Micron® Adaptive Write Technology brings TLC write speed to QLC SSDs

SSD write speed matters — whether you are manufacturing a new platform, loading a corporate OS image, or just moving large files.

Micron's unique Adaptive Write Technology™ (AWT) enhances QLC SSD performance, raising the bar for QLC SSD write speed. AWT brings a new level of optimization to everyday computing and helps improve large file writes, as commonly seen with:

- Large operating system image loading (in manufacturing)
- Custom operating system image loading or reloading (by IT teams)
- Frequent, large file transfers for tasks like video editing and content creation (including saving work in progress)
- Game installation
- Code base loading for software development

The Micron 2600 NVMe SSD is the world's first QLC SSD to benefit from Micron AWT.

Figure 1: The Micron 2600 SSD is the first QLC SSD with Micron AWT

Key findings

Micron AWT manages how a QLC SSD writes data to the NAND itself, helping deliver the performance of faster NAND technologies, specifically SLC and TLC, with the economics of QLC.[3]

AWT continuously adjusts among different NAND "modes" based on the volume of written data, the SSD capacity, how the SSD is used, and many other factors.

SLC mode: Optimized for speed.

TLC mode: Balanced between speed and capacity.

QLC mode: Optimized for maximum capacity.

AWT manages traffic by controlling which mode is used, enabling the performance benefits of SLC and TLC modes with the native capacity benefits of QLC mode.

AWT enables amazing results with QLC SSDs

4X **Faster QLC write speed[4]**

micron.com/2600

1. Performance improvement statements relate to a similar QLC SSD without AWT.
2. As per public information available at the time of this feature's announcement.
3. Capacity and performance-related statements are generalized and may not reflect measured capacity or performance for any specific SSD. Economic statements are based on the number of bits stored in each NAND cell by mode: SLC mode stores one bit per cell (baseline capacity), TLC mode stores three bits per cell (3x the bits per cell of SLC), and QLC mode stores four bits per cell (4x the bits per cell of SLC).
4. AWT improves sequential write speed by 4x for the first 40% of the SSD's rated capacity; based on Micron testing, writing a 400GB file to a 1TB QLC SSD.

Challenges of traditional QLC SSDs

QLC (quad-level cell) NAND is great for building high-capacity SSDs. But when large files are written to traditional QLC SSDs, the write speed can drop significantly. This happens because QLC technology is naturally slower than SLC or TLC when writing data.

Micron AWT addresses this traditional QLC challenge head-on. It improves QLC performance without compromising SSD capacity or durability.

A quick NAND refresher

Micron AWT leverages a key feature of Micron QLC NAND: AWT can write QLC NAND in single-level cell (SLC) mode, triple-level cell (TLC) mode, or quad-level cell (QLC) mode. The NAND stores one data bit per cell in SLC mode, offering the best speed of the three modes. In this case, SLC mode is used as the economic baseline (more bits per cell is more economical).

TLC mode stores three bits per cell; it is optimized for performance and economics. With more bits per cell, TLC mode offers excellent speed with better economics than SLC mode.

QLC mode stores four bits per cell, which provides the highest capacity and best economics. It has good write speed and is the most economical of the three modes.

Ideally, QLC mode is used for its economic value and SLC or TLC modes can be used when speed is needed. Micron uses special commands to write data in SLC, TLC, or QLC mode. These special commands do not change the SSD's advertised maximum capacity.

Micron AWT: A revolution in QLC NAND technology

AWT enables QLC SSDs to write data at SLC and TLC speeds while maintaining QLC economics. The NAND device itself does not change (it is still QLC NAND) — only how the data is written changes. Micron AWT can optimize the user experience by automatically writing data in SLC, TLC, or QLC modes.

Figure 2 represents how different modes support different speeds and capacities. With each QLC mode, speed is shown horizontally (a longer line is better), and capacity (bits per cell) is displayed vertically (taller is better). Micron AWT (shown in purple) adapts how data is written to deliver the cost effectiveness of QLC and the overall write speed of SLC or TLC when needed.

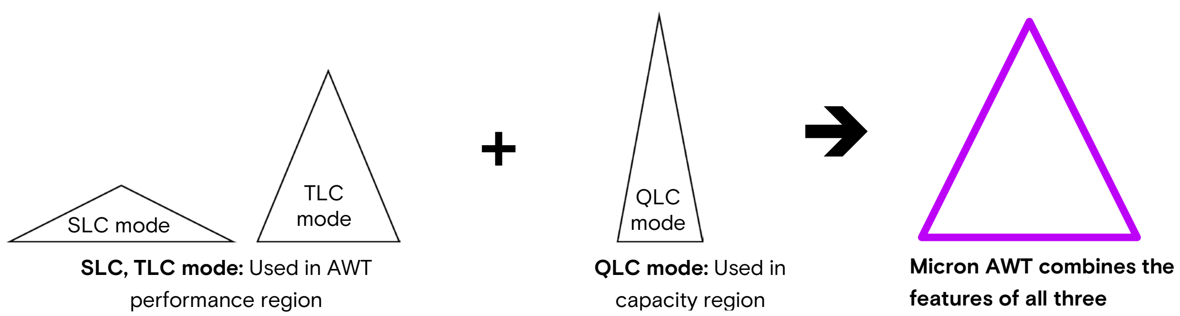


Figure 2: Micron AWT

AWT builds an enhanced user experience for demanding applications

By adjusting the mode in which data is written, AWT creates a balanced solution that provides exceptional performance and economics for everyday use. It helps make larger-capacity SSDs more performant — even in budget-focused devices — and it helps deliver essential performance under some of the most demanding uses, such as:

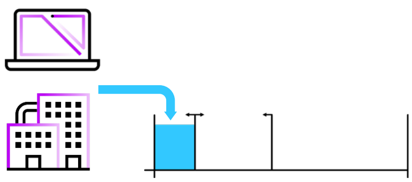
- **Frequent, large file transfers:** Examples include loading or reloading an operating system, regularly transferring large files, or installing large software packages. Here, the SSD can benefit from the faster write speeds of SLC and TLC modes, which quickly and efficiently reduce waiting times and improve productivity.
- **Video editing and content creation:** Fast SSD write speeds are crucial for those who work with high-resolution video editing or other content creation tasks.

- **Gaming and software development:** Gamers and software developers often copy or move large game files or complex codebases. Fast SSD write speeds help users copy game files and migrate code bases efficiently.

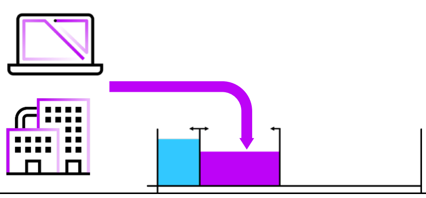
AWT constantly optimizes data placement to improve performance

Figure 3 shows an example of writing data to a QLC SSD that features AWT. At the top, the SSD is empty, as when a system is first manufactured or if an IT shop loads an operating system image. As data is written, AWT manages whether data is written in SLC or TLC mode, adjusting the mode as the SSD fills. This monitoring and adjustment enable AWT to optimize results while ensuring the rated SSD capacity is available.

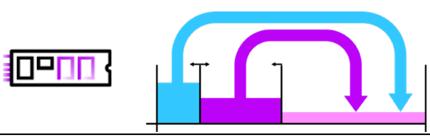
When both SLC and TLC mode areas are full, AWT migrates data from those areas to QLC mode when the SSD is idle, even for a short amount of time. As this process continues, AWT continues to migrate data from the SLC and TLC mode caches, folding that data into QLC mode.[5] AWT also resizes the SLC and TLC regions to ensure the advertised capacity is available, as indicated by the arrows shown at the top of each SLC and TLC region's border.



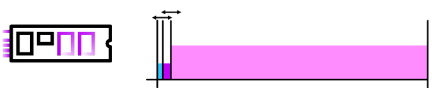
1. **First, write in SLC mode:** When an SSD with AWT is new, no data is written. As data is written to the new SSD (when placing an OS image in manufacturing, by IT, or when a user loads large files), AWT writes in SLC mode (blue) first, which helps ensure the fastest possible write performance. The SLC and TLC region sizes are adjusted to match demand.



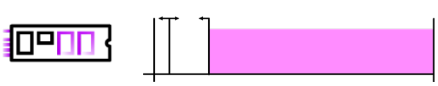
2. **As SLC mode fills, write in TLC mode:** As more data is written to the SSD and SLC mode fills, AWT directs new data to be written in TLC mode (purple). Writing in TLC mode enables the SSD to maintain excellent write speed. As before, the SLC and TLC region sizes are adjusted to match demand.



3. **As SLC and TLC modes fill or when the SSD is idle, AWT migrates data to QLC mode:** As the TLC mode also fills, AWT migrates the SLC and TLC mode data to QLC mode (pink). This data migration inside the SSD is an automatic process. It helps ensure that the SSD's full rated capacity is available.



4. **As needed, AWT resizes all regions:** AWT resizes all regions based on several factors (such as when more data is stored). This resizing can expand the QLC (while also shrinking the SLC and TLC regions) to ensure rated capacity. Again, the region boundaries are dynamic.



5. **With continued use, AWT dynamically adjusts region size:** As the SSD is used, AWT continues to adjust the SLC and TLC regions to accept new, incoming data, which helps ensure that the SSD write performance is again able to accelerate incoming data. This continues as the SSD is used.

Figure 3: Micron AWT in action

Legend

Manufacturing or IT process

User actions

Micron AWT

5. Figures represent illustrative values only and are not intended to reflect actual capacities, sizes, or other details related to actual use cases.

Here's what to know

Although traditional QLC SSDs were often relegated to low-performance platforms, Micron Adaptive Write Technology™ (AWT) changes this. This innovative technology dynamically adjusts how data is written to optimize performance, helping ensure faster write speeds on QLC SSDs. AWT offers a balanced, QLC-based solution that combines the speed advantages of SLC and TLC with the cost effectiveness and capacity of QLC. This delivers a high-capacity solution that is the right fit, even for use cases where TLC SSDs are typically used.

By implementing AWT, write-heavy bottlenecks often associated with traditional QLC SSDs are reduced while keeping all the read performance, capacity, and endurance the same.

Manufacturers, IT teams, and users can have a superior experience for everyday computing tasks such as operating system image placement, quick transfers of large video files, rendering of creative projects, quicker backups, and smoother installations.

The Micron 2600 NVMe SSD is the world's first to use Micron AWT. Learn more about AWT and this breakthrough SSD at micron.com/2600.

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