SLOVENSKI STANDARD
oSIST prEN IEC 61124:2022

01-januar-2022

Preskušanje zanesljivosti - Ustreznostni preskusi za konstantno pogostost odpovedi in konstantno intenzivnost odpovedi

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

Prüfungen der Funktionsfähigkeit - Prüfpläne für konstante Ausfallrate und konstante Ausfalldichte

Essais de fiabilité - Plan d'essais de conformité d'un taux de défaillance constant et d'une intensité de défaillance constante

Ta slovenski standard je istoveten z: **prEN IEC 61124:2021**

ICS:

03.120.01	Kakovost na splošno	Quality in general
19.020	Preskuševalni pogoji in postopki na splošno	Test conditions and procedures in general
21.020	Značilnosti in načrtovanje strojev, aparatov, opreme	Characteristics and design of machines, apparatus, equipment

oSIST prEN IEC 61124:2022 **en**

56/1928/CDV

COMMITTEE DRAFT FOR VOTE (CDV)

PROJECT NUMBER: **IEC 61124 ED4**	
DATE OF CIRCULATION: **2021-10-29**	CLOSING DATE FOR VOTING: **2022-01-21**
SUPERSEDES DOCUMENTS: **56/1859/CD, 56/1877C/CC**	

IEC TC 56 : DEPENDABILITY	
SECRETARIAT: United Kingdom	SECRETARY: Mr Amit Patel
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	
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TITLE:

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

PROPOSED STABILITY DATE: 2024

NOTE FROM TC/SC OFFICERS:

Contents

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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International Standard IEC 61124 has been prepared by IEC technical committee 56: Dependability.

This fourth edition of IEC 61124 cancels and replaces the third edition, published in 2012, and constitutes a technical revision.

The main changes with respect to the previous edition are as follows:

a) The truncated sequential probability ratio test (SPRT) [1, 2, 3][1] has been significantly developed in recent years [4, 5, 6]. In this edition, type A test plans (optimally truncated SPRT) have been significantly changed, as follows:

   – the tests are significantly truncated (the maximal test time is low) without substantially increasing the expected accumulated test time to decision (ETT);

   – the true producer's and consumer's risks (α', β') are given and are very close to the nominal values;

   – the range of the test parameters is wide (risks and discrimination ratio);

[1] Numbers in square brackets refer to the bibliography.

232 – the test plans include various risk ratios (not restricted to equal risks only);
233 – the values of ETT are accurate and given in the relevant region (for practical use);
234 – guidelines for extension of the tests set (using accurate interpolation) are included.

235 b) Other ready-to-use test plans (types B, C, D) are not changed, only the form of
236 presentation of the data on their border lines and the characteristics has been changed.
237 This form is made unified for all types of test plans, which helps the comparison of
238 different plans and, accordingly, to facilitate the selection of the most appropriate.

239 c) FTFT design procedures, to extend the set of test plans B, are significantly changed and
240 make the design accurate and simple. The implementation of this design is given on a
241 spreadsheet program. A unified approach to the calculation of the operational
242 characteristics of all types of test plans is introduced.

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

FDIS	Report on voting
XX/XXXX/FDIS	XX/XXXX/RVD

244
245 Full information on the voting for the approval of this standard can be found in the report on
246 voting indicated in the above table.

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

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

251 • reconfirmed,
252 • withdrawn,
253 • replaced by a revised edition, or
254 • amended.

255

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256

INTRODUCTION

A compliance test is an essential part of the reliability assurance system [7, 8, 9]. Reliability is affected by many random factors, so its prediction is not accurate. The direct way to check if the item meets its reliability specifications is to perform a compliance test.

The tests described in this standard can be applied to objects that have a failure rate or failure intensity (denoted by λ) which can be considered as a constant. The procedures are based on the assumption that trials of the test are statistically independent. If it is necessary to test the constant failure rate/constant failure intensity assumption, the procedures given in IEC 60605-6 should be used.

The test serves to verify the compliance with a specified λ_0, that is, to verify that $\lambda \leq \lambda_0$.

The probability of making the correct decision in the test depends on the test duration and on the sample size (number of failures). The tests usually require a large sample size and, accordingly, a large consumption of time and funds. The consumptions are especially high for reliability testing. For this reason, sampling plans of the tests must be carefully planned in order to reduce the consumption.

This document is dedicated to sampling plans for the tests.

The tests are characterized by the operating characteristic (OC) and test duration until the test stops with the accept/reject decision on the compliance.

OC is the probability of accepting an item as meeting the requirements. In this document, the OC is represented by the coordinates of its two points (see ISO 3534-2 [10]):

– (λ_0, 1 – α) are the coordinates of the producer's risk point (PRP);

– (λ_1, β) are the coordinates of the consumer's risk point (CRP);

where α and β are producer's and consumer's risks, and $\lambda_1 > \lambda_0$.

The test duration (test time) is a random value and in this document is usually characterized by its expected (ETT) and maximum (MaxTT) values.

This document contains the following types of tests:

– optimally truncated sequential probability ratio test (SPRT, type A);

– maximally truncated SPRT (type C);

– fixed time/failure terminated test (FTFT, type B);

– FTFT – calendar time terminated test without replacement;

– combined test plan (type D).

The tests can be used for testing equipment (repaired or non-repaired) as well as for components (replaced or not replaced when failing).

All the plans in this standard are sequential, that is, every time an event occurs during the test, a decision is made to continue/stop the test. An event occurs in two cases: when a failure occurs, or when the acceptance boundary is crossed, which means that there is compliance with the requirements. The decision can be one of three types:

- accept the compliance and stop the test;
- reject the compliance and stop the test;
- continue the test, because there is not enough information to stop it.

The difference between the types of tests is in the shape of border lines.

The FTFT is characterized by decision rules for accepting or rejecting compliance when the MaxTT has been reached, or the acceptable number of failures has been exceeded. This test

has the smallest MaxTT among all tests with specified PRP and CRP. If for a tested object $\lambda \leq \lambda_0$, then ETT is close to MaxTT; otherwise, if $\lambda > \lambda_0$, then ETT decreases. In fact, the only advantage of the FTFT over the SPRT is the simplicity of designing new test plans. A detailed procedure for the design is provided in this standard.

Optimally truncated SPRT (type A) has a MaxTT of 1,1 to 1,2 times greater than FTFT with the same PRP and CRP. However, the ETT of the SPRT is significantly smaller than that of the corresponding FTFT, and for $\lambda \leq \lambda_0$ it can be 1,4 to 1,8 times smaller. This is a great advantage of the SPRT. This standard contains an extensive set of ready-to-use type A plans. The set also allows the design of additional tests by simple interpolation according to the procedure provided in the standard.

Maximally truncated SPRT (type C) has a MaxTT, like FTFT; however, its ETT is less than that of FTFT, but greater than that of type A SPRT.

In the combined test plan (type D), test items with early failures will not be rejected in the initial stages of the test.

Some of the ready-to-use tests listed in this standard have a very large maximal acceptable number of failures, which is why they are likely to be rarely used. However, the data allows the user of this document to assess the economic benefit of the OC test requirements and, in general, to assess the advisability of performing the test.

Accumulated test time can be reduced by accelerated testing (see IEC 62506 [12]).

An example of objects covered by this standard may be electronic equipment and its components, which usually have a failure rate or failure intensity that can be considered constant.

Clause 4 presents the requirements and area of application of the tests and recommendations for their selection. Clause 5 explains the general elements of the test procedure. Clause 6 explains the characteristics of the ready-to-use SPRT and the parameters of the border lines (their values are given in Annex A). Extension of the set of SPRT tests are given in Annex C. Clause 7 is devoted to the ready-to-use FTFT. Clause 8 presents the design of FTFT plans that are not covered in the tables of this standard. Mathematical references and procedures of the design of FTFT plans are given in Annex E and in Annex F. Clause 9 is devoted to the calendar FTFT for non-replaced items (examples and mathematical references of their design are given in Annex G). Clause 10 is devoted to the combined test plans (parameters of their border lines are given in Annex B). Clause 11 explains performing the test and presentation of results. Annex D presents the approximation of OC by Wald's formula. Annex H is devoted to the mathematical reference for the test plans of GOST R 27.402 [12].

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 border lines and characteristics. 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 operating 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 assumed to be constant.

Four types of test plans are described as follows:

– truncated sequential probability ratio test (SPRT);
– fixed time/failure terminated test (FTFT);
– fixed calendar time terminated test without replacement;
– combined test.

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 are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-192, *International Electrotechnical Vocabulary (IEV) – Chapter 192: Dependability.*

IEC 60300-3-5, *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 61123:2019, *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 60050-192 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

ADT accept decision time – time that the test was terminated with accept decision

CDF cumulative distribution function

CRP consumer's risk point

ETT expected accumulated test time to accept/reject decision

FTFT fixed time/failure terminated test

MaxTT maximal accumulated test time and accumulated truncation time of the test

MTBF mean operating time between failures

MTTF mean operating time to failure

OC operating characteristic

PDF probability density function

PRP producer's risk point

RDS reject decision segment – segment of time/failure line when the test was terminated with reject (see Figure 2)

SPRT truncated 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 operating time to failure, MTTF.

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

$$\lambda = 1/m$$

Test plans are based on m as a reliability measure; thus in these cases:

$$m = 1/\lambda$$

c acceptable number of failures during FTFT

D discrimination ratio; $D = m_0/m_1$ or $D = \lambda_1/\lambda_0$

m true MTBF or MTTF

m_j indexed m, where $j = \mathrm{L}, 1, \mathrm{M}, 0, \mathrm{H}$ (as in Figure 1 and in Table 3)

m_0 specified MTTF or MTBF, $m_0 = 1/\lambda_0$

m_1 lower limit for MTTF or MTBF, $m_1 = 1/\lambda_1$

n	number of test items at the beginning of the test
P_a	probability of acceptance
p_0	acceptable failure ratio
q_0	acceptable success ratio, $q_0 = 1 - p_0$
$R(t)$	reliability function
r	observed number of failures during the test
r_0	maximum number of failures where an “accept” decision is possible (see Figure 2)
r_e	expected number of failures to reach a decision
T^*	accumulated test time
T_a^*	accumulated test time stated as accept criterion (ADT)
$T_{a,min}^*$	minimum test time for $r = 0$ stated as accept criterion
T_e^*	expected accumulated test time to decision
$T_{e,j}^*$	indexed T_e^*, where j = L, 1, M, 0, H (which are related to the five values of m_j as in Figure 1)
$T_e^*(+)$	expected accumulated test time to acceptance
T_r^*	accumulated test time stated as reject criterion
T_t^*	accumulated test time stated as termination criterion for FTFT and MaxTT for A, C and D tests
t	test time
t^*	test time for each tested item
t_e^*	expected test time to decision
t_t^*	test truncation time
t_i	test time of failed item i
$t^*_{cal,t}$	calendar test time stated as termination criterion
R_D	optimization criterion, Formula (E.11)
R_R	optimization criterion, Formula (E.12)
$P(r)$	probability of r failures
α	producer’s risk (type I risk)
α'	true producer’s risk (type I risk)
β	consumer’s risk (type II risk)
β'	true consumer’s risk (type II risk)
λ	true failure rate per item
λ_0	specified expected failure rate per item (design goal)
λ_1	upper limit for constant failure rate per item

4 General requirements and area of application

4.1 Requirements and characteristics

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 assumed to be constant. Under this assumption, there is no difference between failure rate and failure intensity. Therefore, they are both called λ and referred to in the following as failure rate.

It is assumed that the requirement is specified in one of the terms: the acceptable constant failure rate or the acceptable mean number of failures per time unit, λ_0, or the acceptable mean operating time to failure or mean operating time between failures, m_0.

The tests are characterized by an operating characteristic (OC) and test time to decision.

The OC of a test is the probability of accepting an item as meeting the requirements (see example in Figure 3). The OC is a function of the true value of m, or of λ. In this standard, the OC is represented by the coordinates of its two points (by ISO 3534-2):

- (m_0, 1 – α) are the coordinates of the producer's risk point (PRP), or (λ_0, 1 – α);
- (m_1, β) are the coordinates of the consumer's risk point (CRP), or (λ_1, β).

The test time to reaching a decision regarding the test is a random value and in this standard is usually characterized by its expected (ETT) and maximum (MaxTT) values (see example in Figure 1). ETT is a function of the true value of m, or λ.

It is possible that special treatments will be required to ensure the constant failure rate or failure intensity, for example, screening for the elimination of early life failure period.

If it is necessary to test the constant failure rate/constant failure intensity assumption, the procedures given in IEC 60605-6 should be used.

4.2 Applicability to replaced and repaired items

The truncated sequential probability ratio test plans (see Clause 6), the time/failure terminated test plans (see Clause 7) and the combined test plans (see Clause 10) are applicable to the following:

– replacement of failed items;

– without replacement of failed items;

under the assumption that

– an item can be replaced by repair of the item itself;

– the accumulated test time is calculated as elapsed operating item-time, in accordance with Clausee 5.4;

– replaced items belong to the same population as the original items;

– repaired items can be considered to have the same failure intensity after repair as they had before they failed.

The calendar time/failure terminated test plans in Clause 9, however, are applicable to cases where failed items are not replaced and where a fixed number of items are placed on test for a fixed calendar time. This means that the test is running, even though the number of items under test may not remain constant because some items may not survive.

4.3 Types of test plans

4.3.1 General

Test plans are given for the following test types:

– optimally truncated SPRT (type A ready-to-use plans, see Clause 6);