# Video Specifications

# Time Shift Buffer Hardware Specification

# OC-SP-TSB-I01-140611

## ISSUED

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# Document Status Sheet

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## Key to Document Status Codes

| | |
|---|---|
| **Work in Progress** | An incomplete document, designed to guide discussion and generate feedback that may include several alternative requirements for consideration. |
| **Draft** | A document in specification format considered largely complete, but lacking review by Members and vendors. Drafts are susceptible to substantial change during the review process. |
| **Issued** | A generally public document that has undergone Member and Technology Supplier review, cross-vendor interoperability, and is for Certification testing if applicable. Issued Specifications are subject to the Engineering Change Process. |
| **Closed** | A static document, reviewed, tested, validated, and closed to further engineering change requests to the specification through CableLabs. |

## Trademarks

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# 1 INTRODUCTION

## 1.1 Overview

The Time Shift Buffer (TSB) Specification provides the TSB memory, performance and hardware requirements for various products supplied by a variety of manufacturers. These TSB solutions are for devices which do not have a DVR already implemented, but require "trick play" capability often associated with a DVR. The TSB solutions are broken down as Client and Gateway depending on platform requirements. Client TSB solutions are further broken down by hardware interface for SD Card or USB. Each solution will have the same requirements for longevity and management.

## 1.2 Purpose of Document

This document defines specific requirements for Time Shift Buffer Solutions.

## 1.3 Organization of Document

The document is organized as follows:

Sections 1-4 present basic information, including references and acronyms.

Section 5 provides general background information for usage models for an SD Card use as the TSB.

Section 6 provides detailed requirements for flash memory TSB solutions.

## 1.4 Scope

This specification provides requirements regarding the hardware and host implementation for the non-DVR based Time Shift Buffer solutions, such that it operates as required within a network to provide services to MSO subscribers.

## 1.5 Requirements

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

| | |
|---|---|
| "MUST" | This word means that the item is an absolute requirement of this specification. |
| "MUST NOT" | This phrase means that the item is an absolute prohibition of this specification. |
| "SHOULD" | This word means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course. |
| "SHOULD NOT" | This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label. |
| "MAY" | This word means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item. |

# 2 REFERENCES

## 2.1 Normative References

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references.

All references are subject to revision, and parties to agreement based on this specification are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

| | |
|---|---|
| [CEN] | CENELEC EN 55022:2010 Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement and EN 55024:2010 Information technology equipment - Immunity characteristics - Limits and methods of measurement. |
| [FCC] | FCC CFR Title 47 Part 15 Subpart B. |
| [SD-Physical] | SD Publication Part 1, Physical Layer Specification, Ver 3.01 Final, February 18, 2010 or latest update. |
| [SD-Mechanical] | SD Publication Part 1, Standard Size SD Card Mechanical Addendum, Version 4.00 or later. |
| [USB] | Universal Serial Bus Specification Revision 2.0, April 27, 2000. |

## 2.2 Informative References

This specification uses the following informative references.

| | |
|---|---|
| [13818-1] | ISO/IEC 13818-1:2013, Information technology – Generic coding of moving pictures and associated audio information: Systems. |
| [14496-10] | ISO/IEC 14496-10:2012, Information technology – Coding of audio-visual objects – Part 10: Advanced video coding. |

## 2.3 Reference Acquisition

- Cable Television Laboratories, Inc., 858 Coal Creek Circle, Louisville, CO 80027;
  Phone +1-303-661-9100; Fax +1-303-661-9199; http://www.cablelabs.com
- SD Association, c/o Global Inventures, Inc., 2400 Camino Ramon, Suite 375, San Ramon, CA 94583 USA, Phone: +1.925.275.6615 Fax: 1.925.886.4870

  SDA Specs can be accessed at https://www.sdcard.org/downloads
- Federal Communications Commission, 445 12th Street SW, Washington, DC 20554, Phone: 1-888-225-5322, TTY: 1-888-835-5322, Fax: 1-866-418-0232

  FCC rules and regulations can be accessed here http://www.fcc.gov/encyclopedia/rules-regulations-title-47
- International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56 - CH-1211 Geneva 20, Switzerland, http://www.iso.org/iso/home/standards.htm
- CENELEC, 17, Avenue Marnix, B-1000 Brussels, Phone: +32 2 519 68 71M Fax: +32 2 519 69 19

  CENELEC specifications can be found here
  http://www.cenelec.eu/dyn/www/f?p=104:22:1780244011067308::::FSP_ORG_ID,FSP_LANG_ID:814,25#2

# 3 TERMS AND DEFINITIONS

This specification uses the following terms:

| | |
|---|---|
| **Multi-Level Cell (MLC) memory** | Stores two bits in each cell. By storing more bits per cell, a Multi-Level Cell memory card will have higher power consumption and lower cell endurance than a Single-Level Cell memory card. The advantage of Multi-Level Cell memory is the lower manufacturing cost. |
| **Single-Level Cell (SLC) memory** | Stores one bit in each cell, leading to faster transfer speeds, and higher cell endurance. The only disadvantage of Single-Level Cell is the manufacturing cost per MB, meaning that the SLC flash technology is used in high-performance memory cards where speed and reliability are important. |
| **Triple-Level Cell (TLC) memory** | Stores three bits in each cell. A Triple-level Cell memory card will typically have slower transfer speeds, higher error rates and significantly lower cell endurance than both Multi-level Cell and Single-level Cell memory cards. The advantage of Triple-level Cell memory is that it is the cheapest to produce. TLC flash technology is used mostly in low-end memory devices where speed and reliability are not important. Most "off-the shelf" inexpensive SD cards or USB flash memory devices use TLC technology. |
| **Trick Play** | A term used to describe the use of DVR time-shifted viewing with a TV Remote Control device. Features include fast forward, rewind and pause. |
| **Time Shift Buffer** | A buffer used to cache a duration of the current transport stream for use in pause, skip forward, skip back behavior. |
| **Wear Leveling** | A technique for prolonging the service life of some kinds of erasable computer storage media, such as flash memory used in solid-state drives (SSDs) and USB flash drives. There are a few wear-leveling mechanisms used in flash memory systems, each with varying levels of longevity enhancement. |
| **Write Amplification** | An undesirable phenomenon associated with flash memory and solid-state drives (SSDs) where the actual amount of physical information written is a multiple of the logical amount intended to be written. |

# 4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations:

| | |
|---|---|
| **CC** | Closed Caption |
| **CEA** | Consumer Electronics Association |
| **CLP** | Card Lock Password |
| **CMD42** | Command protocol for a Class 7 SD device |
| **COAM** | Customer Owned and Managed |
| **COP** | Card Ownership Password |
| **DVR** | Digital Video Recorder |
| **EIA** | Electronics Industry Association |
| **ESD** | Electrostatic Discharge |
| **FCC** | Federal Communications Commission |
| **GOP** | Group Of Pictures |
| **HD** | High Definition |
| **IEC** | International Electrotechnical Committee |
| **IEEE** | The Institute of Electrical and Electronics Engineers |
| **ISO** | International Organization for Standardization |
| **MLC** | Multi-Level Cell |
| **MSO** | Multiple System Operator |
| **MTBF** | Mean Time Between Failure |
| **P/E** | Program/Erase |
| **PiP** | Picture in Picture |
| **PNM** | Product Name |
| **RDK** | Reference Design Kit |
| **RF** | Radio Frequency |
| **RH** | Relative Humidity |
| **SD** | Secure Digital |
| **SLC** | Single-Level Cell |
| **SPTS** | Single Program Transport Stream |
| **STB** | Set-top Box |
| **TLC** | Triple-Level Cell |
| **TSB** | Time Shift Buffer |
| **USB** | Universal Serial Bus |
| **WA** | Write Amplification |

# 5 GENERAL

## 5.1 Nominal Performance and Endurance Calculations

This section is informative, and used to show calculations for flash memory performance and endurance. Flash memory endurance and performance are affected by host device behavior for writing to and reading from the flash memory. For all calculations, it is expected the host device is optimized to write to and read from the flash memory efficiently. This means the host device is writing in block sizes the flash memory expects and the host device is not introducing any bottlenecks to writing and reading.

### 5.1.1 Buffer Size

The physical maximum duration of the TSB is based on the amount of flash memory, and the average bitrate of content being written. Table 1 shows sample duration calculations for a single stream assuming average bitrates and allowing for 10 percent overhead used for indexing and file-system.

***Table 1 - TSB Duration Samples***

| Buffer Size in bytes | Average Bit Rate (Mb/s) | Buffer Length (Minutes) |
|---|---|---|
| 3,960,000,000 | 16 | 30 |
| 7,920,000,000 | 19.2 | 50 |
| 7,920,000,000 | 16 | 60 |
| 7,920,000,000 | 8 | 120 |

### 5.1.2 Endurance

Flash memory is composed of cells. Endurance is calculated based on the number of P/E (Program/Erase) cycles the cells will handle, and the average bitrate of content being written to the cells. This calculation is independent of buffer size as wear leveling allows for all cells to be used in equal amounts.

Write Amplification (WA) is the value factored into endurance calculations that allows for inefficiencies in block sizes when writing. WA is expressed as a multiplier to show the percentage of inefficiency. If a host is configured to always write all data to match the exact block size of the SD Card, then a Write Amplification of 1 (one) could potentially be attained. WA values must be used in calculating endurance as each time a cell is rewritten, it shortens the life of that cell; and when blocks are not aligned, all cells must still be written to. For all calculations in Table 2, a WA value of 1.2 is used.

Table 2 is used to show endurance models for the flash memory. Requirements for P/E cycles and flash memory size are the only parameters controlled by the flash memory. Average use is estimated by using a combination of software controls (i.e., standby parameters), and user behavior. Average bitrate is determined based on types of programming (Standard Definition is typically less than High Definition) and the associated average bitrate of that content.

***Table 2 - Endurance Models***

| Lifetime (years) | Average Use per Day (hours) | Average Bitrate (Mb/s) | Flash Memory Size (GB) | P/E Cycles |
|---|---|---|---|---|
| 1 | 6 | 10 | 4 | 3080 |
| 9 | 6 | 12 | 4 | 29,269 |
| 5.5 | 6 | 12 | 8 | 9,756 |
| 8.5 | 6 | 8 | 8 | 10,052 |
| 8.5 | 4 | 12 | 8 | 10,052 |
| 1.4 | 24 | 12 | 8 | 9,934 |

| Lifetime (years) | Average Use per Day (hours) | Average Bitrate (Mb/s) | Flash Memory Size (GB) | P/E Cycles |
|---|---|---|---|---|
| 11 | 6 | 12 | 16 | 9,756 |

While specific requirements are listed in Section 6.3, the following are guidelines for typical scenarios.

- Retail grade flash memory typically uses TLC or low-end MLC, which have effective P/E cycles between 150 and 1,000 per cell.
- Custom, high endurance MLC will have P/E cycles between 3,000 and 15,000 per cell.
- SLC can have 10 times the endurance of MLC with P/E cycles between 30,000 and 100,000 per cell.

### 5.1.3 Performance

Throughput performance requirements of the flash memory are based primarily on the amount of data that needs to be simultaneously read and written. It is expected the host device performance is greater than or equal to the flash memory performance requirements so that no bottlenecks are introduced into the system. Calculations are done on a per-stream basis. For a client with single stream, this calculation is straightforward. Devices with multiple streams being buffered, such as gateways, introduce inefficiencies in writing. These inefficiencies of write must be factored in when calculating performance requirements. Additional overhead must be added to the requirements for a TSB for a gateway or multi-stream profile.

SD Card 3.01 interface can be at throughputs greater than 90 MB/s, which exceeds all typical TSB use cases.

USB 2.0 interface has a maximum throughput of 60 MB/s. When overhead of USB is factored in, the actual maximum throughput is approximately 48 MB/s. This will meet many of the TSB use cases; however, USB 3.0 should typically be targeted for client or basic gateway use cases.

USB 3.0 interface has a theoretical maximum throughput of approximately 600 MB/s and an actual maximum of approximately 480 MB/s. If the host device supports full USB 3.0 throughput, a USB 3.0 TSB can be used for all typical TSB use cases.

# 6 REQUIREMENTS

Specific profiles are mentioned in this specification. Unless a specific profile is noted, all TSB Devices must be compliant with the requirement. If a specific profile is noted, only the profile noted must be compliant.

TSB Devices MUST be one of the profiles from Table 3 based on ordering options.

***Table 3 - Device Profiles***

| Profile Name | Streams |
|---|---|
| Client 1 | 1 |
| Client 2 | 2 |
| Gateway 1 | 4 |
| Gateway 2 | 6 |

Client 1 profile is for devices which only require buffering of a single stream.
Client 2 profile is primarily targeted for configurations where buffering of two streams is needed. This can include buffering of present and last channel, servicing of a COAM device, or Picture-in-Picture (PiP) scenarios.

## 6.1 Physical

### 6.1.1 SD Card TSB

SD Card MUST be an SD Card as specified in [SD-Physical].

SD Card physical size MUST meet standard memory card dimensions of a normal thickness card as specified in [SD-Mechanical].

### 6.1.2 USB TSB

The USB TSB Adapter MUST be of minimal size based upon good engineering practices.

The USB Adapter MUST have a USB Type A male connector as specified in [USB].

The USB Adapter MUST be either USB 2.0 or USB 3.0, depending on host device requirements.

### 6.1.3 SD Card Labeling

Each SD Card MUST have the following labeling on the bottom of the card etched in during manufacturing:

- Card Capacity Code (CC). See Table 4 for code mapping to capacity.
- YYDDD to indicate the year and day in that year when the card was manufactured
- Last 5 digits from Bill of Materials
- Single character Manufacturing site indicator
- Memory lot identifier

***Table 4 - Capacity Code Mapping***

| Capacity Code | Size |
|---|---|
| BH | 4 GB |
| BI | 8 GB |
| BL | 16 GB |
| BM | 32 GB |
| BN | 64 GB |
| BP | 128 GB |

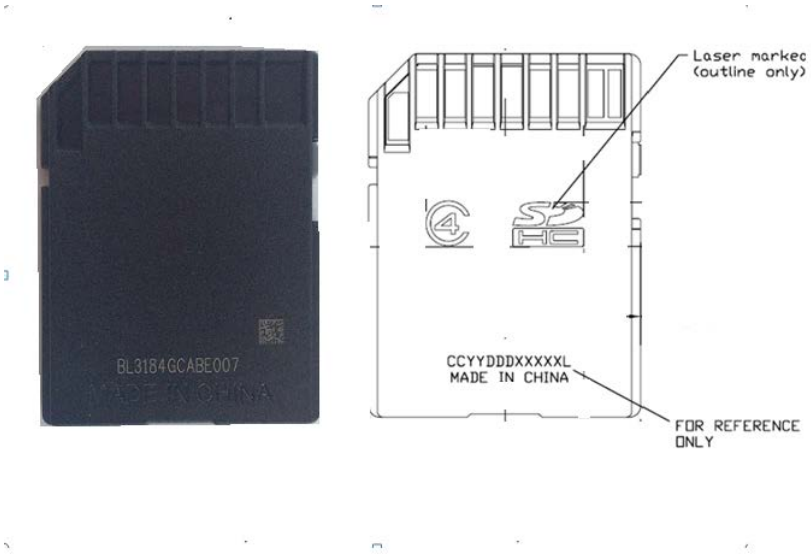


***Figure 1 - SD Card Bottom Label Sample***

A 2D barcode with the properties above MAY be provided.

Each SD Card MUST have a printed label.

Printed labels MUST use Pantone Black M on Bright White stock.

Each SD Card MUST have the following labeling on the printed label of the SD Card:

- MSO Logo
- Appropriate SD logo with SD Card Class
- Manufacturer Part or Model number
- "Instant Replay"
- Compliance markings as needed
- Any other required regulatory agency compliance

Any required certification labels MUST be clearly visible and compliant with the appropriate agency guidelines.

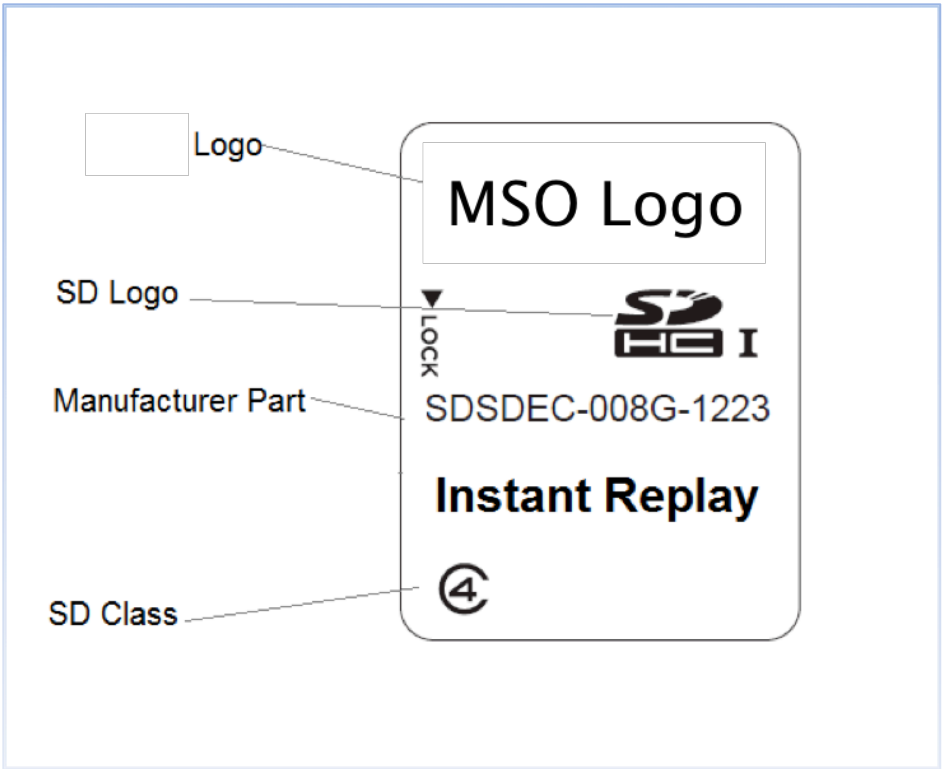


***Figure 2 - Sample SD Card Label***

The SD Card label MUST conform to the following:

- Surface Reflectivity > 70% (contrast between print and print surface)
- Resistant to smudging or staining
- Able to remain in position under humidity conditions of 5%-98%
- Water resistant, such that label remains in position and suffers no adverse effect after below tests:
  - The water dip test: dipped in 20°C water for a day. Water should have a pH of 6.5 to 7.5 and 2% salinity.
  - The cloth wiped test: wiping on the label by cotton broadcloth using a force of 200g per square cm 100 times reciprocating after dip test.
- Heat resistant, such that label remains in position and suffers no adverse effect when exposed to a maximum temperature of 75°C and when exposed to the environmental conditions and periods included in the Storage Tolerances (Section 6.2.6) of this specification for the life of the product.

### 6.1.4 USB Device Labeling

Based on the space available on the device, USB Devices SHOULD have an MSO-specific label or logo on the outside of the USB TSB Device.

### 6.1.5 Regulatory Compliance

The TSB SD Card MUST meet or exceed all applicable federal, state, and local regulations and/or compliance programs that may be needed for national and local deployment.

- FCC per [FCC]
- CENELEC per [CEN]

## 6.2 Environmental

### 6.2.1 Operating Temperature

The TSB Device MUST be fully operational within all specifications in a junction temperature of 0°C to 75°C.

### 6.2.2 Thermal Shock

The TSB Device MUST continue to be fully operational within specification after being subjected to the following thermal shock testing over 10 full cycles where the temperature transition occurs over a maximum interval of one half hour.

- -40ºC ambient for 4 hours
- +60ºC ambient for 4 hours

### 6.2.3 Altitude

The TSB Device MUST be fully operational within specification at an altitude range of -60 to +3,700 meters.

The TSB Device MUST tolerate being transported for the purposes of shipping through an altitude in excess of 5,000 meters.

### 6.2.4 ESD

#### *6.2.4.1 SD Card ESD*

SD Card ESD MUST be per [SD-Physical].

The SD Card MUST be fully operational after each of the following ESD:

- Air Discharge operational 4KV
- Air Discharge non-operational 8KV
- Contact discharge +/- 4KV Contact Discharge (100pF 1500Ω)
- Contact discharge +/- 200V Contact Discharge (200pF 0Ω)
- Contact discharge +/- 4KV Contact Discharge (150pF 330Ω)

  **Note:** Contact to body and connector.

#### *6.2.4.2 USB ESD*

TBD

### 6.2.5 Operating Humidity

The TSB Device MUST be fully operational within specification under the operating conditions described above between 5% and 95% of non-condensing humidity.

### 6.2.6 Storage Tolerances

A new TSB Device MUST be fully operational within specification after storage of up to 4 years at 0ºC to 60ºC, 30 days continuous storage at -10ºC to 70ºC, and 7 days storage at -40ºC to 80ºC. All conditions are at a range of 5% to 95% relative humidity and between -60 meters and 4,500 meters in altitude.

## 6.3 Performance

Wear leveling MUST be used in a way that cells are utilized evenly across the TSB Device.

Lifetime (Endurance) of Client Profile TSB Devices MUST meet P/E (Program/Erase Cycles) from Table 5 based on TSB Device size.

***Table 5 - Client P/E Requirements***

| Size | Profile | Minimum P/E Cycles | Comments |
|---|---|---|---|
| 4 GB | Client 1 | 25,000 | SLC based |
| 8 GB | Client 1 | 10,000 | High endurance MLC |
| 8 GB | Client 1 or Client 2 | 20,000 | |
| 16 GB | Client 1 or Client 2 | 10,000 | High endurance MLC |

Lifetime of Gateway 1 and Gateway 2 Profile TSB Devices MUST be a minimum of 10,000 P/E (Program/Erase Cycles).

TSB Devices MUST meet or exceed minimum throughput parameters from Table 6 throughout the lifetime of the card.

***Table 6 - SD Card Throughput***

| Profile Name | Sequential Write | Sequential Read |
|---|---|---|
| Client 1 | 5 MB/s | 7 MB/s |
| Client 2 | 8 MB/s | 10 MB/s |
| Gateway 1 | 14 MB/s | 16 MB/s |
| Gateway 2 | 21 MB/s | 24 MB/s |

TSB Devices MUST be designed to handle any memory failure, as defined below:

- The TSB Device failure rate MUST NOT exceed 2% per year for any quantity of units analyzed over the specified P/E cycles of the device.
- The TSB Device MUST be able to retain all data written to it for a minimum of 24 hours.

## 6.4 Management

TSB Devices may be reformatted with a file system by the host.

### 6.4.1 Card Health

SD Card MUST provide CMD56 information for health status.

USB Device MUST use SCSI Diagnostic commands to provide information for health status.

TSB Dervices MUST provide health status based on percentage of P/E cycles designed into the card.

When queried correctly, the card will respond with data packet. The health status response is as shown in Table 7.

***Table 7 - Health Monitoring Return Values***

| Value | Percentage used |
|---|---|
| 0x0A | 0-10 |
| 0x14 | 11-20 |
| 0x1E | 21-30 |
| 0x28 | 31-40 |
| 0x32 | 41-50 |

| Value | Percentage used |
|---|---|
| 0x3C | 51-60 |
| 0x46 | 61-70 |
| 0x50 | 71-80 |
| 0x5A | 81-90 |
| 0x64 | 91-100 |
| 0x6E | >100 |

Health status reporting MUST be updated in 10% increments. For example, if an SD Card is certified for 10,000 P/E cycles, the reports would be updated with a frequency of every 1000 P/E cycles (10%).

**Note:** Actual card usage may go over 100 % if host device software is configured to do so. SD Card manufacturer is not responsible for any endurance failure which could occur after end of design life.

The TSB Device MUST have the following parameters stored in the device so they can be reported through the electrical interface:

- A unique device identifier for the part
- TSB Model identifier
- Manufacturer identifier

### 6.4.2 SD Card Security

Card Check is the method where the device will query the SD Card for a specific identifier. If this identifier is not found, the SD Card is not qualified for TSB capability and the card will not be used for TSB functions. The primary use case for this is to remove risk of failures from unsupported hardware.

The SD Card MUST populate the Product Name (PNM) field with the string 'TSBBx' where 'Bx' is used as a capacity identifier.

**Note:** Host devices should query based on the first three characters (TSB) in the PNM field to determine card usage.

The SD Card capacity identifier MUST use values as listed in Table 4.

Host Lock is the method where once an SD Card has been inserted into an RDK host, it will be locked to only work in RDK hosts. The primary use case for this is to reduce potential for SD card theft and reuse in other devices such as cameras or computer equipment.

Card Lock/Unlock requires the card to support SD Card Lock/Unlock protocol as defined in [SD-Physical], which includes CMD42 for pairing Card Lock Password (CLP) to the host, and support of an enhanced CMD42 function, Card Ownership Password (COP), which requires a password to be used to enable a forced erase and recovery of the SD card.

SD Cards with a capacity of 16 GB or larger MUST have the Card Lock support as defined in [SD-Physical], with the extensions as illustrated in Figure 3.

**Note:** CMD42 password will be provided by a separate method by request and approval to authorized individuals.

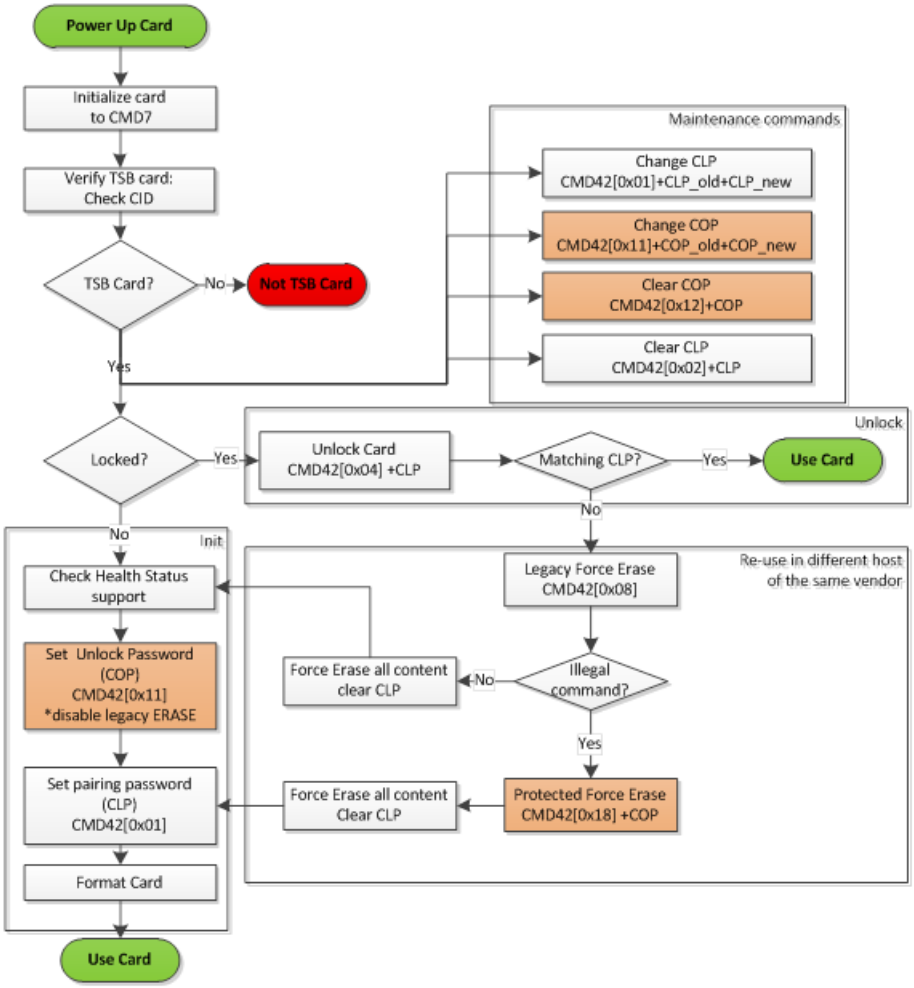


***Figure 3 - SD Card Initiation for Card and Host Lock***

SD Card Device properties MUST NOT be capable of being overwritten by typical consumer usage and tools.

## 6.5 Packaging

TSB Devices MUST be packaged in anti-static packaging.

Bulk packaging MAY be used per SD Card or USB Device manufacturer's processes.