INTERNATIONAL STANDARD

ISO/IEC 29121

Fourth edition
2021-01

Information technology — Digitally recorded media for information interchange and storage — Data migration method for optical disks for long-term data storage

Technologies de l'information — Supports enregistrés numériquement pour échange et stockage d'information — Méthode de migration de données pour disques optiques pour le stockage à long terme

Reference number
ISO/IEC 29121:2021(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 23, *Digitally Recorded Media for Information Interchange and Storage*.

This fourth edition cancels and replaces the third edition (ISO/IEC 29121:2018), which has been technically revised.

The main changes compared to the previous edition are as follows:

— ISO/IEC 16963 has been identified as the referee test method for the lifetime estimation;

— the ambient conditions for the measurement of maximum data error have been added;

— the requirements for test drives have been changed considering the use condition of users;

— the requirements for the estimated lifetime have been defined more clearly;

— the requirements for the periodic performance test have been defined more clearly.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Many organizations now use optical disks for long-term storage of information. It is assumed that a disk selected for recording has already been qualified for that purpose. It is therefore important to be able to verify that data have been recorded correctly and remains readable for the required amount of time. Previous International Standards clearly defined requirements for interchange, but they did not contain requirements for longevity.

Longevity is limited both by disk deterioration and by technology obsolescence. Interchange is regularly verified to assure that information on existing recorded disks will continue to be recoverable. Users can have a maintenance policy that protects disks against unanticipated failure or use, such as by making one copy, another to function as a backup or master and another for routine access. Hardware support life cycles typically vary between 5 and 10 years, and technology life cycles usually end after 20 years. Consequently, recordings that require a longer life cycle can have to be transferred to upgraded platforms every 10 to 30 years.

Optical disks for long-term storage should be evaluated. Significant longevity differences can exist for disks from different manufacturers and even between disks from the same manufacturer. It is preferable that disks selected for long-term preservation have a long-estimated lifetime, which can be estimated according to ISO/IEC 16963.

Disks with initially poor quality do not offer sufficient headroom and can reach the unrecoverable error threshold before the next scheduled inspection, which is to be avoided for long-term data storage. This means that a disk of high initial recorded quality that maintains this condition for life is expected to have superior longevity.

Because read data are corrected by an error correction decoder, it is impossible to detect deterioration without detecting the raw error rate or raw error number. The error rate measured before error correction is applied, which represents the raw error rate, can be detected with a standard test drive. The quality of the disk can be specified as the number of erroneous inner parity detections with DVD-R, DVD-RW, +R and +RW disks. The quality of a DVD-RAM disk is defined instead by its byte error rate. Deterioration can be monitored by checking the error rate and continues to be monitored. Methods described in this document define a quality-control policy that can non-destructively identify deterioration, and thereby support timely and effective corrective action.

DVD-R, DVD-RW, DVD-RAM, +R and +RW disks are based on the technology now widely known as DVD in the market. This entails the use of red laser diodes, two 0,6 mm thick substrates bonded together by an adhesive layer to protect the recording layer from dust, write-once (DVD-R, +R) or phase change recording layers (DVD-RW, DVD-RAM, +RW) and a 0,60 or 0,65 NA objective lens to ensure good spatial margins required for a professional data preservation. Disks having dual recording layers with a spacer between them are used in addition to those with a conventional single recording layer.

After the issuance of the previous edition of this document, ISO/IEC standards for the physical format of BD recordable and rewritable disks were published in 2013. ISO/IEC 16963 was also updated to include testing of BD recordable and rewritable disks in 2015. Accordingly, work started to include BD recordable and rewritable disks in this document. The BD data migration part of this work was standardized separately as ECMA-413. CD-R and CD-RW disks included in ISO/IEC 16963 are also incorporated. The error rate measured before error-correction is applied is also defined in each International Standard of CD-R, CD-RW, BD recordable and BD rewritable disk.

Information technology — Digitally recorded media for information interchange and storage — Data migration method for optical disks for long-term data storage

1 Scope

This document specifies the data migration method for DVD-R, DVD-RW, DVD-RAM, +R, +RW, CD-R, CD-RW, BD Recordable and BD Rewritable disks for long-term data storage. By applying this document for information storage, digital data can be migrated to a next new disk without loss from the present disk if data errors are completely corrected before and during the migration and provided copying of the data is allowed.

This document specifies:

— a data migration method for long-term data storage;

— test methods for measuring maximum data error, including ambient condition, test area, test drive, disk preparation and test execution;

— an initial performance test and a periodic performance test that check an error rate of data recorded on the disks with categorized maximum data error tables;

— precautions to reduce the possibility of deterioration in order to assure the integrity of the disks during their use, storage, handling or transportation; and

— the estimated lifetime of B_{mig} ($B_{0,000\ 1}$) life to determine the test interval for the periodic performance test.

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.

ISO/IEC 16963, *Information technology — Digitally recorded media for information interchange and storage — Test method for the estimation of lifetime of optical disks for long-term data storage*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
B_{mig} life
lifetime (3.9) for use of *data migration* (3.5) and identical to $B_{0.000\ 1}$ life which is 0,000 001 quantile of the lifetime distribution (i.e. 0,000 1 % failure time) or 99,999 9 % survival lifetime

Note 1 to entry: See Annex E.

3.2
B_5 life
5 percentile of the *lifetime* (3.9) distribution (i.e. 5 % failure time) or 95 % survival lifetime

[SOURCE: ISO/IEC 16963:2017, 3.4]

3.3
$(B_5 \text{ life})_L$
95 % lower confidence bound of B_5 *life* (3.2)

[SOURCE: ISO/IEC 16963:2017, 3.5]

3.4
B_{50} life
50 percentile of the *lifetime* (3.9) distribution (i.e. 50 % failure time) or 50 % survival lifetime

[SOURCE: ISO/IEC 16963:2017, 3.6]

3.5
data migration
process to copy data from one storage device or medium to another

3.6
error correction code
ECC
mathematical computation yielding check bytes used for the detection and correction of errors in data

Note 1 to entry: For DVD-R, DVD-RW, DVD-RAM, +R and +RW disks, the Reed-Solomon product code defined in ISO/IEC 16448 for DVD-ROM systems is applied. For BD recordable and BD rewritable disks, the long-distance code (LDC) + burst-indicating subcode (BIS) defined in ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192 and ISO/IEC 30193 is applied. For CD-R and CD-RW disks, the cross interleaved Reed-Solomon code (CIRC) and the Reed-Solomon Product-like Code (RSPC) defined in ISO/IEC 10149 are applied.

3.7
error rate
rate of errors or error count measured on the signal at the input of error-correction decoder, which represents raw-error rate of data recorded on a disk

3.8
initial performance test
first test of the *error rate* (3.7) of data recorded on a disk before storing

3.9
lifetime
time that information is retrievable in a *system* (3.18)

3.10
maximum byte-error rate
BER_{max}
greatest level of byte-error rate at any consecutive 32 *error correction code* (3.6) blocks in one of the relevant area on a disk as measured in the first pass of the decoder before correction

Note 1 to entry: BER_{max} is applied to DVD-RAM disks.

3.11
maximum C1 average 10
$C1_{ave\ 10,max}$
greatest level of C1 errors per second at the standard (1x) data transfer rate in one of the relevant area on a disk measured on the signal at the input of error correction decoder averaged over any 10 s

Note 1 to entry: See ISO/IEC 16963.

3.12
maximum data error
greatest level of *error rate* (3.7) anywhere in one of the relevant areas on the disk

[SOURCE: ISO/IEC 16963:2017, 3.13, modified — Note 1 to entry has been deleted.]

3.13
maximum parity inner sum 8
$PI_{sum\ 8,max}$
greatest revel of parity (of the) inner code error count at any consecutive 8 *error correction code* (3.6) blocks in one of the relevant area on a disk as measured in the first pass of the decoder before correction

Note 1 to entry: See ISO/IEC 16448, ISO/IEC 23912, ISO/IEC 17341, ISO/IEC 17342 and ISO/IEC 17344.

3.14
maximum random symbol error rate
$RSER_{max}$
greatest level of random symbol error rate measured on the signal in one of the relevant area on a disk at the input of error-correction decoder, which excludes burst errors of length greater than or equal to 40 bytes

Note 1 to entry: See ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192, ISO/IEC 30193 and ISO/IEC 16963.

3.15
periodic performance test
periodic test of the *error rate* (3.7) of data recorded on a disk during the storage

3.16
retrievability
ability to recover information as recorded

[SOURCE: ISO/IEC 16963:2017, 3.14]

3.17
system
combination of hardware, software, storage medium and documentation used to record, retrieve and reproduce information

[SOURCE: ISO/IEC 16963:2017, 3.20]

3.18
uncorrectable error
error in the read-out data that cannot be corrected by the error-correction decoders

3.19
X_{mig} interval
migration interval (year) which is determined by the user

Note 1 to entry: See Annex F.

4 General

Information is physically recorded on a disk as digital data. Although it is inevitable to cause errors in the physical recording process, error correction technologies can retrieve the physically recorded information completely from the read-out raw data with acceptable errors. If the errors in the read-out raw data exceed the error correcting capability, some of information is lost and the original information cannot be retrieved. The main cause of the errors is the physical deterioration of a disk. The deterioration can be measured by monitoring the error rate, and the original information can be migrated to a new disk in advance of an appearance of uncorrectable errors. Using the data migration method described in this document, the physically recorded information can be stored without loss of the original information, then the retrievability is maintained for a long time.

In order to check the error rate of data recorded on a disk, the maximum data error is measured using a test drive.

When data are recorded on a disk, the error rate shall be checked with the initial performance test. Depending on the test result of the initial performance test, the disk is judged to be used for long-term data storage.

The error rate of data recorded on those disks shall be periodically checked in the storage duration with the periodic performance test unless the data are migrated to the new disk before the first periodic performance test. Depending on the test result of the periodic performance test, the necessity of the data migration is judged.

In order to determine the test interval for the periodic performance test, B_{mig} life: (see Clause 6 for detailed definition) is used. ISO/IEC 16963 specifies an accelerated aging test method for estimating the lifetime of the retrievability of information stored on recordable or rewritable optical disks. ISO/IEC 16963 offers B_{50} life and B_5 life, and B_{mig} life is introduced using B_{50} life and B_5 life (see Annex E for detailed definitions). ISO/IEC 16963 shall be the referee test method for the lifetime estimation of disks and alternative test methods with equivalent statistical accuracy may also be applied, such as ISO/IEC 10995 for DVD disks or ISO 18927 for CD disks.

ISO/IEC 16963, ISO/IEC 10995 and ISO 18927 specifies the details of the accelerated test method. In case that the test conditions such as the acceleration conditions and/or the sample numbers are different from those specified in the standard, the estimated lifetime may be used on the condition that the statistical accuracy is maintained. Users of this document can determine the migration interval (X_{mig}) (Annex F for detailed specifications) with no relation to the estimated lifetime of the disk. In case the X_{mig} is introduced, follow the procedure defined in Annex F.

5 Test method for measuring maximum data error

5.1 Maximum data error for each disk

The maximum data error to be measured for a disk defined in each international standard is as follows:

For DVD-R disk defined in ISO/IEC 12862 and ISO/IEC 23912, DVD-RW disk defined in ISO/IEC 13170 and ISO/IEC 17342, +R disk defined in ISO/IEC 17344 and ISO/IEC 25434, and +RW disk defined in ISO/IEC 17341, ISO/IEC 26925 and ISO/IEC 29642, the each maximum parity inner sum 8 ($PI_{sum\ 8,max}$) shall be measured.

For DVD-RAM disk defined in ISO/IEC 17592, the maximum byte-error rate (BER_{max}) shall be measured (see Annex C for additional information).

For CD-R disk defined in ECMA-394 and CD-RW disk defined in ECMA-395, each maximum C1 average 10 ($C1_{ave\ 10\ ,max}$) shall be measured.

For BD recordable disk defined in ISO/IEC 30190 and ISO/IEC 30191 and BD rewritable disk defined in ISO/IEC 30192 and ISO/IEC 30193, each maximum random symbol error rate ($RSER_{max}$) shall be measured (see Annex H for additional information).

5.2 Ambient condition of maximum data error measurement

The ambient condition is the surrounding condition in a room where a test drive is located. The ambient conditions for the maximum data error measurement are as follows:

— temperature: 15 °C to 30 °C;

— relative humidity: 20 % to 75 %.

5.3 Test area and sample disk

The test area is the recorded area to be tested in a disk.

The whole recorded area of all disks shall be tested for the initial performance test.

The whole recorded area of all disks should be tested for the periodic performance test. Although the integrity of the data becomes lower, the user may reduce the test area and/or the number of sample disks based on a certain sampling method, considering the value of information (see Annex G for additional information). For the reduction of test area, see ISO/IEC 16963:2017, 7.5, for additional information. The number of sample disks should be enough to guarantee statistical effectiveness. If the sample disks have different attributes such as disk standards, recording conditions or storage conditions, the disks should be divided into groups of disks considering the attributes so that the sampling can be applied on each group with the statistical effectiveness.

5.4 Test drive

5.4.1 General

For DVD-R and DVD-RW disks, +R and +RW disks, the test drive shall have capability to measure $PI_{sum\ 8,max}$.

For DVD-RAM disk, the test drive shall have capability to measure BER_{max}.

For CD-R and CD-RW disks, the test drive shall have capability to measure $C1_{ave\ 10,max}$.

For BD recordable disks and BD rewritable disks, the test drive shall have capability to measure $RSER_{max}$.

The test drive shall have the capability to evaluate the error rate level specified in the initial performance test and the periodic performance test.

There are two cases of the test drive. One is that the drive serves both as a test drive and a recorder which records the data on the disk. The other is that the test drive is different from the recorder. For both cases, the data recorded on the disk by the recorder shall fulfil the error rate level specified in the initial performance test and the periodic performance test.

NOTE The measuring circuit for RSER described in ISO/IEC 30191 and ISO/IEC 30193 is different from that described in ISO/IEC 30190 and ISO/IEC 30192, especially in HF signal pre-processing circuit. See ISO/IEC 30190:2021, Annex H, and ISO/IEC 30191:2021, Annex H, for additional information.

5.4.2 Test drive check

The test drive shall be checked by using a reference disk prepared by the test drive manufacturer or the disk prepared by the user, so that it fulfils the requirements in 5.4.1. When using the reference disk prepared by the test drive manufacturer, the check of the test drive shall be done at the intervals recommended by the manufacturer. When using the disk prepared by the user, it is recommended for the user to set an appropriate interval and to check the test drive at the interval.

5.5 Disk preparation

Prior to conducting tests, the disks shall be checked that there is no dust, fingerprints or other contaminants on them. If there is dust, fingerprints or other contaminants, such contaminants shall be removed in accordance with the procedure recommended by the disk-manufacturer. Certain options are contained in Annex B. Microscopic examination can reveal physical deterioration, such as delamination and porosity of the protective coating.

5.6 Test execution

Before testing disks, the test drive shall be verified by the procedure defined in 5.4.2. If the drive does not pass the verification, the test drive shall not be used for the test.

On testing disks, care handling of the disks shall be taken in order to avoid introducing unexpected defects (see Annex I for additional information).

6 Test interval for periodic performance test

In order to determine the test interval for the periodic performance test, B_{mig} life is used.

B_{mig} life shall be calculated according to Annex E, and B_{50} life and B_5 life or B_{50} life and standard deviation, σ, shall be provided (see Clause 4). The test interval shall be determined according to Annex F.

In case B_{mig} life is not available as shown below, the test interval should be three years or less. Relaxation of the test interval causes the risk of data loss and failure in the data migration. In case such a risk is unacceptable, the test interval of three years or less is strongly recommended.

— The estimated lifetime data is not provided.

— The estimated lifetime data is provided but lacks the statistical accuracy.

The ambient storage-condition for the lifetime estimation should be controlled storage condition (temperature, T = 25 °C and relative humidity R_H= 50 %) or harsh storage condition (T = 30 °C and R_H = 80 %). The estimated lifetime is affected by the storage condition. If the actual storage condition is far from the controlled storage condition or harsh storage condition, the estimated lifetime may be adjusted (see Annex D for additional information).

The occurrence of retrievability problems can indicate a need for immediate testing.

When tests indicate deterioration of one disk, additional tests may be performed on the other disks of the same type, the same age or the same lot to ascertain their conditions. Replacement of all disks affected by similar conditions should be considered if such additional tests indicate significant problems.

7 Test result evaluation

7.1 Initial performance test

The initial error rate is categorized as Level 1, 2 or 3 according to the maximum data error as shown in Table 1.

At least, the initial error rate shall be within Level 1. Disks showing a Level 2 initial error rate should not be used. Disks showing a Level 3 initial error rate are out of the specification and shall not be used.

If the initial error rate is worse than Level 1, the performance of the disk and drive used for recording the data should be verified because the maximum data error depends on the performance of both disks and drives. If the drive is not good, the drive should be replaced. If the disk is not good, another lot of disks should be used.

