QLC Challenges

QLC SSD’s Require Deep FTL Tuning
Karl Schuh – Micron
The Wonders of QLC

- Cost
- Capacity
- Performance
  - Error Rate depends upon compensation for transaction history
- Endurance
  - Data Organization is Key
  - Complex NAND Management algorithms required to support the target Total Bytes Written

Not 3 bits-per-cell to 4 bits-per-cell, but 8 charge levels to **16 charge levels**!
Performance and Endurance

*Inextricably interconnected in QLC*

- **Data Organization and Steerage – driven by the workload**
  - SLC, MLC and TLC caching to filter high frequency data, and smooth throughput
  - Read / Write mix
  - Logical Saturation
  - Over-Write and Deallocation frequency
  - Streams aid in Data Separation

- **Write Throughput**
  - Careful attention to history and environment
  - NAND characterization

- **Read Latency**
  - Continuous Tuning
  - Complex algorithms based on transaction history and characterization
- **Flat FTL tables**
  - Direct lookup for Reads
  - Writes mapped sequentially to a RAID Block across all die
  - Maximize active die, which in turn maximizes throughput

- **Hierarchical tables are functionally equivalent**
Intermediate Caching
*Endurance and Burst Performance*

- **SLC or MLC or TLC cache**
  - Write bursts absorbed by the Cache
  - High frequency updates filtered prior to QLC
  - Low FUA latency
  - Improved Endurance

- **Reliability**
  - Host Writes stored in Single Pass programming Blocks
  - Asynchronous power loss handled using few or no Capacitors
Dynamic Caching

Burst Performance

- **Host Burst Pattern**
  - Logical Saturation
  - Size of the Cache
  - Rate of Recycling
  - Transition from Caching to direct Write
  - Consistent Throughput

- **Endurance**
  - Wear Management
  - SLC / MLC / TLC vs. QLC Wear Ratio

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Write Throughput

Active Management

- QLC Programming requires active management
- Tuning required for partially written Blocks
  - Erase History
  - Read History
  - Program Tuning
- Traditionally we leverage relationships between physical Blocks and Pages
Physical Organization of Blocks becoming increasingly complex

- Fewer LUNs
- Endurance Sets
- Namespaces
- Streams
Write Throughput

- Don’t forget about Recycling
  - Doubles the number of active Blocks

As Physical Data Layout complexity increases,
We can no longer leverage Block to Block relationships
Read Latency

Minimal and Consistent

- Die Characteristics
- Block History
  - Erase Count, and Time
- Page History
  - Read Frequency
  - Adjacent Page operations
  - When and at what temperature data was written

- Significant Tuning Data Available
  - Pre and Post Computation / Organization
  - At a fine granularity
  - Accessed and updated Every IOP

Manage the Trigger Rate
Summary

- Challenges and Efforts
  - Significant Logical and Physical data tracking
  - Continuous Tuning and Adjustment
  - Directed and Aligned NAND characterization

- Endurance
- Write Throughput
- Read Latency / Consistency

QLC offers many options over TLC, but is exponentially more complex to manage.
Thank You!