

JEDEC STANDARD

Solid-State Drive (SSD) Endurance Workloads

JESD219A.01

(Revision of JESD219A, July 2012)

JUNE 2022

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 2022
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.

sobco

SOLID STATE DRIVE (SSD) ENDURANCE WORKLOADS

(From JEDEC Board Ballot, JCB-12-16, formulated under the cognizance of the JC-64.8 Subcommittee on Solid-State Drives.)

1 Scope

This standard defines workloads for the endurance rating and endurance verification of SSD application classes. These workloads shall be used in conjunction with the Solid State Drive (SSD) Requirements and Endurance Test Method standard, JESD218.

2 Reference documents

JESD218, *Solid State Drive (SSD) Requirements and Endurance Test Method*

3 Terms and definitions

cluster: The minimum # of contiguous LBAs allocated by the host operating system.

Cold LBA Range: An LBA Range not referenced by a write or trim in a trace.

command trace: A trace of I/O commands.

compression: The process of scaling LBAs associated with commands in the Reference Trace to produce a Test Trace with a smaller LBA Range.

entropy: The non-compressibility of a data pattern when in file format such that 100% entropy has no reduction in file size and 50% entropy has approximately a 50% reduction in file size when converting to a zip file.

expansion: The process of scaling LBAs associated with commands in the Reference Trace to produce a Test Trace with a larger LBA Range.

footprint: A set of LBAs.

Free LBA Space: A set of LBAs within LBA Address Space, which are not currently allocated for data storage by the host OS.

LBA Address Space: The full set of user addressable LBAs on the device.

LBA Range: The set of contiguous LBA addresses bounded by the lowest and highest LBA of an addressed structure.

Maximum LBA: A value specifying the LBA number corresponding to the last LBA in the LBA Address Space.

Reference Trace: A command trace typical of a period of continuous drive operation in a typical client environment, from which Test Traces are derived.

3 Terms and definitions (cont'd)

PreCond%full: The % of clusters in LBA Address Space that are assigned to valid data on the device under test by the preconditioning process.

SSD_Capacity: See JESD218.

Test Trace: A command trace comprising I/O operations to a drive under test that is run during the test phase of a client workload.

Trim: A command from the host that identifies data that is no longer used by the operating system, allowing the memory space to be considered Free LBA Space by the drive.

4 Enterprise endurance workload

The enterprise endurance workload consists of random data distributed across an SSD in a manner similar to some enterprise workload traces that are publicly available for review.

Prior to running the workload, the SSD under test shall have the user-addressable LBA space filled with valid data (e.g., the drive does not return a data read error because of the content of the LBA prior to being written during the test routine). Initialization may not be necessary if the formatted SSD satisfies this requirement.

- a) The enterprise endurance workload shall be comprised of random data with the following payload size distribution:

512 bytes (0.5K)	4%
1024 bytes (1K)	1%
1536 bytes (1.5K)	1%
2048 bytes (2K)	1%
2560 bytes (2.5K)	1%
3072 bytes (3K)	1%
3584 bytes (3.5K)	1%
4096 bytes (4K)	67%
8192 bytes (8K)	10%
16,384 bytes (16K)	7%
32,768 bytes (32K)	3%
65,536 bytes (64K)	3%

- b) The data payloads greater than or equal to 4096 bytes data payload sizes shall be arranged such that the data payloads less than 4096 bytes are pseudo randomized among the data payloads greater than or equal to 4096 bytes. Data payloads greater than or equal to 4096 bytes are aligned on 4K boundaries.

4 Enterprise endurance workload (cont'd)

- c) The workload shall be distributed across the SSD such that the following is achieved:
- 1) 50% of accesses to first 5% of user LBA space (LBA group a)
 - 2) 30% of accesses to next 15% of user LBA space (LBA group b)
 - 3) 20% of accesses to remainder of user LBA space (LBA group c)
- d) To avoid testing only a particular area of the SSD, the distribution described in c) is offset through the user LBA space on different units under test such that all of the SSD LBAs are subjected to the highest number of accesses (e.g., SSD 1 has LBA group a applied to the first 5% of LBAs, SSD 2 has LBA group a applied to the next 5% of LBAs, etc).
- e) The write data payload size distribution shall be applied to each of the three LBA groups concurrently. The write sequence across the LBA groups may be applied in either a deterministic fashion or randomly, depending on the capabilities of the test tools, so long as the percentage of accesses to each LBA group conforms to those specified in [4c](#) and the LBA access shall be random (not sequential) within each LBA group. An example of a deterministic method is given in [Annex A.1](#) and an example of a random method is given in [Annex A.2](#).
- f) Random data is considered to have 100% entropy. The randomization of the data shall be such that if data compression/reduction is done by the SSD under test, the compression/reduction has the same effect as it would on encrypted data. It is acceptable to substitute a few bytes in each sector with metadata (such as the LBA number) or other information in place of the random data in those bytes if the addition of such information provides enhanced test interpretation capability. The random data for the payload may be generated by various means. An informative example script for generating the random data and the read/write distribution across LBA groups is provided in [Annex A.2](#). This script uses open-source software that may be found at vdbench.org.

5 Client endurance workload

5.1 Client endurance workload overview

The client endurance workload consists of a standard reference trace of standard ATA I/O commands, played back on the target device.

The standard TBW rating for a client drive shall be derived for and verified under the following workload conditions:

- a) PreCond%full = 100%;
- b) trim commands enabled; and
- c) random data pattern.

Additional TBW ratings may optionally be derived and verified for different values of these parameters; however, such ratings shall be reported only in addition to the standard TBW rating. See [clause 6](#) concerning extrapolation of non-standard TBW ratings.

5.1 Client endurance workload overview (cont'd)

The application of the client workload occurs in two phases:

1. Preconditioning Phase

The preconditioning phase establishes an initial pattern of free LBA distribution within the LBA Address Space of the drive under test. This phase creates the logical fullness of the drive at the start of the test phase, as defined by the PreCond%full parameter specified for the test.

The preconditioning phase comprises the following two steps.

- 1) Write once, sequentially, to the full LBA Address Space using random data (see 5.3.2). If additional TBW ratings are being determined with non-random data (see 5.3.3), non-random data shall be used for this step instead of random data.
- 2) Create Free LBA Space from the Maximum LBA contiguous to the lower LBA address corresponding to the PreCond%full value if the PreCond%full value is less than 100%.

2. Test Phase

The test phase stresses the drive in a manner that is representative of use during long-term operation in a client environment. The test phase comprises multiple runs of a Test Trace. The Test Trace has the same LBA footprint for each iteration.

During the test phase, a Test Trace, as specified in 5.2.2, is run repeatedly, per the methods specified in JESD218.

The client endurance workload traces referenced in this standard are contained in a trace library maintained by JEDEC.

5.2 Client Endurance Workload Traces

5.2.1 Reference Trace

A Reference Trace is a command trace from which all Test Traces within the SSD_Capacity range of the Reference Trace in the trace library are derived. It comprises drive input/output operations captured over extended period of time in a single user PC with an installed operating system that supports trim commands. The Reference Trace incorporates all I/O operations to a representative SSD, including those occurring during shutdown/boot and hibernate/restore activity. Operations include the following:

- a) write commands;
- b) trim commands¹;
- c) flush cache commands.

This Reference Trace should not be used to verify the endurance of SSD's utilized in cache applications since the workload may vary from the activity performed in the client workload Reference Trace.

¹ JESD219 refers to trim commands. Trim applies to the ATA command set. The equivalent of the trim command is defined in other interface standards (e.g., SCSI Unmap; NVMe Deallocate). If a device using a command set other than ATA is being tested, the relevant form of trim for the device's command set should be used by the test software.

5.2.1 Reference Trace (cont'd)

A Reference Trace may be scaled to produce Test Traces for use with a drive of any capacity within the SSD_Capacity range of the Reference Trace by means of compression or expansion. Compression or expansion is used to create a Test Trace with an LBA Range that almost spans the LBA address range of the drive to which it relates.

Compression is achieved by reducing the length of Cold LBA Ranges in the trace. Expansion is achieved by increasing the length of Cold LBA Ranges in the trace.

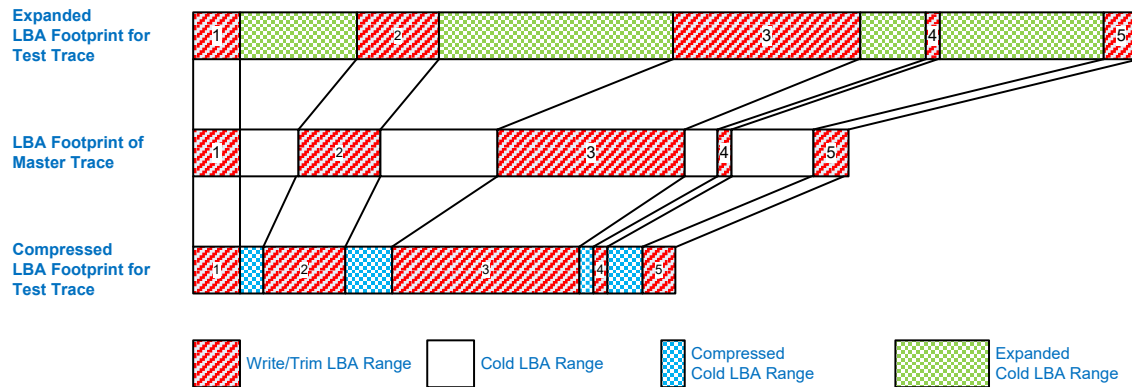


Figure 1 — Compression and Expansion of Reference Trace

If the Reference Trace has an LBA Range = M, and it is required to create a Test Trace with LBA Range = T, then the total length of Cold LBA Ranges within the Reference Trace is compressed (or expanded) by M-T in order to create the Test Trace.

If the total length of all the Cold LBA Ranges within the Reference Trace is C, then the length of each individual Cold LBA Range, of length > 20MB, shall be reduced by a fraction (M-T)/C, or increased by a fraction (T-M)/C, as appropriate. During reduction or expansion, the change in length of an individual Cold LBA Range should be a multiple of 4KB.

5.2.2 Test Trace

A Test Trace contains all commands that are present in the Reference Trace.

The LBA Range of a Test Trace almost spans the LBA address range of the drive to which it relates. A Test Trace for a specified SSD_Capacity parameter is derived from the Reference Trace with the use of compression or expansion if required.

The Test Trace may combine consecutive trim commands found in the Reference Trace into a single trim command.

Multiple Test Traces exist in the JEDEC trace library, each corresponding to a specific value of the SSD_Capacity parameter.