standard was approved by CENELEC on 2012-06-27. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 56/1461/FDIS, future edition 3 of IEC 61124, prepared by IEC/TC 56 "Dependability" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61124:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-03-27
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-06-27

This document supersedes EN 61124:2006.

EN 61124:2012 includes the following significant technical changes with respect to EN 61124:2006:

- a number of new test plans have been added based on the Russian standard GOST R 27.402, and it is intended to align the new edition of MIL-HDBK-781 with this edition. Algorithms for optimizing test plans using a spreadsheet program are given and a number of optimized test plans are listed. Furthermore, emphasis is laid on the fact that the test should be repeated following design changes;
- discrepancies in test plans A, B as well as Annexes A and B that originated in IEC 60605-7, now withdrawn, have been corrected so these test plans differ from those given in previous edition of EN 61124. As requested by the National committees, mathematical background material and spreadsheet program information has been moved to informative annexes. In addition, the symbol lists have been divided, so that some annexes have separate lists of symbols;
- guidance on how to choose test plans has been added as well as guidance on how to use spreadsheet programs to create them. Test plans A.1 to A.9 and B.1 to B.13 have been corrected;
- Subclauses 8.1, 8.2, 8.3, Clause 9, Annex C, Clauses G.2, I.2, I.3 and Annex J are unchanged, except for updated terminology and references;
- corrections to the second edition proposed by National Committees have been implemented.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61124:2012 was approved by CENELEC as a European Standard without any modification.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-191	-	International Electrotechnical Vocabulary (IEV) - Chapter 191: Dependability and quality of service	-	-
IEC 60300-3-5	2001	Dependability management - Part 3-5: Application guide - Reliability test conditions and statistical test principles	-	-
IEC 60605-2	-	Equipment reliability testing - Part 2: Design of test cycles	-	-
IEC 60605-4	2001	Equipment reliability testing - Part 4: Statistical procedures for exponential distribution - Point estimates, confidence intervals, prediction intervals and tolerance intervals	-	-
IEC 60605-6	-	Equipment reliability testing - Part 6: Tests for the validity and estimation of the constant failure rate and constant failure intensity	-	-
IEC 61123	1991	Reliability testing - Compliance test plans for - success ratio	-	-

CONTENTS

FOREWORD.....	8
1 Scope.....	10
2 Normative references	10
3 Terms, definitions, abbreviations and symbols.....	11
3.1 Terms and definitions	11
3.2 Abbreviations and symbols	11
3.2.1 Abbreviations	11
3.2.2 Symbols	11
4 General requirements and area of application	13
4.1 Requirements	13
4.2 Applicability to replaced and repaired items.....	13
4.3 Types of test plans	13
4.3.1 General	13
4.3.2 Advantages and disadvantages of the different test plan types	14
5 General test procedure	14
5.1 Test conditions	14
5.2 General characteristics of the test plans	15
5.3 Data to be recorded.....	15
5.4 Calculation of accumulated test time, T^*	15
5.5 Number of failures	16
6 Sequential test plans	17
6.1 General	17
6.2 Common test procedure	17
6.3 Decision criteria	17
6.4 Overview of test plans	17
7 Fixed time/failure terminated test plans – Fixed duration test plans	18
7.1 General	18
7.2 Common test procedure	18
7.3 Decision criteria	19
7.4 Test plans	19
8 Design of alternative time/failure terminated test plans	20
8.1 General	20
8.2 Design procedures	20
8.3 Common test procedure	20
8.4 Decision criteria	21
9 Calendar time/failure terminated test plans for non-replaced items	21
9.1 General	21
9.2 Common test procedure	21
9.3 Decision criteria	21
9.4 Use of Table 2 of IEC 61123:1991 for fixed calendar time tests	22
9.4.1 General	22
9.4.2 Procedure when the test time is given	22
9.4.3 Procedure when the number of items is given	22
10 Combined test plans	23

10.1 General	23
10.2 Common test procedure	23
10.3 Decision criteria	23
10.4 Test plans	24
11 Performing the test	24
12 Presentation of results	24
Annex A (normative) Tables and graphs for sequential test plans	25
Annex B (normative) Graphs for fixed time/failure terminated test plans	44
Annex C (normative) Graphs for alternative time/failure terminated test plans	53
Annex D (normative) Tables and graphs for combined test plans and additional sequential test plans	60
Annex E (informative) Examples and mathematical references for sequential test plans	78
Annex F (informative) Design of sequential test plans using a common spreadsheet program	86
Annex G (informative) Examples and mathematical references for fixed time/failure terminated test plans – Fixed duration test plans	97
Annex H (informative) Design of fixed duration time/failure terminated test plans using a spreadsheet program	99
Annex I (informative) Examples and mathematical references for the design of alternative time/failure terminated test plans	105
Annex J (informative) Examples and mathematical references for the calendar time terminated test plans	112
Annex K (informative) Derivation and mathematical reference for the optimized test plans of GOST R 27 402	114
Bibliography	122
Figure A.1 – Accept and reject lines for test plan A.1	25
Figure A.2 – Test plan A.1 – Operating characteristic curve	26
Figure A.3 – Test plan A.1 – Expected accumulated test time to decision	27
Figure A.4 – Accept and reject lines for test plan A.2	27
Figure A.5 – Test plan A.2 – Operating characteristic curve	28
Figure A.6 – Test plan A.2 – Expected accumulated test time to decision	29
Figure A.7 – Accept and reject lines for test plan A.3	29
Figure A.8 – Test plan A.3 – Operating characteristic curve	30
Figure A.9 – Test plan A.3 – Expected accumulated test time to decision	31
Figure A.10 – Accept and reject lines for test plan A.4	31
Figure A.11 – Test plan A.4 – Operating characteristic curve	32
Figure A.12 – Test plan A.4 – Expected accumulated test time to decision	33
Figure A.13 – Accept and reject lines for test plan A.5	33
Figure A.14 – Test plan A.5 – Operating characteristic curve	34
Figure A.15 – Test plan A.5 – Expected accumulated test time to decision	35
Figure A.16 – Accept and reject lines for test plan A.6	35
Figure A.17 – Test plan A.6 – Operating characteristic curve	36
Figure A.18 – Test plan A.6 – Expected accumulated test time to decision	37
Figure A.19 – Accept and reject lines for test plan A.7	37

Figure A.20 – Test plan A.7 – Operating characteristic curve	38
Figure A.21 – Test plan A.7 – Expected accumulated test time to decision	39
Figure A.22 – Accept and reject lines for test plan A.8	40
Figure A.23 – Test plan A.8 – Operating characteristic curve	41
Figure A.24 – Test plan A.8 – Expected accumulated test time to decision	41
Figure A.25 – Accept and reject lines for test plan A.9	42
Figure A.26 – Test plan A.9 – Operating characteristic curve	43
Figure A.27 – Test plan A.9 – Expected accumulated test time to decision	43
Figure B.1 – Operating characteristic curves for test plans B.1, B.2, B.3 and B.4	44
Figure B.2 – Test plan B.1 – Expected test time to decision	45
Figure B.3 – Test plan B.2 – Expected test time to decision	45
Figure B.4 – Test plan B.3 – Expected test time to decision	46
Figure B.5 – Test plan B.4 – Expected test time to decision	46
Figure B.6 – Operating characteristic curves for test plans B.5, B.6, B.7 and B.8	47
Figure B.7 – Test plan B.5 – Expected test time to decision	47
Figure B.8 – Test plan B.6 – Expected test time to decision	48
Figure B.9 – Test plan B.7 – Expected test time to decision	48
Figure B.10 – Test plan B.8 – Expected test time to decision	49
Figure B.11 – Operating characteristic curves for test plans B.9, B.10 and B.11	49
Figure B.12 – Test plan B.9 – Expected test time to decision	50
Figure B.13 – Test plan B.10 – Expected test time to decision	50
Figure B.14 – Test plan B.11 – Expected test time to decision	51
Figure B.15 – Operating characteristic curves for test plans B.12 and B.13	51
Figure B.16 – Test plan B.12 – Expected test time to decision	52
Figure B.17 – Test plan B.13 – Expected test time to decision	52
Figure C.1 – Discrimination ratio, D , and the acceptable number of failures, $c = 0$ to 8, as a function of the expected number of failures, μ_0 , for recommended values, 2,5 %, 5 %, 10 %, 20 %, and 30 % of $\alpha = \beta$	56
Figure C.2 – Operation characteristic curves for $c = 0$ to 8; probability of acceptance P_a as a function of the (unknown) true expected number of failures, μ_0	57
Figure C.3 – Discrimination ratio, D , as a function of the expected number of failures, μ_0 , for recommended values, 2,5 %, 5 %, 10 %, 15 %, 20 % and 30 % of $\alpha = \beta$	58
Figure C.4 – Acceptable number of failures, c , minus expected number of failures, μ_0 ($\Delta\mu_0 = c - \mu_0$) as a function of the expected number of failures μ_0 for recommended values 2,5 %, 5 %, 10 %, 20 %, and 30 % of $\alpha = \beta$	59
Figure D.1 – Accept and reject lines	61
Figure D.2 – Expected test time to decision T_e^*	62
Figure D.3 – Expected test time to decision of acceptance $T_e^*(+)$	62
Figure D.4 – Operating characteristic P_a	62
Figure D.5 – Accept and reject lines	63
Figure D.6 – Expected test time to decision T_e^*	64
Figure D.7 – Expected test time to decision of acceptance $T_e^*(+)$	64
Figure D.8 – Operating characteristic P_a	64

Figure D.9 – Accept and reject lines	65
Figure D.10 – Expected test time to decision T_e^*	66
Figure D.11 – Expected test time to decision of acceptance $T_e^*(+)$	66
Figure D.12 – Operating characteristic P_a	67
Figure D.13 – Accept and reject lines	68
Figure D.14 – Expected test time to decision T_e^*	69
Figure D.15 – Expected test time to decision of acceptance $T_e^*(+)$	69
Figure D.16 – Operating characteristic P_a	69
Figure D.17 – Accept and reject lines	70
Figure D.18 – Expected test time to decision T_e^*	71
Figure D.19 – Expected test time to decision of acceptance $T_e^*(+)$	71
Figure D.20 – Operating characteristic P_a	71
Figure D.21 – Accept and reject lines	72
Figure D.22 – Expected test time to decision T_e^*	73
Figure D.23 – Expected test time to decision of acceptance $T_e^*(+)$	73
Figure D.24 – Operating characteristic P_a	73
Figure D.25 – Accept and reject lines	74
Figure D.26 – Expected test time to decision T_e^*	74
Figure D.27 – Expected test time to decision of acceptance $T_e^*(+)$	74
Figure D.28 – Operating characteristic P_a	75
Figure D.29 – Accept and reject lines	75
Figure D.30 – Expected test time to decision T_e^*	76
Figure D.31 – Expected test time to decision of acceptance $T_e^*(+)$	76
Figure D.32 – Operating characteristic P_a	76
Figure E.1 – Example of a sequential test using test plan A.3 – $\alpha = \beta = 10\%$, $D = 3$, $m_0 = 1,11 \times 10^6$ h; r versus $\frac{T^*}{m_0}$	80
Figure F.1 – SPRT spreadsheet graphing example	92
Figure F.2 – OC curve for probability of acceptance, P_a	95
Figure F.3 – Expected test time for making a decision	95
Figure H.1 – OC curve plotted from the spreadsheet calculations	104
Figure K.1 – Test plan types and terminology	115
Figure K.2 – Principle of test plans	117
Figure K.3 – Partitioning of the test plan graph	117
Figure K.4 – Interior nodes and border nodes	118
Figure K.5 – Paths to the accept line	118
Figure K.6 – Paths to the reject line	118
Figure K.7 – Probabilities of paths transfer between nodes	119

Figure K.8 – The recurrent element – Two cases	121
--	-----

Table 1 – Advantages and disadvantages for the different test plan types.....	14
Table 2 – Overview of the sequential test plans given in Annex A and D.....	18
Table 3 – Fixed time/failure terminated test plans	19
Table 4 – Combined test plans in Annex D.....	24
Table A.1 – Accept and reject lines for test plan A.1	26
Table A.2 – Accept and reject lines for test plan A.2	28
Table A.3 – Accept and reject lines for test plan A.3	30
Table A.4 – Accept and reject lines for test plan A.4	32
Table A.5 – Accept and reject lines for test plan A.5	34
Table A.6 – Accept and reject lines for test plan A.6	36
Table A.7 – Accept and reject lines for test plan A.7	38
Table A.8 – Accept and reject lines for test plan A.8	40
Table A.9 – Accept and reject lines for test plan A.9	42
Table D.1 – Sequential test plans in this annex.....	60
Table D.2 – Combined test plans in this annex	60
Table D.3 – Accept and reject lines.....	61
Table D.4 – Expected test time to decision and operating characteristic P_a	62
Table D.5 – Accept and reject lines.....	63
Table D.6 – Expected test time to decision and operating characteristic P_a	65
Table D.7 – Accept and reject lines.....	66
Table D.8 – Expected test time to decision and operating characteristic P_a	67
Table D.9 – Accept and reject lines.....	68
Table D.10 – Expected test time to decision and operating characteristic P_a	69
Table D.11 – Accept and reject lines.....	70
Table D.12 – Expected test time to decision and operating characteristic P_a	71
Table D.13 – Accept and reject lines.....	72
Table D.14 – Expected test time to decision and operating characteristic P_a	73
Table D.15 – Accept and reject lines.....	74
Table D.16 – Expected test time to decision and operating characteristic P_a	75
Table D.17 – Accept and reject lines.....	76
Table D.18 – Expected test time to decision and operating characteristic P_a	77
Table E.1 – Example for a sequential test using test plan A.3 (with example data).....	80
Table E.2 – Constants for border line formulae and their coordinates for sequential test plans A.1 to A.9	85
Table F.1 – Beginning of the spreadsheet prepared to obtain a sequential test graph	87
Table F.2 – Continuation of parameters calculation for the lines necessary for the SPRT graph.....	88
Table F.3 – Calculations of accept and reject line for the SPRT graph	88
Table F.4 – Determination of the test termination time	89
Table F.5 – Formulae for accept and reject line along with the test termination.....	91
Table F.6 – Spreadsheet set-up for construction of the OC curves for the SPRT.....	94

Table H.1 – Set-up of the spreadsheet with embedded formulae – Example	100
Table H.2 – Formulae embedded into the spreadsheet shown in Table H.1	101
Table H.3 – OC curve for the time/failure terminated fixed duration test	103
Table I.1 – Cumulative normal distribution for fixed u_γ values	111
Table I.2 – Inverse cumulative normal distribution for fixed $1-\gamma$ values	111

RELIABILITY TESTING – COMPLIANCE TESTS FOR CONSTANT FAILURE RATE AND CONSTANT FAILURE INTENSITY

1 Scope

This International Standard gives a number of optimized test plans, the corresponding operating characteristic curves and expected test times. In addition the algorithms for designing test plans using a spreadsheet program are also given, together with guidance on how to choose test plans.

This standard specifies procedures to test whether an observed value of

- failure rate,
- failure intensity,
- mean time to failure (MTTF),
- mean operating time between failures (MTBF),

conforms to a given requirement.

It is assumed, except where otherwise stated, that during the accumulated test time, the times to failure or the operating times between failures are independent and identically exponentially distributed. This assumption implies that the failure rate or failure intensity is constant.

Four types of test plans are described as follows:

- truncated sequential tests;
- time/failure terminated tests;
- fixed calendar time terminated tests without replacement;
- combined test plans.

This standard does not cover guidance on how to plan, perform, analyse and report a test. This information can be found in IEC 60300-3-5.

This standard does not describe test conditions. This information can be found in IEC 60605-2 and in IEC 60300-3-5.

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 60050-191, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

IEC 60300-3-5:2001, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

IEC 60605-2, *Equipment reliability testing – Part 2: Design of test cycles*

IEC 60605-4:2001, *Equipment reliability testing – Part 4: Statistical procedures for exponential distribution – Point estimates, confidence intervals, prediction intervals and tolerance intervals*

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

IEC 61123:1991, *Reliability testing – Compliance test plans for success ratio*

3 Terms, definitions, abbreviations and symbols

3.1 Terms and definitions

For the purposes of this document the terms and definitions given in IEC 60050-191 apply.

The terms "failure rate" and "failure intensity" are used as meaning constant failure rate and constant failure intensity.

3.2 Abbreviations and symbols

3.2.1 Abbreviations

MTBF	mean operating time between failures
MTTF	mean time to failure
OC	operating characteristic
SPRT	sequential probability ratio test (in some literature called probability ratio sequential test (PRST)).

3.2.2 Symbols

The generic symbol λ is used in the following for failure rate and failure intensity.

The symbol m is used to denote both the following reliability measures:

- mean operating time between failures, MTBF;
- mean time to failure, MTTF.

When used, the relationship between the above quantities, under the given assumptions, is:

$$\lambda = \frac{1}{m}$$

Sequential test plans (see Clause 6) and fixed time/failure terminated test plans (see Clause 7) are based on m as a reliability measure, thus in these cases:

$$m = \frac{1}{\lambda}$$

c	acceptable number of failures during the test
D	discrimination ratio; $D = m_0/m_1$ or $D = \lambda_1/\lambda_0$
k	summation variable for failures