

JEDEC STANDARD

Solid-State Drive (SSD) Requirements and Endurance Test Method

JESD218B.01

(Revision of JESD218B, March 2016)

JUNE 2016

JEDEC SOLID STATE TECHNOLOGY ASSOCIATION



NOTICE

JEDEC standards and publications contain material that has been prepared, reviewed, and approved through the JEDEC Board of Directors level and subsequently reviewed and approved by the JEDEC legal counsel.

JEDEC standards and publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for use by those other than JEDEC members, whether the standard is to be used either domestically or internationally.

JEDEC standards and publications are adopted without regard to whether or not their adoption may involve patents or articles, materials, or processes. By such action JEDEC does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the JEDEC standards or publications.

The information included in JEDEC standards and publications represents a sound approach to product specification and application, principally from the solid state device manufacturer viewpoint. Within the JEDEC organization there are procedures whereby a JEDEC standard or publication may be further processed and ultimately become an ANSI standard.

No claims to be in conformance with this standard may be made unless all requirements stated in the standard are met.

Inquiries, comments, and suggestions relative to the content of this JEDEC standard or publication should be addressed to JEDEC at the address below, or refer to www.jedec.org under Standards and Documents for alternative contact information.

Published by
©JEDEC Solid State Technology Association 2016
3103 North 10th Street
Suite 240 South
Arlington, VA 22201-2107

This document may be downloaded free of charge; however JEDEC retains the copyright on this material. By downloading this file the individual agrees not to charge for or resell the resulting material.

PRICE: Contact JEDEC

Printed in the U.S.A.
All rights reserved

PLEASE!

DON'T VIOLATE
THE
LAW!

This document is copyrighted by JEDEC and may not be
reproduced without permission.

For information, contact:

JEDEC Solid State Technology Association
3103 North 10th Street
Suite 240 South
Arlington, VA 22201-2107

or refer to www.jedec.org under Standards-Documents/Copyright Information.

SOLID STATE DRIVE (SSD) REQUIREMENTS AND ENDURANCE TEST METHOD

Contents

1	Scope.....	1
2	Reference Documents	1
3	Terms, definitions, abbreviations, and technical background.....	2
3.2	Data Error	2
3.3	Data Retention	2
3.4	Endurance	2
3.5	Endurance failure	2
3.6	Endurance Rating (TBW rating).....	2
3.7	Erase block.....	3
3.8	Failure	3
3.9	Functional Failure	3
3.10	Functional Failure Requirement (FFR).....	3
3.11	Gigabyte (GB).....	3
3.12	Host	3
3.13	Host writes	3
3.14	Logical Block Address (LBA).....	3
3.15	Non-Volatile Memory (NVM).....	3
3.16	Page	3
3.17	Program/erase cycle (p/e cycle)	3
3.18	Qualification Family	4
3.19	Retention failure	4
3.20	Solid State Drive (SSD).....	4
3.21	Terabyte (TB)	4
3.22	Uncorrectable Bit Error Rate, or ratio (UBER)	4
3.23	Wear leveling.....	5
3.24	Workload	5
3.25	Write amplification factor (WAF)	5
4	General SSD Ecosystem Factors	6
4.1	Capacity.	6
4.2	Form Factors	6
5	Application classes and SSD Endurance Rating.....	6
5.1	Purpose of application classes	6
5.2	Definition of Application Classes.....	6
5.3	SSD Endurance Rating	7
5.4	Estimation of the SSD endurance rating.....	7
6	Endurance Test Method	8
6.1	Direct method	8
6.1.1	Sample Size and Acceptance Criteria	9
6.1.2	Categorization of failures.....	11
6.1.3	Endurance Stress Phase.....	11
6.1.4	High Temperature Retention Stress	14
6.1.5	Room temperature retention evaluation.....	15
6.2	Extrapolation method.....	16
6.2.1	Short Stroke Extrapolation Method	16
6.3	Endurance verification given alternative requirements.....	17
7	Apparatus and Precautions.....	17

7.1	Apparatus.....	17
7.2	Precautions.....	17
8	Summary	18
Annex A (normative): Calculations of Temperature-Accelerated Stress Times.....		19
Annex B (normative): Assessment of Room-Temperature Data Retention.....		21
Annex C (normative): SSD Capacity		23
C.1	SSD Capacity General Overview.....	23
C.2	LBA Counts from Advertised Capacity for Low Capacity Drives	24
C.2.1	LBA Counts from Advertised Capacity for Low Capacity Drives Overview	24
C.2.2	LBA Counts from Advertised Capacity for Low Capacity Drives with logical block size of 512 bytes	24
C.2.3	LBA Counts from Advertised Capacity for Low Capacity Drives with logical block size of 4096 bytes	24
C.3	LBA Counts from Advertised Capacity for High Capacity Drives	24
C.3.1	LBA Counts from Advertised Capacity for High Capacity Drives Overview.....	24
C.3	LBA Counts from Advertised Capacity for High Capacity Drives (cont'd).....	25
C.3.1	LBA Counts from Advertised Capacity for High Capacity Drives Overview (cont'd).....	25
C.3.2	LBA Counts from Advertised Capacity for 5xx High Capacity Drives	25
C.3.3	LBA Counts from Advertised Capacity for 4xxx High Capacity Drives	25
Annex D (informative): Estimated Retention Time for Nonstandard Active Use temperatures		26
Annex E (informative): Estimation of SSD Endurance Rating.....		27
Annex F (informative) - Differences between JESD218B and JESD218A.....		28

SOLID STATE DRIVE (SSD) REQUIREMENTS AND ENDURANCE TEST METHOD

(From JEDEC Board Ballot JCB-16-09, formulated under the cognizance of the JC-64.8 Subcommittee on Solid State Drives (Items 303.19, 303.20, 303.21, 303.22, 303.23, 303.26, 303.27, 303.28, and 303.32).)

1 Scope

This standard defines JEDEC requirements for solid state drives. For each defined class of solid state drive, the standard defines the conditions of use and the corresponding endurance verification requirements. Although endurance is to be rated based upon the standard conditions of use for the class, the standard also sets out requirements for possible additional use conditions as agreed to between manufacturer and purchaser.

Qualification of a solid state drive involves many factors beyond endurance and retention, so such qualification is beyond the scope of this standard, but this standard is sufficient for the endurance and retention part of a drive qualification. This standard applies to individual products and also to qualification families as defined in this standard.

The scope of this standard includes solid state drives based on solid-state non-volatile memory (NVM). NAND Flash memory is the most common form on memory used in solid state drives at the time of this writing, and this standard emphasizes certain features of NAND. The standard is also intended to apply to other forms of NVM.

2 Reference Documents

The revision of the referenced documents shall be that which is in effect on the date of the qualification plan.

JESD22-A117, *Electrically Erasable Programmable ROM (EEPROM) Program/Erase Endurance and Data Retention Stress Test*

JESD47, *Stress-Test-Driven Qualification of Integrated Circuits*

JEP122, *Failure Mechanisms and Models for Semiconductor Devices*

JESD219, *Solid State Devices (SSD) Endurance Workloads*

SFF-8447, *LBA Count for Disk Drives*

3 Terms, definitions, abbreviations, and technical background

3.1 Cycling pool

Erase blocks used by the SSD during read, write, or erase operations at a specific point in time.

NOTE The SSD may have additional erase blocks besides those in the current cycling pool that may be used as spares or for other purposes. The cycling pool is typically larger than the user-accessible LBA count.

3.2 Data Error

A type of failure in which the drive fails to return correct data to the host.

NOTE One data error occurs if a read of a logical sector causes the drive to return an unrecoverable error message or to return incorrect data. Data errors are counted as such even if they are transient. See 6.1.2 for further discussion of data errors.

3.3 Data Retention

The ability of the SSD to retain data over time. Synonymous with *retention* in this document.

3.4 Endurance

The ability of an SSD to withstand multiple data rewrites.

3.5 Endurance failure

A failure that is caused by endurance stressing.

NOTE 1 Endurance failures may be data error (3.1) types or functional failure (3.9) types.

NOTE 2 In an endurance stress, some failures may occur that are unrelated to endurance. For example, a solder joint could fail. A failure is considered unrelated to endurance if it was not caused by the endurance stress itself (i.e., if it was not caused by the repetitive writing of data to the drive). Such non-endurance failures are not considered as part of endurance verification.

NOTE 3 A number of distinct failure mechanisms are responsible for endurance failures, and in general these are accelerated in different ways by temperature and other adjustable qualification parameters. For example, in floating-gate memories failure may be caused by charge trapping (normally accelerated by lower temperatures) in the charge transfer dielectric or by oxide rupturing (normally accelerated by higher temperatures) in the transfer dielectric or in peripheral dielectrics. For these reasons, endurance may depend on temperature but it is not known *a priori* whether high temperature is worse than low temperature, or vice-versa.

3.6 Endurance Rating (TBW rating)

The number of terabytes that may be written to the SSD such that the SSD meets the requirements defined in 5.2.

NOTE 1 Several factors impact the endurance rating including how optimally the wear leveling has been implemented, write amplification factor and the cycling capability of the NAND components. The relationship between TBW, write amplification factor and the wear-leveling efficiency are highly dependent on the workload applied for the characterization of endurance.

NOTE 2 The TBW rating may also be expressed in an alternative form called drive-writes-per-day (DWPD), with the assumed lifetime also stated. The value of DWPD is $TBW/(C*Y*365)$, where TBW is the endurance rating in terabytes written, C is the capacity in terabytes, and Y is the lifetime in years that is stated along with the DWPD rating.

3.7 Erase block

The smallest addressable unit for erase operations, typically consisting of multiple pages.

3.8 Failure

The noncompliance of an SSD to the electrical or physical requirements specified for the device.

NOTE Failures may be permanent or transient. For the purpose of this standard, a permanent failure is an SSD that fails sometime during a reliability stress and continues to fail at the final test at the end of that same stress. A transient failure is an SSD that fails during a reliability stress but passes in the final test at the end of that stress.

3.9 Functional Failure

A failed drive that fails to function properly in a way that is more severe than having a data error.

NOTE See 6.1.2 for discussion of functional failures.

3.10 Functional Failure Requirement (FFR)

The allowed cumulative functional failures over the TBW rating. See 5.2.

3.11 Gigabyte (GB)

Approximately equal to 10^9 bytes when used in reference to SSD capacity. See Annex C (normative): SSD Capacity.

3.12 Host

The computer system, test system, or other device, which writes data to and reads data from the SSD.

3.13 Host writes

Data transmitted through the primary SSD interface to be written to the SSD.

3.14 Logical Block Address (LBA)

The logical address used to reference a data sector (block) in the drive.

NOTE 1 LBA is synonymous with the data sector itself.

NOTE 2 Block in the drive is a logical construct separate from that of an erase block in the NVM.

3.15 Non-Volatile Memory (NVM)

A memory which retains data after the power is turned off.

NOTE 1 Non-volatile memories considered in this standard are capable of being electrically rewritten.

3.16 Page

A sub-unit of an erase block consisting of a number of bytes which can be read from and written to in single operations, through the loading or unloading of a page buffer and the issuance of a program or read command.

3.17 Program/erase cycle (p/e cycle)

The writing of data to one or more pages in an erase block and the erasure of that block, in either order.

3.18 Qualification Family

A group of SSD products which differ only in storage capacity and in minor design details that are directly related to the capacity differences.

NOTE To be considered part of the same qualification family, SSD products must use the same nonvolatile memory products, or different nonvolatile memory products that are themselves part of the same component qualification family (defined in JESD47). The SSD products must also use the same controller and the same firmware, except to the extent that the firmware requires different settings to support the different capacities of the drives. The SSD products must also have the same ratio of TBW specification to capacity; for example, a 100 GB drive with a 100 TBW specification could be in the same family as a 50 GB drive with a 50 TBW specification. Due to the complexity of SSD designs, it is beyond the scope of this specification to completely define what constitutes a qualification family. The burden of proof falls upon the SSD manufacturer who chooses to use the qualification family concept.

3.19 Retention failure

A data error occurring when the SSD is read after an extended period of time following the previous write.

NOTE A number of distinct failure mechanisms are responsible for retention failures, and in general these are accelerated in different ways by temperature and other adjustable qualification parameters. For example, in floating-gate memories, failure may occur due to defects that allow charge to leak through the transfer dielectric or by the detrapping of charge in the transfer dielectric; the former can be weakly accelerated or even decelerated by high temperature, and the latter can be highly temperature accelerated (see JEP122). For these reasons, retention may depend on temperature but it is not known *a priori* whether high temperature is worse than low temperature, or vice-versa.

3.20 Solid State Drive (SSD)

A solid state drive (SSD) is a non-volatile storage device. A controller is included in the device with one or more solid state memory components. The device should use traditional hard disk drive (HDD) interfaces (protocol and physical) and form factors.

3.21 Terabyte (TB)

For the purpose of this standard, a terabyte is equal to $1 \cdot 10^{12}$ bytes.

3.22 Uncorrectable Bit Error Rate, or ratio (UBER)

A metric for the rate of occurrence of data errors, equal to the number of data errors per bits read. Mathematically,

$$UBER = \frac{\text{number of data errors}}{\text{number of bits read}} \quad (1)$$

NOTE Although the UBER concept is in widespread use in the industry, there is considerable variation in interpretation. In this standard, the UBER values for SSDs are to be *lifetime* values for the *entire population*. The numerator is the total count of data errors detected over the full TBW rating for the population of SSDs, or the sample of SSDs in the endurance verification. Multiple sectors containing corrupted data may be counted as a single data error if: 1) they occur at the same point in time in the endurance verification test; and 2) the quantity of corrupted data is 64KB or less. A data error is to be counted only once in the numerator, even if it is read multiple times and each time fails to return correct data. The denominator is the number of bits written at the TBW rating limit, which aligns to the usual definition of errors per bit read when the read:write ratio is unity. See 7.1.1 for a further discussion of UBER calculation.

3.23 Wear leveling

Methods employed by the drive to spread the p/e cycles across the NVM physical locations even when the workload may be unevenly distributed across the logical drive capacity.

3.24 Workload

The detailed sequence of host writes and reads (including data content and timing) applied to the drive during endurance testing. See JESD219 for specification of workload.

3.25 Write amplification factor (WAF)

The data written to the NVM divided by data written by the host to the SSD.

NOTE 1 For the purpose of calculating WAF, data written by the host is considered to be in multiples of drive capacity. For example, if 150GB of data is written to an SSD with capacity of 100GB, the data written by the host is considered to be 1.5. Also, data written to the NVM is considered to be the average number of p/e cycles experienced by NVM blocks in use in the SSD. For example, if the average number of p/e cycles is 3, then the data written to the NVM is considered to be 3. In this example, the WAF would be 2.

NOTE 2 Write amplification factor will depend on the workload and may vary over the lifetime of the device.