Micron® Flex Capacity Feature — Tunable Storage in a Flash

Micron SSDs with Flex Capacity Feature Give You Control of Performance and Capacity

Overview

The Micron® Flex Capacity feature is designed to unleash the true capabilities of storage media by giving IT administrators the ability to tune their SSDs to meet specific workload characteristics such as performance[1], capacity and endurance.

First introduced with the Micron 5100 SATA SSD portfolio, the Micron Flex Capacity feature provides a consistent experience across all Micron SSDs equipped with this feature. This creates commonality and gives longevity to SSD investments, dramatically simplifying the selection, qualification and deployment processes.

Flex Capacity enables easy adjustments to equipped Micron SSDs' product capacity to match a wide variety of applications, workloads and requirements — all serviced from less inventory (fewer drive stock keeping units or SKUs) for better overall economics and lower support costs.

As more storage architects are turning to SSDs, there is a commensurate demand for "tuned" storage capacity and fills per day for several reasons. Some deployments demand an SSD with greater capacity (where the workload is highly read-focused), some demand a cost-sensitive approach to workloads that need read/write balance, and some need an SSD that offers greater write performance and fills per day. Budgets demand that we satisfy requirements for both capacity and fills per day across a broad range of interfaces with minimal variety of SSD types to minimize qualification and inventory expense.

Fast Facts

Unleash Your Applications:	Match SSD performance and capacity to your needs.
Lower Deployment Complexity:	Manage fewer drive types and enable better economics.
Reduce Risk, Ease Management:	Qualify one SSD then tune it for multiple workloads.
Gain Predictable Performance:	Precisely tune SSDs, see consistent, predictable results.

Meet the needs of a variety of applications, workloads and requirements with the Micron Flex Capacity feature.

1. When mentioned in this paper, 'performance' means either IOPS, MB/s or both.

Balancing these competing demands has always been a challenge. We have to choose different types of SSDs for our read-focused workloads, our write-focused workloads and our balanced read/write use needs. And we have to qualify each type separately, as well as stock appropriate spares for long-term maintenance. Although this tactic of buying specialty SSDs for each workload can produce good results for each application, the expanding number of SSD types to buy, stock, deploy and manage can be taxing; and each may require a compromise (for example, capacity or fills per day is optimal).

This technical brief describes Micron SSDs with the Flex Capacity feature, which enables precise, application-level optimization while also overcoming the challenges of performing multiple SSD qualifications and storing excessive inventory spares (SKUs) for maintenance.

What Is Over-Provisioning?

Over-provisioning (OP) on any SSD refers to spare capacity that the drive may use to optimize internal processes. All flash-based SSDs contain some level of OP. For example, suppose we have an SSD with 1TB of NAND on the circuit board (1TB equals 1024GB). This is the “raw” capacity of this SSD. Typically, having 1TB of storage on the circuit board does not mean that the entire 1TB is available for system use.

Depending on the SSD design, 960GB, 800GB, 480GB or some other amount of the 1TB of space may be available for the host to use. Each of these SSDs would have different advertised capacities — 960GB, 800GB, or 480GB respectively, and all would have the same raw capacity. We would typically think of each as a different product.

Figure 1 shows how OP is calculated. The blue area (including the area underneath the green crosshatched area) is the total raw capacity of the SSD (1TB in this example). The green crosshatched area is the portion that is available for the system to use. The difference is the drive’s OP, which depends on the drive’s design.

Over-Provisioning, Write IOPS Performance and Capacity

SSDs are designed with a default level of OP that affects the SSD’s write IOPS performance and available capacity. The OP level is usually set in the factory.

Using the 1TB raw capacity example, designers can set the OP level very low and make 960GB of the 1TB available. An SSD like this is well suited for read-intensive storage (data that rarely changes but is often read, like in artificial intelligence, machine learning, quick-access data archives, capacity/bulk storage, and so on). This 960GB SSD would have great read performance and high capacity, but limited write performance due to its low OP.

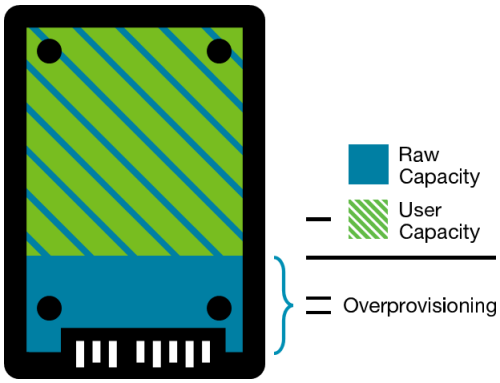

Figure 1: SSD OP

In the past, changing the OP level was difficult. If an SSD designed for small I/O-size mixed use (like 8K 67% read, 33% write) was needed, the manufacturer could start with that same 1TB raw capacity example SSD and add more OP by setting the user capacity to 800GB at the factory. The additional OP would give the 800GB drive better write performance but less user capacity. This was set at the factory and was not easy to modify.

If a write-intensive SSD was needed, the manufacturer might have taken the same 1TB raw design and set the OP to make 480GB available for system use. This SSD (with still more OP) would have the greatest write performance of all three examples, but the smallest user capacity.

SSD designers have controlled these compromises for many years. In general, for a given raw SSD, the more OP the factory sets, the more write IOPS performance but the less available capacity, which is a tradeoff.

Micron Flex Capacity Feature Puts You in Control

With the Micron Flex Capacity feature, you can easily optimize a Micron SSD equipped with Flex Capacity for diverse applications and workloads You can manage the exact write performance and capacity you need from fewer types of SSDs while matching the SSDs' capabilities to your needs.

Figure 2 shows how the Micron Flex Capacity feature improves the SSD's write performance while simultaneously adjusting its available capacity.

Note that the raw media capacity remains the same for each drive — only the available capacity (green crosshatched area) changes as we apply the Micron Flex Capacity feature to tune the SSD.

Figure 2 shows the effect of the Micron Flex Capacity feature on available space in a 1TB raw example. On the left is an example that is factory-configured with an available 960GB of capacity. At 960GB, this SSD offers the Micron default user/system capacity, the factory-set over-provisioning and the factory-set write IOPS performance. The factory-set capacity of 960GB is a good default option; it works well in a variety of data center applications, workloads and deployments.

The center drive in Figure 2 shows how we can use the Micron Flex Capacity feature to improve the SSD's write performance and slightly reduce the available capacity to 800GB. The advantages are twofold: The 800GB user capacity enables better write IOPS performance, or if we need to replace an 800GB SSD (perhaps from another vendor or because one has failed), we can use the 960GB Micron SSD and easily reset it to 800GB for an exact match.

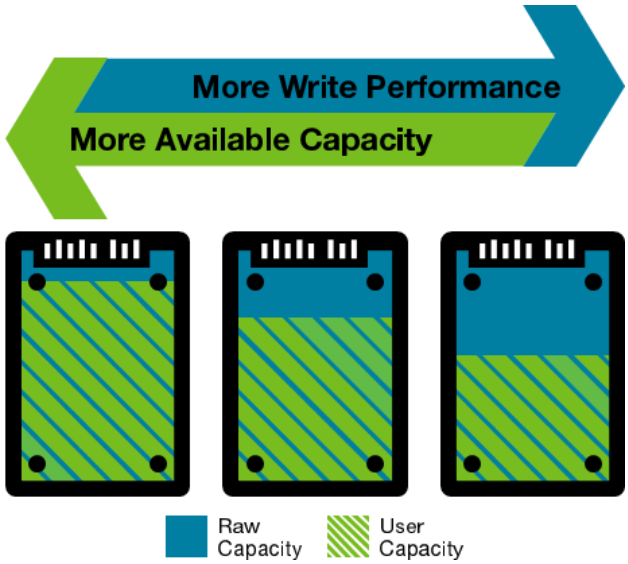

Figure 2: Flex Capacity at work

The drive on the right in Figure 2 shows another way to use the Micron Flex Capacity feature to further improve write performance by, in turn, tuning the user capacity to 480GB. We can now use the same example SSD for even more write-intensive workloads or use it to replace a 480GB SSD that may have been retired.

In this example, we reset a 960GB Micron SSD to tune write IOPS performance or match the capacity of an existing 800GB or 480GB SSD. However, with the Micron Flex Capacity feature, it is just as easy to reset the Micron SSD to 627GB, 472GB or any capacity needed (so long as the needed capacity is less than the factory-set [default] capacity).

The same effect is available for other Micron SSDs with the Flex Capacity feature, albeit with different factory and user capacities.

The Micron Flex Capacity feature can also help minimize the impact on qualification resources. One SSD SKU of a product family can be qualified for read-intensive workloads. The same SKU can be set to a slightly reduced capacity for mixed use or set to a further-reduced capacity if the workload is write-intensive. The same SSD and same qualification has multiple uses.

Use the Micron Flex Capacity Feature to Tune Write IOPS Performance

Because the Micron Flex Capacity feature lets you easily change the available gigabytes, you can also choose to make write IOPS performance and capacity adjustments permanent or temporary. You can set your SSD to best match known workloads or change the characteristics to manage unexpected application I/O demand more easily. You can increase the SSD's write IOPS performance permanently or only when you need it, for as long as you need it. The Micron Flex Capacity feature lets you choose what is best.

Tuning IOPS Performance: Mixed-Use Workload Micron SSD Example

When an SSD is fresh from the factory, its write performance is at its highest. As applications write and rewrite to the SSD, write performance changes until it reaches a steady state, after which write performance remains relatively constant. For data center SSDs, steady state is the primary performance state of interest.

This section describes an example of how Micron Flex Capacity can be used to tune the results of a Micron SSD with a small-transfer (8K), random, mixed-use workload: 67% read and 33% write. Similar tuning applies to other Micron SSDs with the Flex Capacity feature, but the values may differ.

Starting with a 960GB (factory-default capacity, designed for read-centric use) SSD as the example performance baseline, we then reset it to 800GB and 480GB capacity and compared the results. After each capacity test, we restored the SSD to a fresh-out-(of)-box (FOB) state, used Micron Flex Capacity features to reset its user capacity, and repeated the test with the new capacity.

Figure 3 shows relative IOPS performance compared to the 960GB baseline capacity. The horizontal axis shows time (from FOB at the start of testing on the left) and the vertical axis is IOPS performance relative to the baseline 960GB (shown as a percentage improvement relative to baseline 960GB IOPS). In Figure 3, IOPS performance improves compared to the baseline 960GB drive as the line goes up.

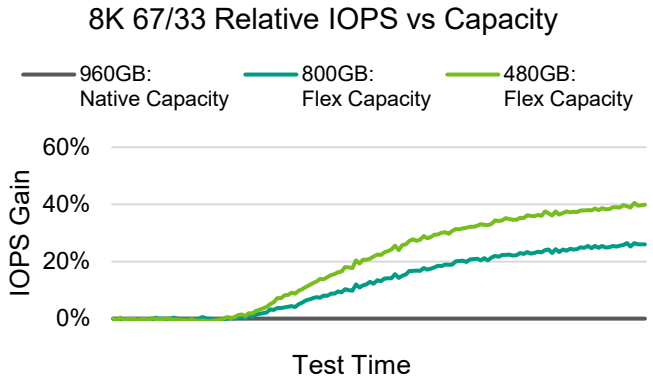

Figure 3: 8K Mixed-Use IOPS Performance Gain vs. Flex Capacity Tuning

As expected, write performance for the 960GB, 800GB and 480GB all start at the same reference IOPS level (far left). As the drives are filled and refilled, the write IOPS decreases with time until reaching steady state.

Capacity at 800GB: Setting the capacity at 800GB with the Flex Capacity feature shows an 8K IOPS improvement as expected. Starting at approximately a third of the way through the test, the 800GB capacity write IOPS begins to improve with the observed maximum at steady state (end of test) reflecting a 26% 8K mixed-use IOPS improvement.

Capacity at 480GB: The 480GB capacity created with the Micron Flex Capacity feature shows a more significant improvement over the 960GB default. Again, starting at the same IOPS value at FOB (far left), the 480GB 8K IOPS performance also begins to diverge a third of the way through the test, reaching its maximum improvement of about 40% at steady state (far right).

Notes:

- These are example capacities only. As noted earlier, other Micron SSDs may also support the Micron Flex Capacity feature, enabling you to set the write IOPS performance and user capacity you need. (All possible capacities have not been tested, so user validation during qualification is required.)
- Combined average performance may not result in a linear relationship when reads and writes are mixed. We cannot always take 100% write workload IOPS performance and average it with a 33% write workload IOPS performance to determine a 67% write IOPS workload performance because servicing a WRITE command in steady state requires more internal bandwidth than READ commands. Although workload averaging may work in select cases, this is not a safe (universal) assumption.
- Similarly, capacity averaging may not result in a linear relationship. The performance of a 960GB (native capacity) SSD averaged with the performance of the same SSD set to 480GB may not accurately model the results of a 720GB setting. Using Micron's Flex Capacity feature enables you to verify specific performance by resetting the drive to 720GB.
- It is expected that the performance change as the SSD is written to (the shape of the WRITE IOPS versus time curve) may differ depending on the Micron Flex Capacity feature setting.
- Micron SSDs with different host interfaces may behave differently than the example drive. While each SSD may support the Micron Flex Capacity feature, they are very different products with different interfaces and are targeted for different uses. They will show different write IOPS performance as their capacity is adjusted.

Flex Capacity Feature and Drive Writes per Day

All SSDs wear as they are written; they have a finite write lifespan. An SSD's lifespan is rated in total bytes written (TBW). To make planning, design, deployment and support simpler, an SSD's lifespan is often expressed in how many times you can write the SSD's capacity (completely fill the drive) every day over its warranty period, which is also referred to as the drive writes per day (DWPD). You may also see the term drive fills per day (DFPD), which means the same thing. The following section uses an example Micron SSD to show how TBW and DWPD are related and how using the Micron Flex Capacity feature affects the DWPD value. As with write IOPS, the same principles apply to other Micron SSDs, but the calculated values may differ.

Micron Flex Capacity Feature and Changing DWPD

For illustration purposes, we use a different Micron SSD with an 11TB factory capacity setting and rated the endurance of 15.7PB over its warranty period of five years. Using these factory default values, we can calculate DWPD for five years:

TBW = 15.7PB
Time period = 5 years
Factory capacity = 11TB

For each day of the five-year period, we can write

GB/day = Rated TBW / time period

= 15.7PB / 5 years

= 16,076.8TB / 1826 days

= 8.8TB / day

TBW is a fixed value; using the Micron Flex Capacity feature does not change the TBW. However, depending on the Micron Flex Capacity setting, the DWPD can change. Using the example default capacity of 11TB and the flex capacities of 8.8TB and 5.5TB, it is straightforward to calculate DWPD.

For any capacity, DWPD equals the amount of data that can be written per day based on its TBW value, divided by the drive capacity of interest: **DWPD = (TB / day) / 9200 capacity**

For the 11TB default capacity, take the TBW rating (145.7PB) and divide by the 5-year period, which yields about 8.8 TB/day — a value that we can use to calculate DWPD for three example 9200 capacities.

Starting with the factory default capacity of 11TB, we have:

11TB DWPD = 8.8TB (per day) / 11TB capacity
= **0.8 DWPD**

When we use the Micron Flex Capacity to resize this same SSD to 8.8TB capacity, the DWPD changes:

8.8TB DWPD = 8.8TB (per day) / 8.8TB capacity
= **1.0 DWPD**

And finally, if we resize to 5.5TB:

5.5TB DWPD = 8.8TB (per day) / 5.5TB capacity
= **1.6 DWPD**

Although the TBW is the same, the tuned capacity changes the DWPD. In general, we expect DWPD to increase when we decrease the available capacity. Similar calculations apply to other Micron SSDs with the Micron Flex Capacity feature. To reduce the drive's capacity, we change its effective DWPD. TBW does not change with changes to usable capacity.

Using the Micron Flex Capacity Feature With Micron's Storage Executive

Micron's Storage Executive tool unifies the method of capacity and performance tuning across all of our SSDs and is the preferred tool to use with the Micron Flex Capacity feature.

Storage Executive is available for download from micron.com, along with complete documentation. Implementing the Micron Flex Capacity feature via Storage Executive is beyond the scope of this paper. Please refer to the Storage Executive User Guide for specific instructions.

Conclusion

Different applications and workloads demand different storage for best results. With data center mainstream storage moving rapidly toward SSDs, precisely optimized configurations for both IOPS performance and available capacity are in greater demand.

With the Micron Flex Capacity feature, planners, designers, implementers and administrators no longer have to compromise because of the limited number of SSD configurations, performance options and capacities. The Micron Flex Capacity feature lets you easily create application-tunable SSDs in a flash.

Whether your applications and workloads need greater capacity with a read-focused workload that is highly cost-focused, greater write IOPS performance for write-intensive workloads, or performance to work well for mixed uses (with a read/write balance), the Flex Capacity feature enables the precise performance and capacity tuning you need while helping minimize qualification cycles and inventory (spares) and cost.

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