

# Symphonic™

## Cooperative Flash Management

- SSD firmware, host libraries and API that replace the Flash Translation Layer (FTL)
- Enables system software to cooperatively perform Flash management (garbage collection)
- Transforms SSD in an offload engine
- Abstracts NAND programming and geometry while operating in host address space
- Provides Forward Compatibility and RAS functionality

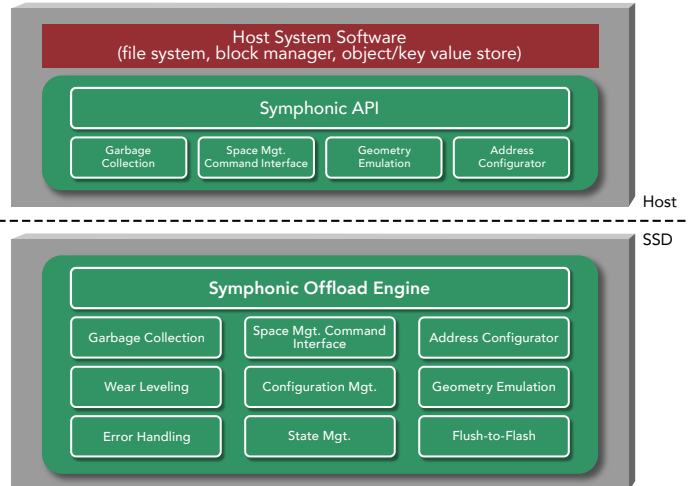
### Symphonic Cooperative Flash Management (CFM)

Symphonic is a type of Software-Defined Flash that replaces the Flash Translation Layer (FTL) found in conventional SSDs to dramatically improve performance and cost metrics while providing the functionality of a data center class product.

- Magnitude improvement in QoS (latency spikes)
- >80% increase in IOPS & User Bandwidth
- Raw Flash reduced 15% or more
- No device level Write Amplification
- Metrics scale linearly with additional SSDs

System software, e.g., file systems, block virtualization managers, or object/key value stores have comprehensive capabilities to intelligently manage storage media. But this system software is not equipped to directly perform some of the unique processes required to manage Flash memory.

Symphonic abstracts several properties of the Flash memory, but provides an interface to the system software that enables it to perform Flash management processes cooperatively. Through this abstraction and



by turning the SSD into an offload engine, Symphonic performs Flash management processes like garbage collection, but does so under host system control, operating in host address space. This approach eliminates the inefficient, redundant abstraction of a FTL to realize the full potential of Flash storage.

The Symphonic host libraries and API interface into the existing system software, providing extensible access and management capabilities. A Symphonic SSD is treated as a block device and the API is based upon the industry standard NVMe command set, with the design also intended to support the SAS protocol.

The Symphonic firmware is a collection of integrated state machines, translation tables, and counters. This functionality provides garbage collection, wear leveling, and error handling capabilities. Abstraction and address configuration functionality minimizes modifications to existing system software while still enabling optimal performance efficiencies. Designed around ACID principles, Symphonic supports RAS (Reliability, Availability, and Serviceability) requirements essential for data center products.

# Solving Software-Defined Flash for the Data Center

## Offload Accelerator Engine

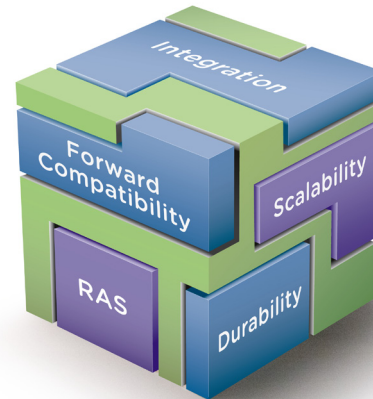
- Symphonic firmware turns the SSD into an offload accelerator engine
- State machines are integrated with mapping tables and statistical counters
- Generates and maintains comprehensive metadata
- Tracks valid/release states and uses heuristic analysis to generate qualitative range fragmentation metrics
- Provides linear scalability across metrics as additional SSDs are added to the system

## Cooperative Garbage Collection

- Garbage collection (copy/move/erase) operations executed by Symphonic firmware, performed entirely on SSD
- Processes scheduled and controlled by host and performed in host address space
- Eliminates additional system copying and overhead, freeing host resources

## Wear Leveling and Reliability

- Wear leveling and bad block management performed by Symphonic firmware on the SSD with ECC
- Processes integrated with garbage collection, transparently to the host
- Optional mode to support global host-based wear leveling
- Fault tolerance and support for ACID requirements
- Provides RAS capabilities such as hot swap and FRU functionality
- Enables vendor supported warranties



## Geometry Emulation

- Virtualizes topology of physical NAND array, exporting an emulated version of device geometry to the host
- Abstracts lower level NAND attributes, releasing host from managing NAND constraints
- Maintains symmetric alignment from host down through NAND array
- Minimizes collisions and unpredictable latency spikes while providing maximum parallelization
- Forward Compatibility to help 'future proof' system software from evolutionary changes in geometry and vendor-specific NAND attributes

## Configurable Addressing

- Symphonic libraries provide extensible connectivity from host space management through the system to SSD firmware
- Facilitates host integration and minimizes modifications to existing host software
- Enables readily optimizing opposing performance and efficiency constraints unique to Flash memory
- Preserves host data layout optimizations through to physical media

Target Operating Systems  
Target Interfaces/Protocols

Linux 2.6.x and above; BSD 9.3.x and above  
NVMe command set  
Intended to support SAS

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