SSD Performance States

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Overview

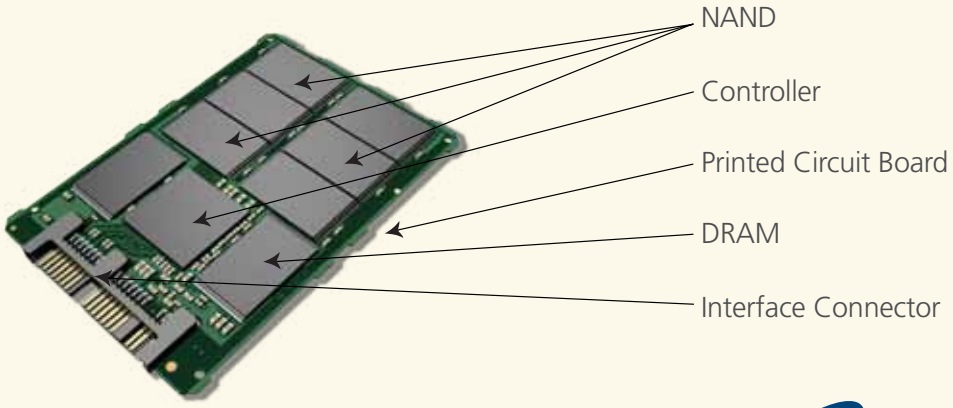
Solid state drives (SSDs) have generated substantial interest recently because of their low power consumption, high performance, and drop in replacement capability.

Despite their deceptively familiar appearance, SSDs differ from rotating hard disk drives. Take for example, performance variability as a function of time. The concept—the performance of an SSD changing as the device is used—may seem unusual at first glance, but this paper will examine this phenomenon and show a real-world example.

How SSDs Are Built

This paper focuses on SSDs that use NAND as their basic storage media. NAND-based SDDs are generally comprised of:

- Printed Circuit Board (PCB)
- Flash Controller
- NAND Storage (or cells)
- Interface Connector (SATA, SAS, etc.)
- DRAM (Note: DRAM is not required for all designs)



Performance

Performance is typically characterized in one of three ways: input/output operations per second (IOPS), throughput in megabytes per second (MB/s), or with a composite benchmark that gives unitless results.

The empirical data referenced in this paper was taken from a sample SSD from a well known manufacturer. Although the exact shape and amplitude of the resultant performance curves may differ among SSDs, most drives currently in the market will experience similar behavior. As the drive fills, performance changes nonlinearly. If the measurement period is sufficiently long, the device will exhibit one or more intermediate performance states observed during the measurement period.

The sample data used in this paper was collected by Calypso Testers (www.calypsotesters.com).

Performance States: A Common Lexicon

There are consistently three different performance states for SSDs: FOB, transition, and steady. The time spent in each state and, to a lesser extent, the order in which they occur will vary among SSDs, but each SSD examined to date shows these performance states. Some will show more, and some will enter and exit a given state more than once.

Fresh Out-of-Box State (FOB)

The condition of a new/unused SSD when first received from the manufacturer is referred to as FOB. Typically, the storage cells on the device will have few or no PROGRAM/ERASE (P/E) cycles applied to them when the device is in this state. The exception would be any P/E cycling done at the factory as part of the manufacturing process. All storage elements are pre-erased and the device is ready to have data stored on it.

Transition State

A performance state in which the observed performance change is consistently increasing or decreasing is called a transition state.

Steady State

The condition where most of the transient performance behavior has died away is called steady state. Note that a drive may have several steady state regions in its performance curve. Steady state performance is typically reflected in a small change in performance over a relatively lengthy timeframe.

Measured Results

Figure 1 shows the measured performance states for several sample SSDs. The data is plotted as a function of time. The plots show data from different devices that was collected identically (same test platform and procedure).

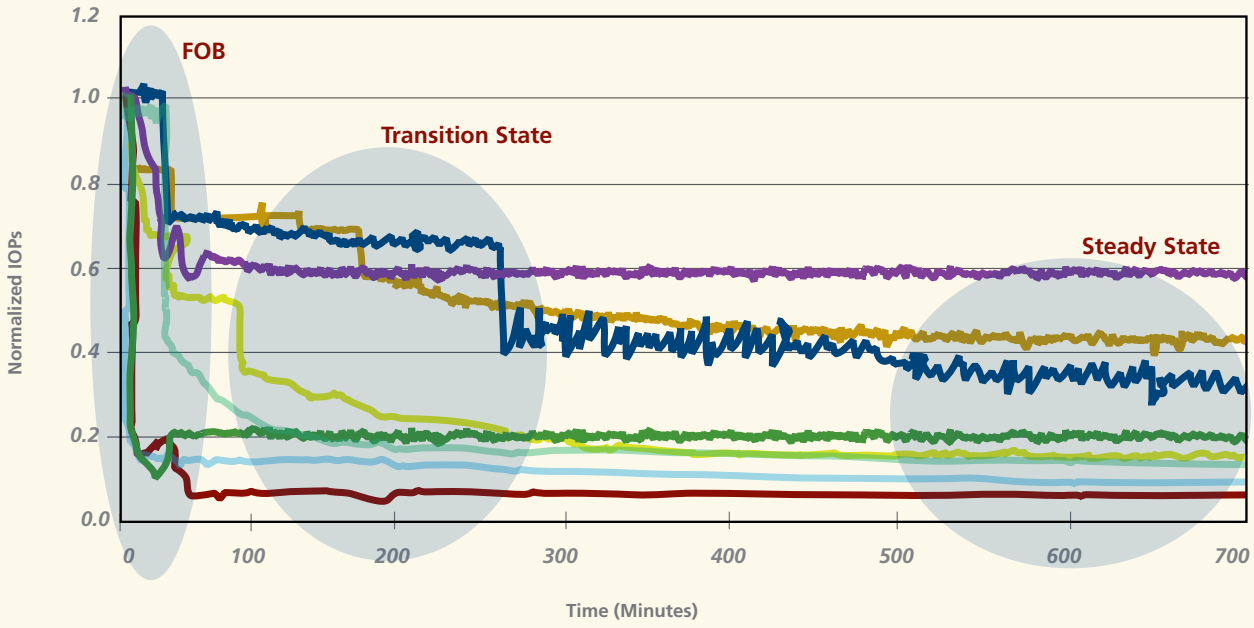


Figure 1: Performance States

- Y-axis: Normalized input (IOPS)
- X-axis: Time in minutes (increasing from left to right)

As the drives were filled, several different performance states were observed:

FOB
The FOB state is visible at the extreme left of the plot. This state is reached when the drive has little to no user data; all the NAND cells are erased and available to receive new data. As the drive is written, the IOPS decrease.

Transition
Immediately following the FOB state, the drive enters a transition state, marked by steadily decreasing performance.

Steady
In this state, drive performance is consistent. Note that although performance decreases again gradually, the performance over time shows little variance.

Conclusion

For this test, the sample drives were subjected to a workload specifically designed to illustrate performance variation with time.

As can clearly be seen from the performance plot, the sampled devices in particular (and NAND-based SSDs in general) show substantial performance variability over time and amount of data written. When the device is in the FOB state, its storage cells are pre-erased and ready to receive data; hence, the performance in this state is greatest. However, as data is added to and removed from the drive, the number of pre-erased cells (those ready to receive new data) and their location is governed by the SSD's internal design (controller and firmware).