API Specification

Software-Enabled Flash™

API Version: 1.13

SEF-API-01-00

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DEFINITIONS AND CLARIFICATIONS

Definition of capacity: we define a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes and a terabyte (TB) as 1,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1GB = 230 = 1,073,741,824 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, such as Microsoft Operating System and/or pre-installed software applications, or media content. Actual formatted capacity may vary.

KiB: A kibibyte (KiB) means 210, or 1,024 bytes, a mebibyte (MiB) means 220, or 1,048,576 bytes, and a gibibyte (GiB) means 230, or 1,073,741,824 bytes.

Read and write speed may vary depending on the host device, read and write conditions, and file size.

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1 Revision History

Version	Date	Description of change(s)
1.10	2020.08.17	Initial version of the document
1.11	2021.01.22	API clarifications
1.12	2021.08.01	API modified to support new SEF command set
1.13	2022.01.10	API modified. Transferred to SoftwareEnabledFlash.org

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2 Introduction

This specification describes the core components of the Software-Enabled Flash™ (SEF) application programming interface (API).

The SEF API provides a simple but powerful interface for developers that abstracts low-level flash details of low-level flash memory device mechanics in such a way that allows hosts to interact with flash memory devices as though they were simple performance-optimized read/write devices. Hosts can make use of the SEF API to implement a custom Flash Translation Layer (FTL) or build SEF native applications bypassing all file systems in accordance with their application-specific requirements.

The SEF API interfaces with SEF Units. SEF Units are PCIe® based NVMe™ devices that implement the SEF specific extensions to the NVMe Base Specification. These extensions are separately defined as the SEF Command Set.

The SEF API addresses the following:

- Maintaining interface compatibility across flash memory generations
- Allowing host control over data placement to enable application-specific optimizations
- Providing mechanisms to enforce hardware isolation to support multi-tenancy and workload isolation
- Provides control over housekeeping functions to support predictable latency
- Reduces CPU cycles and host overhead via powerful API primitives
- Improves flash memory life and health via intelligent automatic resource allocation

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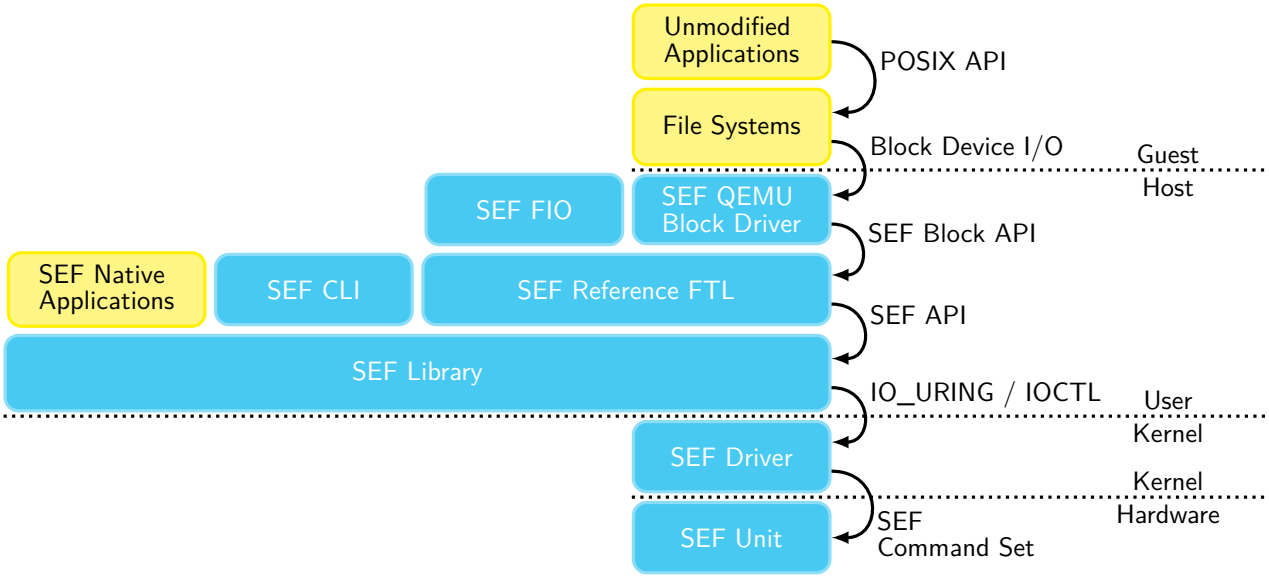
The SEF Library implements the SEF API as a linkable library module. The following figure 2.1 illustrates where the SEF Library is located in the context of a traditional SSD-like application stack. It shows multiple possible integrations of the SEF Library. In some cases the integration is direct like with a SEF enable FIO. Other cases require a host-define FTL exposed to applications as a virtual block device in a QEMU guest. Tooling can also use the SEF Library for configuring SEF units with a command line interface. In all cases, the SEF Library accepts admin and I/O requests and issues a set of commands to the SEF Unit. The SEF Unit then translates this down to an appropriate set of flash memory-level operations and returns status and data back up the stack.

Figure 2.1: SEF Library Application Stack



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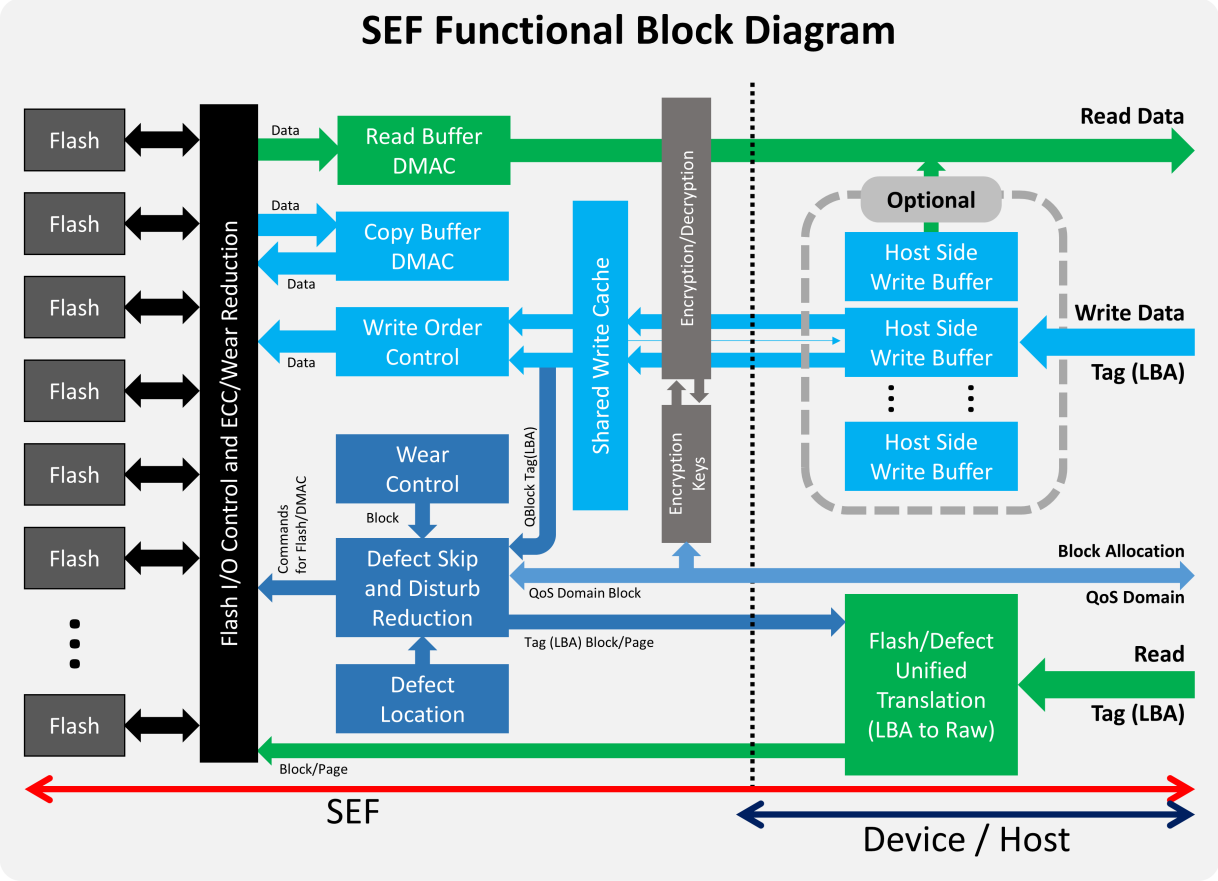
The SEF Unit handles functionality including super block allocation, identifying and working around defective blocks, low-level flash memory I/O, scheduling, prioritization and other device-level concerns. The host layer in turn is responsible for implementing its own data placement strategy (including devising an appropriate logical-to-physical address mapping) as well as coordinating housekeeping functions such as wear leveling, garbage collection, and responding to asynchronous event notifications. The following figure 2.2 provides a detailed view of data flow within a SEF Unit.

Figure 2.2: SEF Block Diagram



Built in conjunction with the SEF API is a SEF SDK that provides a starting point for host application development. The SEF SDK includes quick start guides for tooling to setup SEF devices for use, sample drivers, libraries, supporting documentation, and an implementation of a fully functional Reference FTL that can be extended or modified as appropriate. It is documented separately.

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3 | Definitions and Acronyms

Table 3.1: Definitions and Acronyms

Terms/Acronyms	Definition
Software-Enabled Flash™ (SEF)	A flash memory-based storage hardware platform that is driven by software.
SEF Unit	A PCIe® flash memory storage device. Contains one or more flash memory dies and provides flash memory service functions. The SEF Unit command set consists of a subset of the NVMe™ command set with extensions.
Flash Translation Layer (FTL)	A mapping of Logical Block Addresses (LBA) to flash memory addresses providing a block based API on top of a flash memory API.
Virtual Device (VD)	A set of flash memory dies. A Virtual Device occupies one or more flash memory dies and provides one or more QoS domains and wear leveling service between QoS domains. Flash memory dies can only be assigned to one virtual device; they are never shared between virtual devices. Virtual devices provide true hardware-based isolation. *Refer to Chapter 7 for more information.*
Pseudo Single-Level Cell (pSLC)	SEF devices may optionally support programming flash memory as if it's SLC for increased endurance.

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QoS Domain (QD)	A logical construct exposed to the host and enumerated as a SEF Unit node. QoS domains are created within a single virtual device, and draw super blocks from a common pool within the virtual device. Many QoS domains may be created within a single virtual device. QoS domains provide software-based isolation, impose quotas on capacity, and are comprised of a set of super blocks within a virtual device. Super blocks are not shared between QoS domains. Read/write commands are issued to a specific QoS domain. *Refer to Chapter 8 for more information.*
Super Block	A set of flash memory blocks spanning all of the dies in a virtual device. All flash memory blocks in a super block can be programmed and read in parallel. *Refer to Chapter 10 for more information.*
Logical Block Address (LBA)	Represents one component of an optional user-visible addressing interface implemented by an FTL.
ADU	Atomic data unit. A SEF-defined internal representation of abstract storage that is the minimum read/write quantum (analogous to the block size of a traditional block device). A SEF Unit may support multiple ADU sizes and the ADU size is specified when creating a QoS domain. The minimum ADU size is 4096 bytes.
User Address	Eight bytes of arbitrary metadata that is stored with an ADU. For block storage applications, this is typically the LBA. However the SEF Unit makes no assumptions about the format of this data for non-block storage applications.
Placement ID	A placement ID is used when writing data to a QoS domain. It's used to group data of similar lifetime together. ADUs written with the same placement ID are stored in the same super blocks.
Root Pointer	Provides a bootstrapping mechanism to retrieve metadata from a QoS domain.

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4 Design Environment

The SEF Library runs on a Linux® host. It supports user mode. The library and driver do not support forked processes. The SEF Library API is defined by SEFAPI.h and implemented in libsef.a or libsef.so. It is platform-agnostic and is usable by any code that can use a C interface. The library I/O path functions come in both synchronous and asynchronous versions, which typically have identical functionality and semantics. When this is not true, the API will call out how the synchronous and asynchronous versions differ. Note that callbacks from the library are made from a static internal thread pool and so should not block for long periods of time.

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5 | Design Strategy

The SEF Library is nearly stateless. Nearly all application requests result in one or more requests to the SEF driver. Those requests are submitted using the caller's thread. The completion of asynchronous SEF driver requests is handled by an internal, statically sized thread pool based on the number of CPUs. Therefore, completion routines should not block on resources that require another completion routine to execute as that would risk deadlock. Issuing a synchronous request or waiting for a resource owned by another completion thread won't cause deadlock, but it does reduce the number of threads available to process completions.

Writes to a SEF Unit complete before the final flash memory address has been assigned, returning a preliminary flash address. A notification is sent when the final flash memory address is different than the preliminary address. However, no direct notification is sent when the preliminary flash memory address is the final flash memory address. It can be inferred by utilizing buffer release notifications. The write buffer supplied to the device must remain valid until the data is committed to flash memory. The write call includes a flag that causes notifications to be sent as portions of the buffer have been committed to flash memory. When a buffer release notification is sent, the preliminary addresses for that portion are final, or a notification was already sent for the actual final flash address. In the case of a power failure, up-to-date metadata structures can be rebuilt from the user address data and write serial numbers supplied when the data was written.

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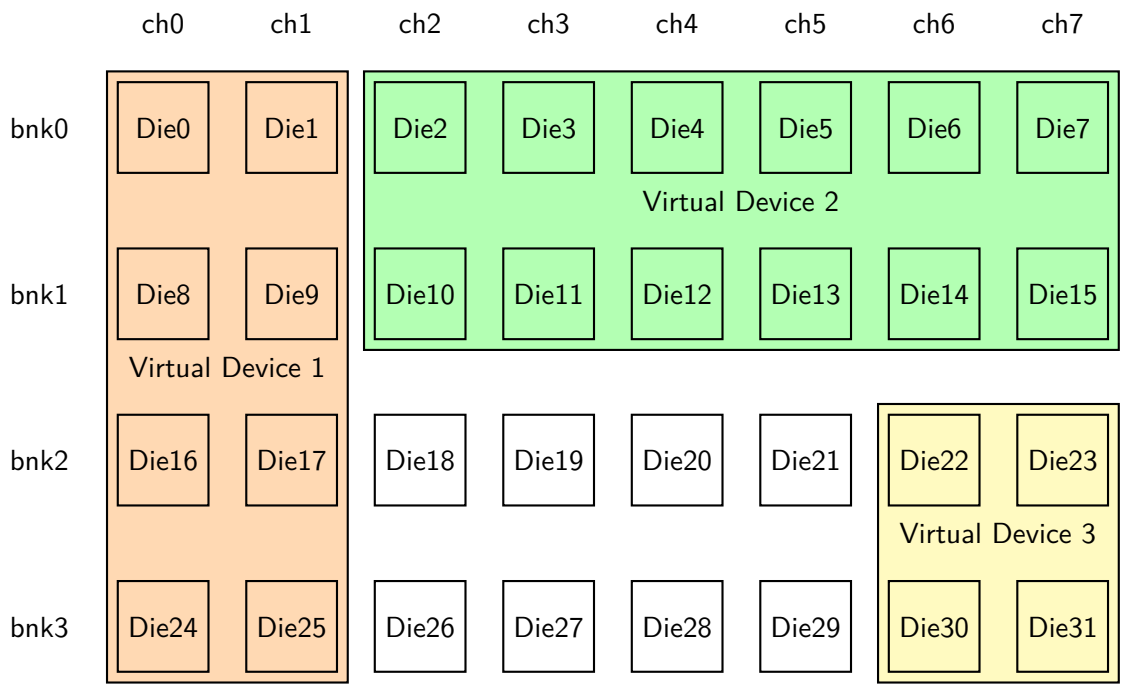
6 | SEF Unit

A SEF Unit is a set of dies and the associated control logic and (optional) DRAM. User-defined lists of dies form a many-to-one mapping of dies to a virtual device. A virtual device represents physical isolation with the number of virtual devices limited by the number of dies in the SEF Unit. Figure 6.1 shows an example of three virtual devices overlaid on an 8 x 4 SEF Unit with eight dies left unallocated.

Figure 6.1: SEF Unit Geometry



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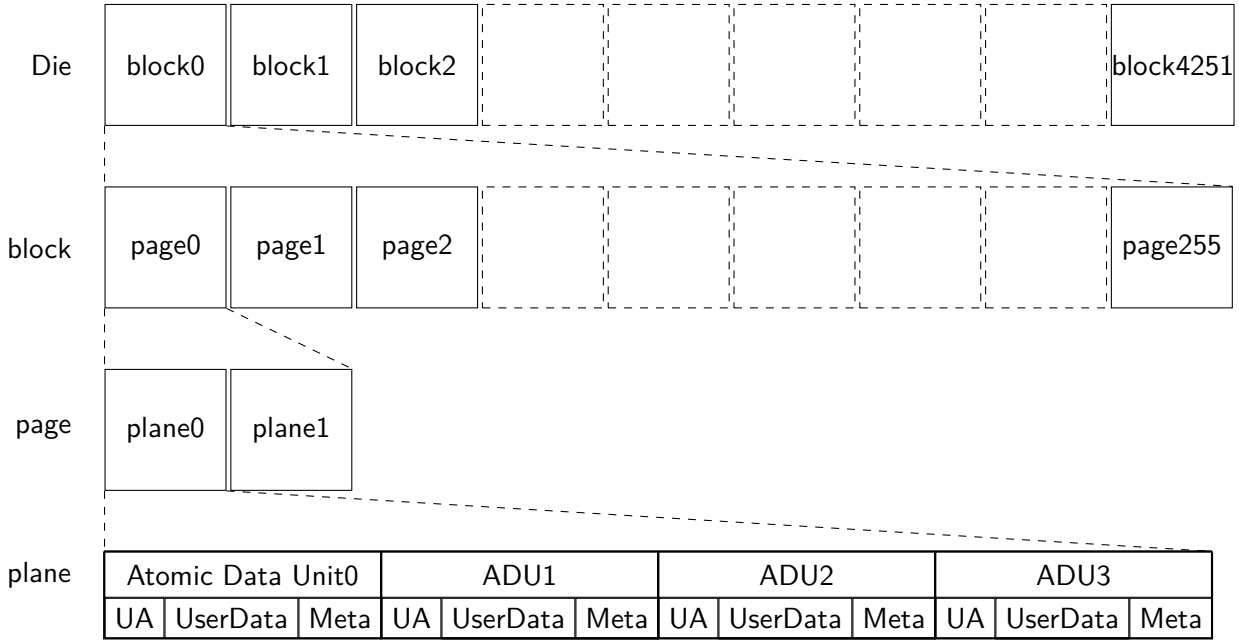
As shown in Figure 6.2, a die is a set of blocks. The blocks are the erase unit for a SEF Unit and consist of a set of pages. A page spans the die planes and is the programing unit. A plane is made up of atomic data units (ADUs). An ADU is the read/write unit holding both user data and metadata. Metadata consists of a user-defined tag data (UA) and a configured number of user supplied metadata (MD).

Figure 6.2: Die Geometry



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7 | Virtual Devices

A Virtual Device encompasses one or more flash memory dies, providing the user the ability to utilize the hardware isolation of separate dies. Dies are not shared across separate virtual devices. I/O operations on one Virtual Device will not compete for die time with other virtual devices. There may be a minimal amount of latency caused by contention between virtual devices due to any internal controller bottlenecks or flash memory channel conflicts for virtual devices that share flash memory channels.

When virtual devices are created, several parameters are specified to define the characteristics of each virtual device. Virtual devices are created by using the `SEFCreateVirtualDevices()`. function. The size of each virtual device is user-configurable and dependent on the resources available. Each virtual device must be given a unique ID.

Because virtual devices represent hardware isolation, the SEF Unit will not wear level across the dies in different virtual devices. It is expected that virtual devices will be created when a SEF Unit is first set up and their geometry not subsequently altered.

7.1 Creation-time Parameters

virtualDeviceID: an identifier that will later be used to specify the created virtual device. This identifier must be unique across the entire SEF Unit. The maximum allowed ID is the number of dies in the SEF Unit.

dieList: Lists the dies that will be owned by the created virtual device.

superBlockSize: The number of dies that define a super block. It must evenly divide into the number of dies defined for the virtual device.

Once a virtual device is created it can be further configured with `SEFSetVirtualDeviceSuspendConfig()` and `SEFSetNumberOfPSLCSuperBlocks()`.

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8 | QoS Domains

A QoS domain is the mechanism used to access data within a SEF Unit. QoS domains are created within a virtual device, and it is possible to have multiple QoS domains sharing a single virtual device. When multiple QoS domains share a virtual device, they will draw from a common pool of super blocks. However a super block is never shared between QoS domains and so data for QoS domains will never be intermingled in a super block. When QoS domains share a virtual device, there is no hardware isolation between them, so die-time conflicts are possible. The scheduling and prioritization features of SEF are used to order I/O for shared virtual devices and to resolve these die-time conflicts (e.g., software-defined isolation/quality of service).

When a QoS domain is created, several parameters are specified to define the characteristics of the QoS domain, which will be discussed below. Upon successful creation of a QoS domain, a device node will be created in the operating system namespace corresponding to the newly created QoS domain. It has a capacity and quota. The capacity is storage reserved in the virtual device for use by the QoS domain. The quota is how much total storage can be assigned to the QoS domain. Initially the quota is set to the capacity, but both can be changed later using `SEFSetQoSDomainCapacity()`. At boot time the SEF Unit driver will create device nodes for all QoS domains previously defined for the device. Device nodes for QoS domains may be used to enumerate existing QoS domains as well as to restrict access to/enforce ownership of a QoS domain. All user data access commands are issued against a QoS domain. Typically, a QoS domain will be used by a single application or Flash Translation Layer/block driver/key value driver.

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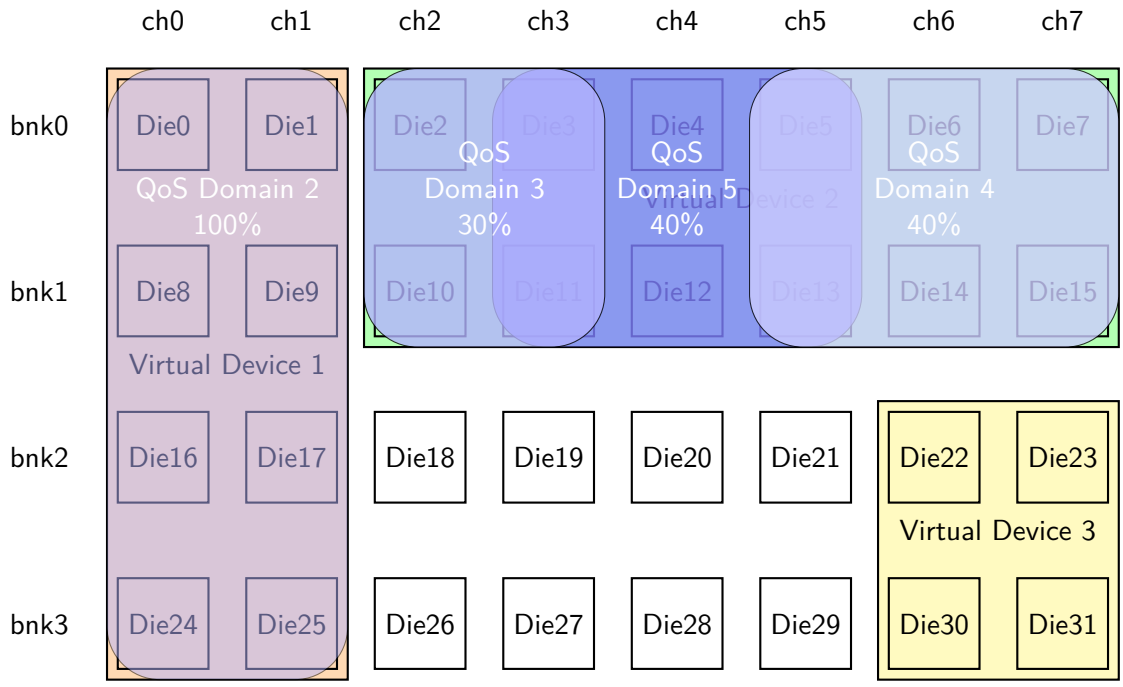
An example of how the virtual devices of a SEF Unit could be divided into QoS domains is shown in the following figure 8.1. A QoS domain is a logical construct that defines a capacity taken from its virtual device's capacity. It also defines a quota that may exceed the capacity of the virtual device as shown with QoS domains three through four. A SEF Unit can have at most 65534 QoS domains defined. The actual limit depends on the specific hardware.

Figure 8.1: QoS Domain Example



Allocated super blocks are owned by only one QoS domain at a time and are never shared. Super blocks are allocated from a shared pool allowing for host-managed thin provisioning. A QoS domain can allocate super blocks until it hits its quota or the free pool is exhausted.

8.1 Creation-time Parameters

vdHandle: the handle to the virtual device the QoS domain will be created in.

QoSDomainID: an identifier that will later be used to specify the created QoS domain. This identifier must be unique across the entire SEF Unit. Valid IDs start at 1 and must be less than or equal to `maxQoSDomains` returned by `SEFGetInformation()`.

flashCapacity: the number of 4KiB ADUs reserved for the QoS domain. It is subtracted from the available ADUs from the virtual device so must be less than the currently available ADUs. This is also used as the initial value for flashQuota.

pSLCFlashCapacity: the number of 4KiB pSLC ADUs reserved for the QoS domain. It is subtracted

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from the available pSLC ADUs from the virtual device so must be less than the currently available pSLC ADUs. This is also used as the initial value for pSLCFlashQuota.

ADUIndex: this is the index into the ADUSize[] array in `SEFInfo` returned by `SEFGetInformation()` to select the data and metadata sizes of an ADU.

api: this field specifies the API to be used for this QoS domain. Currently only the super block API is supported.

defectStrategy: Specifies how defective ADUs are handled by the QoS domain. The choices are Perfect, Packed or Fragmented. The Perfect strategy hides defective ADUs through overprovisioning and mapping. Capacity is reserved, and ADUs are remapped to provide static and consistent flash memory addresses with contiguous ADU offsets. Packed also hides defective ADUs presenting consistent flash memory addresses with contiguous ADU offsets, but the size of super blocks will shrink as the device wears. With the Fragmented strategy, the client is exposed to the device's defect management. ADU offsets are non-contiguous, and super blocks will shrink in size as the device wears. Refer to Chapter 11 for more details.

recovery: Specifies the error recovery strategy for this QoS domain.

encryption: specifies the key the QoS domain is to be encrypted with.

numPlacementIDs: specifies the number of separate, simultaneously opened super blocks that may be used by the QoS domain in auto allocation mode. It does not affect the number of manually opened super blocks, which instead depends on the device itself.

maxOpenSuperBlocks: this is the maximum number super blocks that can be open in a QoS domain. If less than numPlacementIDs it will be set to numPlacementIDs+2. This affects resource and memory usage in the device.

defaultReadQueue: specifies the default read queue to use for read I/O operations. This can be optionally overridden when submitting I/O to a QoS domain. Read queues are defined by the virtual device and shared by the QoS domains defined in the same virtual device.

weights: Specifies the default weights for erase and program.

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9 Super Pages

A Super Page is the optimal unit for physical read and write. It consists of the same hardware page from each die in the super block. When data is read or written, the super page construct allows the data to be striped across the dies to achieve the maximum performance by involving each die of the virtual device in parallel.

The size of a super page is not static but the maximum size is defined by the geometry of the virtual device. The size of a super page may be further constricted by setting a super block size. Super pages are read and written in integer multiples of ADUs. Super pages are grouped into super blocks. The number of super pages contained in a super block is a static number defined by the specific generation of flash memory die being used in the device.

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10 | Super Blocks

Super blocks are the main units of allocation used within the SEF API. By default, super blocks span all the dies within a single virtual device. However, the size of the super block may be changed prior to creating any QoS Domains. The number of super pages in a super block is fixed and is the same as the number of pages in a flash die. The size of a super block, however, is dependent on the configuration of the virtual device that it resides in. A super block can only be a member of a single QoS domain at any point in time. A super block can only be assigned to a different QoS domain after it has been released.

When an erase or allocation occurs within a QoS domain, it is performed in units of super blocks.

10.1 Super Block Management Commands

Super block management commands consist of three functions: `Allocate` , `Close` and `Release`. Super block data commands consist of the commands `Write` and `Copy`. Each command affects state conditions of the super block. Figure 10.1 shows the state transitions regarding super blocks.

Super blocks are allocated either explicitly by the `Allocate` command, or implicitly by the `Write` command. When the reserved flash memory address `SEFAutoAllocate` is specified in a `Write` command, SEF will check if a super block has been allocated for the corresponding placement ID; if not and the QoS domain has not exceeded its capacity limit, a new super block will automatically be allocated and assigned to the placement ID. When a `Write` command with the reserved flash memory address extends past the end of the current automatically opened super block, a new super block will be allocated (assuming the capacity limit is not exceeded) once the current super block is filled.

The host does not need to erase super blocks. When the defect strategy is packed or fragmented, the apparent size of the super block may shrink after it is erased. This affects `SEFWriteWithoutPhysicalAddress()`, `SEFGetSuperBlockInfo()` and `SEFAllocateSuperBlock()`. The number of available ADUs may also shrink as the super block is programmed.

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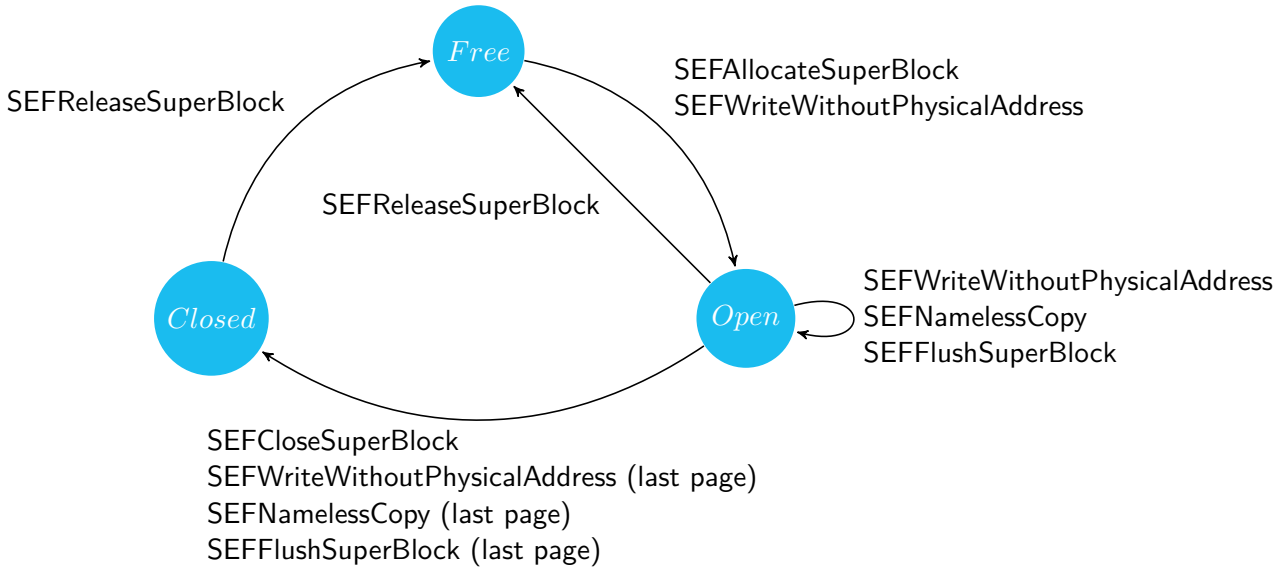
Figure 10.1: Super Block State Transitions



Free State

`Free` is the initial state for super blocks. `Free` super blocks belong to the free pool owned by a Virtual Device.

`Closed` super blocks transit to `Free` upon the Release command.

Open State

This is the state of super blocks in the middle of being programmed. `Free` super blocks transit to `Open` by either the Allocate or Write Without Physical Address command.

There are two sub-states of the `Open` states:

- *Open for Write Without Physical Address*: A super block dedicated to `SEFWriteWithoutPhysicalAddress()`. The super block transits to this state via a Nameless Write command without explicit super block ID. The number of super blocks that can exist in this state is determined by the `placementID` parameter at the time of creation for a QoS domain.
- *Open by Erase*: A super block opened by the super block management command `SEFAllocateSuperBlock()`. This super block can be used as a destination for Nameless copy and by Nameless Write by specifying an explicit super block ID. This is the only way to write to a pSLC super block.

Closed

This is the state of super blocks which retain effective data after all Super Pages have been programmed. `Open` super blocks transit to `Closed` by either a Nameless Write command, a Nameless Copy command, an explicit Close command, an explicit Flush command or a device-initiated automatic flush or close.

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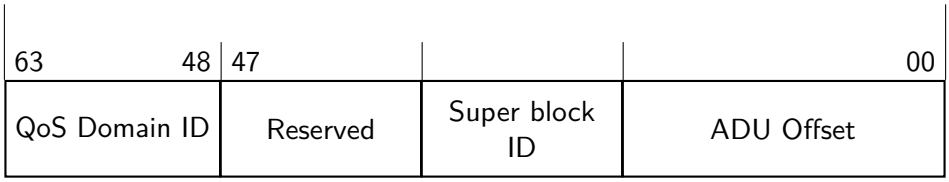
11 | Addressing

The physical address of an ADU is assigned by the SEF Unit and returned after the data has been written to a QoS domain. The returned addresses must be supplied when reading the data back from a QoS domain. Because the layout of a flash memory address depends on the type of a SEF Unit, flash memory addresses should be treated as opaque. When debugging, it can be useful to know their structure. They consist of a QoS domain ID, super block ID and an ADU offset as shown in Figure 11.1.

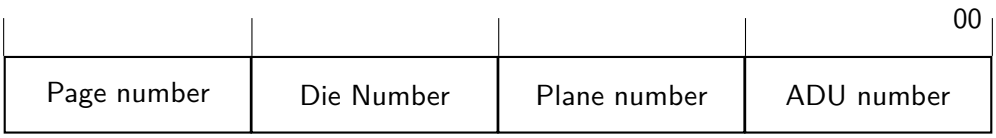
Figure 11.1: Flash Address



QoS domain IDs are 16 bits. The lower 48-bit field of LBA field consists of super block ID in the upper and ADU Offset in the lower, and the remaining part is reserved. The exact size of each field depends on the device type. The functions `SEFParseFlashAddress()` and `SEFCreateFlashAddress()` are used to pull apart and build flash memory addresses.

In Perfect and Packed modes, the ADU offset is contiguous from 0 up to the size of the super block. In Fragmented mode, the ADU Offset is non-contiguous and the defective planes are skipped. The ADU Offset is constructed with ADU number, Plane number, Die number and Page number in low-to-high order. Note that each element is not always a power of two.

Figure 11.2: Elements constructing ADU Offset in Fragmented mode



The function `SEFParseFlashAddress()` and `SEFCreateFlashAddress()` hide the details of deconstructing and constructing a flash memory address.

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12 | API Management Commands

12.1 SEFLibraryInit

```
1 struct SEFStatus SEFLibraryInit(void)
```

Initializes the SEF Library, enumerates the SEF Units present, and returns the number of units found. Every successful call to SEFLibraryInit() must be balanced with a call to SEFLibraryCleanup().
See Also: SEFLibraryCleanup

Table 12.1: Return value of SEFLibraryInit

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.2: Return values of SEFLibraryInit

Error Value	Description
0	The info member returns the number of units

12.2 SEFGetHandle

```
1 SEFHandle SEFGetHandle(uint16_t index)
```

Returns a handle to the SEF Unit at the specified index (zero based)

Table 12.3: Parameters of SEFGetHandle

Type	Name	Direction	Description
uint16_t	index	In	Index of the SEF Unit

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Table 12.4: Return value of SEFGetHandle

Type	Description
SEFHandle	Handle to the SEF Unit

12.3 SEFLibraryCleanup

```
1 struct SEFStatus SEFLibraryCleanup(void)
```

Performs cleanup of the SEF Library and releases resources.
Every successful call to SEFLibraryInit() must be balanced with a call to SEFLibraryCleanup().
Note: When the returned status error and info fields are zero, all open handles are closed, invalidated and are unusable.
See Also: SEFLibraryInit

Table 12.5: Return value of SEFLibraryCleanup

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.6: Return values of SEFLibraryCleanup

Error Value	Description
0	The info field is the library's reference count.
-ENODEV	The SEF Library was not initialized
-EWOULDBLOCK	This function cannot be called on a callback thread

12.4 SEFGetInformation

```
1 const struct SEFInfo* SEFGetInformation(SEFHandle sefHandle)
```

Gets device information.
Returns ADU size(s), number of channels, number of dies, and other associated information. Dynamic values are refreshed just before the structure is returned.

Table 12.7: Parameters of SEFGetInformation

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit

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Table 12.8: Return value of SEFGetInformation

Type	Description
const struct SEFInfo *	SEFInfo struct or NULL if sefHandle is NULL.

12.5 SEFListVirtualDevices

```
struct SEFStatus SEFListVirtualDevices(SEFHandle sefHandle, struct
    SEFVirtualDeviceList *list, int bufferSize)
```

Returns a list of the defined Virtual Devices.
When list is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete list. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the list structure.

Table 12.9: Parameters of SEFListVirtualDevices

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFVirtualDeviceList*	list	Out	Buffer for storing list of Virtual Devices
int	bufferSize	In	Buffer size

Table 12.10: Return value of SEFListVirtualDevices

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.11: Return values of SEFListVirtualDevices

Error Value	Description
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.6 SEFListQoSDomains

```
struct SEFStatus SEFListQoSDomains(SEFHandle sefHandle, struct
    SEFQoSDomainList *list, int bufferSize)
```


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Returns a list of the defined QoS Domains.
When list is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete list. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the list structure.

Table 12.12: Parameters of SEFListQoSDomains

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFQoSDomainList*	list	Out	Buffer for storing list of QoS Domains
int	bufferSize	In	Buffer size

Table 12.13: Return value of SEFListQoSDomains

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.14: Return values of SEFListQoSDomains

Error Value	Description
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.7 SEFGetUserAddressMeta

```
1 static uint32_t SEFGetUserAddressMeta(struct SEFUserAddress
    userAddress)
```

Table 12.15: Parameters of SEFGetUserAddressMeta

Type	Name	Direction	Description
struct SEFUserAddress	userAddress	In	User address to be parsed

Table 12.16: Return value of SEFGetUserAddressMeta

Type	Description
uint32_t	Returns meta value from a user address

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12.8 SEFGetUserAddressLba

```
static uint64_t SEFGetUserAddressLba(struct SEFUserAddress
    userAddress)
```

Table 12.17: Parameters of SEFGetUserAddressLba

Type	Name	Direction	Description
struct SEFUserAddress	userAddress	In	User address to be parsed

Table 12.18: Return value of SEFGetUserAddressLba

Type	Description
uint64_t	Returns LBA value from a user address

12.9 SEFParseUserAddress

```
static void SEFParseUserAddress(struct SEFUserAddress userAddress,
    uint64_t *lba, uint32_t *meta)
```

Return LBA and meta values from a user address.

Table 12.19: Parameters of SEFParseUserAddress

Type	Name	Direction	Description
struct SEFUserAddress	userAddress	In	User address to be parsed
uint64_t *	lba	Out	Lba parsed from the user address
uint32_t *	meta	Out	Meta parsed from the user address

12.10 SEFCreateUserAddress

```
static struct SEFUserAddress SEFCreateUserAddress(uint64_t lba,
    uint32_t meta)
```

Creates a user address from lba and meta values.

Table 12.20: Parameters of SEFCreateUserAddress

Type	Name	Direction	Description
uint64_t	lba	In	lba to be used to generate user address (40 bits)

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uint32_t	meta	In	meta to be used to generate user address (24 bits)

Table 12.21: Return value of SEFCreateUserAddress

Type	Description
struct SEFUserAddress	Returns the user address created from lba and meta values

12.11 SEFCreateVirtualDevices

```
struct SEFStatus SEFCreateVirtualDevices(SEFHandle sefHandle,
    uint16_t numVirtualDevices, struct SEFVirtualDeviceConfig *const
    virtualDeviceConfigs[])
```

Creates the Virtual Devices and allocates physical resources.
Configuring the virtual devices for a SEF Unit is only done during pre-production. Once the flash of a SEF Unit has been written to, it is not possible to change the Virtual Device configuration.
Configuration is accomplished by supplying a array of pointers to virtualDeviceConfigs. Each Virtual Device being configured will have a single array entry. Each of those entries contains a list of die IDs that will define a specific Virtual Device. The superBlockDies in the config must be 0 or evenly divide into the number of dies specified by the die list.
Valid die IDs start at 0 and are less than the total number of dies in a SEF Unit. The total number of dies is equal to SEFInfo::numBanks * SEFInfo::numChannels. The die ID of a die at channel CH, bank BNK, is equal to CH + BNK*SEFInfo::numChannels. The die IDs in the dieList in a virtual device configuration must be in ascending order. A die ID can only be used in at most one Virtual Device configuration. If a die is not included in any Virtual Device configuration, it will be lost capacity that can never be used.
See Also: SEFGetInformation

Table 12.22: Parameters of SEFCreateVirtualDevices

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
uint16_t	numVirtualDevices	In	Number of entries in virtualDeviceConfigs
const struct SEFVirtualDeviceConfig[]*	virtualDeviceConfigs	In	Pointers to configurations describing how to create the virtual devices

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Table 12.23: Return value of SEFCreateVirtualDevices

Type	Description
struct SEFStatus	Status and info summarizing result. Returns 0 on success and negative value on error.

Table 12.24: Return values of SEFCreateVirtualDevices

Error Value	Description
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-EACCES	You don't have the needed permission to perform this operation

12.12 SEFSetNumberOfPSLCSuperBlocks

```
1 struct SEFStatus SEFSetNumberOfPSLCSuperBlocks(SEFVDHandle
    vdHandle, uint32_t numPSLCSuperBlocks)
```

Sets the number of pSLC super blocks.
This defines the number of regular super blocks which are transformed to use as pSLC super blocks. Because it applies to all the dies in the Virtual Device, the value must be a multiple of the ratio of the number of dies in the Virtual Device to the number of configured dies per super block.
Once super blocks have been allocated from the Virtual Device, it may not be possible to modify the number of pSLC super blocks and the call will fail with -ENOSPC.

Table 12.25: Parameters of SEFSetNumberOfPSLCSuperBlocks

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the SEF Unit
uint32_t	numPSLCSuperBlocks	In	The number of pSLC super blocks to set

Table 12.26: Return values of SEFSetNumberOfPSLCSuperBlocks

Error Value	Description
0	The number of pSLC super blocks has been set
-ENODEV	The SEF Handle is not valid
-ENOSPC	No space is available for pSLC super blocks
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid.

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12.13 SEFGetVirtualDeviceUsage

```
struct SEFStatus SEFGetVirtualDeviceUsage(SEFVDHandle vdHandle,
    struct SEFVirtualDeviceUsage *usage)
```

Returns Virtual Device usage.

Table 12.27: Parameters of SEFGetVirtualDeviceUsage

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the Virtual Device
struct SEFVirtualDeviceUsage*	usage	Out	Buffer for storing VD usage

Table 12.28: Return value of SEFGetVirtualDeviceUsage

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.29: Return values of SEFGetVirtualDeviceUsage

Error Value	Description
-ENODEV	The Virtual Device Handle is not valid
-EPERM	The Virtual Device Handle is not open

12.14 SEFGetDieList

```
struct SEFStatus SEFGetDieList(SEFHandle sefHandle, struct
    SEFVirtualDeviceID virtualDeviceID, struct SEFDieList *list, int
    bufferSize)
```

Returns Virtual Device die list.
When list is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete list. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the list structure.

Table 12.30: Parameters of SEFGetDieList

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit

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struct SEFVirtualDeviceID	virtualDeviceID	In	Virtual Device ID
struct SEFDieList*	list	Out	Buffer for storing VD information
int	bufferSize	In	Buffer size

Table 12.31: Return value of SEFGetDieList

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.32: Return values of SEFGetDieList

Error Value	Description
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.15 SEFGetVirtualDeviceInformation

```
1 struct SEFStatus SEFGetVirtualDeviceInformation(SEFHandle
    sefHandle, struct SEFVirtualDeviceID virtualDeviceID, struct
    SEFVirtualDeviceInfo *info, int bufferSize)
```

Returns Virtual Device information.
When info is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete set of information. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the info structure.

Table 12.33: Parameters of SEFGetVirtualDeviceInformation

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFVirtualDeviceID	virtualDeviceID	In	Virtual Device ID
struct SEFVirtualDeviceInfo*	info	Out	Buffer for storing VD information
int	bufferSize	In	Buffer size

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Table 12.34: Return value of SEFGetVirtualDeviceInformation

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.35: Return values of SEFGetVirtualDeviceInformation

Error Value	Description
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.16 SEFSetVirtualDeviceSuspendConfig

```
1 struct SEFStatus SEFSetVirtualDeviceSuspendConfig(SEFVDHandle
    vdHandle, const struct SEFVirtualDeviceSuspendConfig *config)
```

Sets the suspend configuration for a Virtual Device.

Table 12.36: Parameters of SEFSetVirtualDeviceSuspendConfig

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the SEF Unit
const struct SEFVirtualDeviceSuspendConfig*	config	In	Suspend configuration to set

Table 12.37: Return values of SEFSetVirtualDeviceSuspendConfig

Error Value	Description
0	The suspend configuration has been set
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid.

12.17 SEFCreateQoSDomain

```
1 struct SEFStatus SEFCreateQoSDomain(SEFVDHandle vdHandle, struct
    SEFQoSDomainID QoSDomainID, uint64_t flashCapacity, uint64_t
    pSLCFlashCapacity, int ADUindex, enum SEFAPIIdentifier api, enum
```


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```
SEFDefectManagementMethod defectStrategy, enum
SEFErrorRecoveryMode recovery, const char *encryptionKey,
uint16_t numPlacementIDs, uint16_t maxOpenSuperBlocks, uint8_t
defaultReadQueue, struct SEFWeights weights)
```

Attempts to create a QoS Domain in the specified Virtual Device.
Returns an error when the target Virtual Device doesn't have enough flash memory space. The actual flash capacity reserved in the Virtual Device is typically larger than what was requested by flashCapacity.
See Also: SEFGetInformation

Table 12.38: Parameters of SEFCreateQoSDomain

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the Virtual Device
struct SEFQoSDomainID	QoSDomainID	In	QoS Domain ID. Unique across all QoS Domains
uint64_t	flashCapacity	In	Number of required/reserved ADUs
uint64_t	pSLCFlashCapacity	In	Number of required/reserved pSLC adus
int	ADUindex	In	Index into the ADUSize[] array in SEFInfo returned by SEFGetInformation() to select the data and metadata sizes of an ADU.
enum SEFAPIIdentifier	api	In	Specifies the API Identifier for this QoS Domain
enum SEFDefectManagementMethod	defectStrategy	In	Specifies the defect management strategy for the QoS Domain
enum SEFErrorRecoveryMode	recovery	In	Specifies the recovery mode for this QoS Domain
const char *	encryptionKey	In	NULL for disabled.

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uint16_t	numPlacementIDs	In	The maximum number of Placement IDs that can be placed on the QoS Domain.
uint16_t	maxOpenSuperBlocks	In	The maximum number super blocks that can be open in a QoS Domain. If less than numPlacementIDs it will be set to numPlacementIDs+2. This affects resource/memory usage in the device.
uint8_t	defaultReadQueue	In	The default read queue assignment, 0 through numReadQueues-1 defined for the Virtual Device.
struct SEFWeights	weights	In	Weight values for each type of write I/O operations.

Table 12.39: Return value of SEFCreateQoSDomain

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.40: Return values of SEFCreateQoSDomain

Error Value	Description
-ENODEV	The Virtual Device Handle is not valid
-EPERM	The Virtual Device Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-ENOMEM	The library was unable to allocate needed structures. status.info is set to the type of capacity that caused the failure (kForWrite or kForPSLCWrite)

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12.18 SEFSetQoSDomainCapacity

```
struct SEFStatus SEFSetQoSDomainCapacity(SEFVDHandle vdHandle,
    struct SEFQoSDomainID QoSDomainID, enum SEFSuperBlockType type,
    uint64_t flashCapacity, uint64_t flashQuota)
```

Resets the capacity of a QoS Domain.
Sets a new capacity and quota for the QoS Domain. When the flashQuota is less the flashCapacity or the used flashedCapacity, it will be set to the larger of the two.

Table 12.41: Parameters of SEFSetQoSDomainCapacity

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the Virtual Device
struct SEFQoSDomainID	QoSDomainID	In	QoS Domain ID
enum SEFSuperBlockType	type	In	Type of super block
uint64_t	flashCapacity	In	Number of required/reserved ADUs for the specified type of super block
uint64_t	flashQuota	In	Number of ADUs that can be allocated for the specified type of super block

Table 12.42: Return value of SEFSetQoSDomainCapacity

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.43: Return values of SEFSetQoSDomainCapacity

Error Value	Description
-ENODEV	The Virtual Device Handle is not valid
-EPERM	The Virtual Device Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-ENOSPC	The Virtual Device does not have enough space

12.19 SEFSetRootPointer

```
struct SEFStatus SEFSetRootPointer(SEFQoSHandle qosHandle, int
    index, struct SEFFlashAddress value)
```

Sets the value of a QoSDomain root pointer.

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A root pointer may be set to any value. Root pointer values are read back using SEFGetQoSDomainInformation(). When a root pointer is set to a flash address that is valid for the QoS Domain it's stored in, the ADU it points to can be read by SEFReadWithPhysicalAddress() using a flash address of just the root pointer index as the ADU oftset with zeros for the QoS DomainId and super block index.
See Also: SEFReadWithPhysicalAddress

Table 12.44: Parameters of SEFSetRootPointer

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
int	index	In	The index of the root pointer
struct SEFFlashAddress	value	In	Value of the pointer

Table 12.45: Return value of SEFSetRootPointer

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.46: Return values of SEFSetRootPointer

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

12.20 SEFSetReadDeadline

```
1 struct SEFStatus SEFSetReadDeadline(SEFQoSHandle qosHandle, enum
     SEFDeadlineType deadline)
```

Sets target QoS Domain's read deadline policy.
See Also: SEFVirtualDeviceInfo

Table 12.47: Parameters of SEFSetReadDeadline

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
enum SEFDeadlineType	deadline	In	Deadline type for this QoS Domain

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Table 12.48: Return value of SEFSetReadDeadline

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.49: Return values of SEFSetReadDeadline

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open

12.21 SEFGetSuperBlockList

```
1 struct SEFStatus SEFGetSuperBlockList(SEFQoSHandle qosHandle,
    struct SEFSuperBlockList *list, int bufferSize)
```

Returns a list of super blocks assigned to the QoS Domain.
When list is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete list. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the list structure.

Table 12.50: Parameters of SEFGetSuperBlockList

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFSuperBlockList*	list	Out	List of super block records
int	bufferSize	In	Buffer size

Table 12.51: Return value of SEFGetSuperBlockList

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.52: Return values of SEFGetSuperBlockList

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

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0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.22 SEFGetQoSDomainInformation

```
struct SEFStatus SEFGetQoSDomainInformation(SEFHandle sefHandle,
    struct SEFQoSDomainID QoSDomainID, struct SEFQoSDomainInfo *info)
```

Returns QoS Domain information, including the list of super blocks assigned to the QoS Domain.

Table 12.53: Parameters of SEFGetQoSDomainInformation

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFQoSDomainID	QoSDomainID	In	QoS Domain ID
struct SEFQoSDomainInfo*	info	Out	Buffer for storing QoS Domain information

Table 12.54: Return value of SEFGetQoSDomainInformation

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.55: Return values of SEFGetQoSDomainInformation

Error Value	Description
-ENODEV	The SEF handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	SEFQoSDomainInfo was successfully returned.

12.23 SEFGetReuseList

```
struct SEFStatus SEFGetReuseList(SEFQoSHandle qosHandle, struct
    SEFWearInfo *info, int bufferSize)
```

Returns list of super blocks to process for wear-leveling.
Used in support of the implementation of a host-specified wear leveling policy. The SEF Unit has a built in wear-leveling mechanism. It returns closed blocks in the order they should be released if subject to

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the host-specified wear leveling policy.
When info is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete set of information. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the info structure.

Table 12.56: Parameters of SEFGetReuseList

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFWearInfo*	info	Out	Buffer for storing information of blocks to process
int	bufferSize	In	Buffer size

Table 12.57: Return value of SEFGetReuseList

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.58: Return values of SEFGetReuseList

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.24 SEFGetRefreshList

```
1 struct SEFStatus SEFGetRefreshList(SEFQoSHandle qosHandle, struct
    SEFRefreshInfo *info, int bufferSize)
```

Returns a list of blocks that have encountered ECC corrections.
These blocks subsequently need to be re-written, or else data loss may occur. This call should be part of a periodic background check to guard against data loss.
When info is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete set of information. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the info structure.

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Table 12.59: Parameters of SEFGetRefreshList

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFRefreshInfo*	info	Out	Buffer for storing information of blocks to process
int	bufferSize	In	Buffer size

Table 12.60: Return value of SEFGetRefreshList

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.61: Return values of SEFGetRefreshList

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.25 SEFGetCheckList

```
1 struct SEFStatus SEFGetCheckList(SEFQoSHandle qosHandle, struct
    SEFCheckInfo *info, int bufferSize)
```

Returns a list of blocks that have encountered conditions that need to be checked.
In the event that this command indicates that blocks need to be checked, a subsequent patrol command (SEFCheckSuperBlock) should be issued in response. Detailed error statistics will be returned as part of the patrol, and appropriate corrective actions can be based on the returned information.
When info is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete set of information. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the info structure.
See Also: SEFCheckSuperBlock

Table 12.62: Parameters of SEFGetCheckList

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain

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struct SEFCheckInfo*	info	Out	Buffer for storing information of blocks to process
int	bufferSize	In	Buffer size

Table 12.63: Return value of SEFGetCheckList

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.64: Return values of SEFGetCheckList

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.26 SEFGetUserAddressList

```
1 struct SEFStatus SEFGetUserAddressList(SEFQoSHandle qosHandle,
    struct SEFFlashAddress flashAddress, struct SEFUserAddressList
    *list, int bufferSize)
```

Returns the user address list in terms of its underlying super blocks.
Used as part of an FTL reconstruction activity. This can happen in the event of, for example, ungraceful shutdown. This mechanism can also be used to build custom diagnostic tools. This command is not needed during normal operation.
ADUs that have not been written return a user address equal to SEFUserAddressIgnore.
When list is NULL or insufficiently sized or bufferSize is 0, status.info returns the minimum buffer size for the complete list. The data that fits in an insufficiently sized buffer is valid but incomplete. The buffer must be at least the size of the list structure.

Table 12.65: Parameters of SEFGetUserAddressList

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFFlashAddress	flashAddress	In	Flash address of the super block
struct SEFUserAddressList*	list	Out	Buffer for storing list of user addresses

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int	bufferSize	In	Buffer size

Table 12.66: Return value of SEFGetUserAddressList

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.67: Return values of SEFGetUserAddressList

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
0	info field returns the minimum buffer size if the buffer is insufficient or NULL; otherwise, 0

12.27 SEFGetSuperBlockInfo

```
1 struct SEFStatus SEFGetSuperBlockInfo(SEFQoSHandle qosHandle,
    struct SEFFlashAddress flashAddress, int getDefectMap, struct
    SEFSuperBlockInfo *info)
```

Returns information corresponding to the super block.

Table 12.68: Parameters of SEFGetSuperBlockInfo

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFFlashAddress	flashAddress	In	Flash address of the super block
int	getDefectMap	In	When non-zero populates the defectBitmap member of SEFSuperBlockInfo. See SEFSuperBlockInfo for information on the size of defectBitmap
struct SEFSuperBlockInfo*	info	Out	Buffer for storing super block information

Table 12.69: Return value of SEFGetSuperBlockInfo

Type	Description

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struct SEFStatus	Status and info summarizing result.

Table 12.70: Return values of SEFGetSuperBlockInfo

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

12.28 SEFCheckSuperBlock

```
1 struct SEFStatus SEFCheckSuperBlock(SEFQoSHandle qosHandle, struct
    SEFFlashAddress flashAddress)
```

This is a read patrol operation which is used in conjunction with SEFGetCheckList and the kRequirePatrol QoS Notification.
Patrol reads don't use the scheduling queues and are issued as soon as possible. Any actions required by the result of the patrol will generate the appropriate QoS Notification.
See Also: SEFGetCheckList

Table 12.71: Parameters of SEFCheckSuperBlock

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFFlashAddress	flashAddress	In	Flash address of the super block to be checked

Table 12.72: Return value of SEFCheckSuperBlock

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.73: Return values of SEFCheckSuperBlock

Error Value	Description
0	The super block is checked
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

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12.29 SEFDeleteVirtualDevices

```
struct SEFStatus SEFDeleteVirtualDevices(SEFHandle sefHandle)
```

Deletes the Virtual Devices and allocated physical resources.
Deleting virtual devices for a SEF Unit can only be done during pre-production. Once the flash of a SEF Unit has been written to, it is not possible to delete the Virtual Device configuration.

Table 12.74: Parameters of SEFDeleteVirtualDevices

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit

Table 12.75: Return value of SEFDeleteVirtualDevices

Type	Description
struct SEFStatus	Status and info summarizing result. Returns 0 on success and negative value on error.

Table 12.76: Return values of SEFDeleteVirtualDevices

Error Value	Description
-ENODEV	The SEF Handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-EACCES	You don't have the needed permission to perform this operation
-ENOTEMPTY	At least one QoS Domain exists
-EBUSY	The Virtual Device is in use and not all the handles are closed

12.30 SEFDeleteQoSDomain

```
struct SEFStatus SEFDeleteQoSDomain(SEFHandle sefHandle, struct
    SEFQoSDomainID QoSDomainID)
```

Deletes the target QoS Domain.
The QoS Domain must be in the closed state before issuing this command. After closing the target QoS Domain, its assigned super blocks are returned to the Virtual Device's free pool.

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Table 12.77: Parameters of SEFDeleteQoSDomain

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFQoSDomainID	QoSDomainID	In	QoS Domain ID

Table 12.78: Return value of SEFDeleteQoSDomain

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.79: Return values of SEFDeleteQoSDomain

Error Value	Description
-ENODEV	The SEF handle is not valid
-EINVAL	The QoS Domain ID is not valid
-EACCES	You don't have the needed permission to perform this operation
-EBUSY	The QoS Domain is in use and not all the handles are closed

12.31 SEFResetEncryptionKey

```
1 struct SEFStatus SEFResetEncryptionKey(SEFVDHandle vdHandle, struct
    SEFQoSDomainID QoSDomainID)
```

Resets the encryption key for a QoS Domain.

Table 12.80: Parameters of SEFResetEncryptionKey

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the Virtual Drive
struct SEFQoSDomainID	QoSDomainID	In	QoS Domain ID

Table 12.81: Return value of SEFResetEncryptionKey

Type	Description
struct SEFStatus	Status and info summarizing result.

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Table 12.82: Return values of SEFResetEncryptionKey

Error Value	Description
-ENODEV	The Virtual Device handle is not valid
-EPERM	The Virtual Device handle is not open
-EINVAL	The QoS Domain Id is not valid

12.32 SEFOpenVirtualDevice

```
struct SEFStatus SEFOpenVirtualDevice(SEFHandle sefHandle, struct
    SEFVirtualDeviceID virtualDeviceID, void(*notifyFunc)(void *,
    struct SEFVDNotification), void *context, SEFVDHandle *vdHandle)
```

Opens the target Virtual Device.
Since Virtual Devices are persistent, this provides the mechanism for opening a preexisting Virtual Device to resume I/O after reboot. This function needs to be called in order to receive notifications about the Virtual Device, such as in the event that a reduced capacity notification is issued.

Table 12.83: Parameters of SEFOpenVirtualDevice

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFVirtualDeviceID	virtualDeviceID	In	Virtual Device ID
void(*)(void *, struct SEFVDNotification)	notifyFunc	In	Callback to be executed upon event generation
void *	context	In	A void* pointer passed to the async event notification function (used to pass user context information)
SEFVDHandle *	vdHandle	In	Handle to the Virtual Drive

Table 12.84: Return value of SEFOpenVirtualDevice

Type	Description
struct SEFStatus	Status and info summarizing result.

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Table 12.85: Return values of SEFOpenVirtualDevice

Error Value	Description
-ENODEV	The SEF handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-EACCES	You don't have the needed permission to perform this operation
-ENOMEM	The library was unable to allocate needed structures
-EALREADY	The Virtual Device is already open

12.33 SEFCloseVirtualDevice

```
1 struct SEFStatus SEFCloseVirtualDevice(SEFVDHandle vdHandle)
```

Closes an open Virtual Device and shuts down associated event notification.

Table 12.86: Parameters of SEFCloseVirtualDevice

Type	Name	Direction	Description
SEFVDHandle	vdHandle	In	Handle to the Virtual Device

Table 12.87: Return value of SEFCloseVirtualDevice

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.88: Return values of SEFCloseVirtualDevice

Error Value	Description
-ENODEV	The Virtual Device handle is not valid
-EPERM	The Virtual Device Handle is not open
-EWOULDBLOCK	This function cannot be called on a callback thread

12.34 SEFOpenQoSDomain

```
1 struct SEFStatus SEFOpenQoSDomain(SEFHandle sefHandle, struct
    SEFQoSDomainID QoSDomainID, void(*notifyFunc)(void *, struct
    SEFQoSNotification), void *context, const void *encryptionKey,
    SEFQoSHandle *qosHandle)
```


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Opens a previously created QoS Domain.
Since QoS Domains are persistent, this provides the mechanism for opening a preexisting QoS Domain to resume I/O after reboot. This function also provides a channel to receive notifications regarding this QoS Domain.

Table 12.89: Parameters of SEFOpenQoSDomain

Type	Name	Direction	Description
SEFHandle	sefHandle	In	Handle to the SEF Unit
struct SEFQoSDomainID	QoSDomainID	In	QoS Domain ID
void(*)(void *, struct SEFQoSNotification)	notifyFunc	In	Callback to be executed during event generation
void *	context	In	A void* pointer passed to the async event notification function (used to pass user context information)
const void *	encryptionKey	In	In a multitenant environment, different tenants will write to separate QoS domains. Provides for individualized encryption keys on a per-domain basis
SEFQoSHandle *	qosHandle	Out	Handle to the QoS Domain

Table 12.90: Return value of SEFOpenQoSDomain

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.91: Return values of SEFOpenQoSDomain

Error Value	Description
-ENODEV	The SEF handle is not valid
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-EACCES	You don't have the needed permission to perform this operation
-ENOMEM	The library was unable to allocate needed structures

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-EALREADY	The QoS Domain is already open

12.35 SEFCloseQoSDomain

```
struct SEFStatus SEFCloseQoSDomain(SEFQoSHandle qosHandle)
```

Closes an open QoS Domain.
This will close any open super blocks associated with this domain. All outstanding kSuperBlockChangeState events will be delivered before this function returns. A QoS Domain must be in the closed state to be deleted.

Table 12.92: Parameters of SEFCloseQoSDomain

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain

Table 12.93: Return value of SEFCloseQoSDomain

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.94: Return values of SEFCloseQoSDomain

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EWOULDBLOCK	This function cannot be called on a callback thread

12.36 SEFGetQoSHandleProperty

```
struct SEFProperty SEFGetQoSHandleProperty(SEFQoSHandle qos, enum
    SEFPropertyID propID)
```

This function gets a property given a SEFQoSHandle.

Table 12.95: Parameters of SEFGetQoSHandleProperty

Type	Name	Direction	Description

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SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
enum SEFPropertyID	propID	In	The Property ID requested

Table 12.96: Return value of SEFGetQoSHandleProperty

Type	Description
struct SEFProperty	Returns the property stored given the property ID; If an unknown property ID is passed in, the returned type of the property will be kSefPropertyTypeNull. If kSefPropertyPrivateData is not set, the returned type of the property will be kSefPropertyTypeNull.

12.37 SEFSetQoSHandleProperty

```
1 struct SEFStatus SEFSetQoSHandleProperty(SEFQoSHandle qos, enum
     SEFPropertyID propID, struct SEFProperty value)
```

This function sets a property given a SEFQoSHandle.
The only settable property is kSefPropertyPrivateData.

Table 12.97: Parameters of SEFSetQoSHandleProperty

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
enum SEFPropertyID	propID	In	The Property ID being stored
struct SEFProperty	value	In	The value of the property being stored

Table 12.98: Return value of SEFSetQoSHandleProperty

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.99: Return values of SEFSetQoSHandleProperty

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

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12.38 SEFParseFlashAddress

```
struct SEFStatus SEFParseFlashAddress(SEFQoSHandle qosHandle,
    struct SEFFlashAddress flashAddress, struct SEFQoSDomainID
    *QoSDomainID, uint32_t *blockNumber, uint32_t *ADUOffset)
```

This function is used to extract info needed by FTL from an opaque flash address.
The QoS Domain ID of the passed in qosHandle does not have to match the QoS Domain ID of the passed in flash address. No validation is performed and the address is parsed as if it came from the QoS Domain of the passed in qosHandle. When they differ, it's up to the client to ensure the two different QoS Domain IDs are compatible. That is, the virtual devices they live in have the same value for superBlockDies.

Table 12.100: Parameters of SEFParseFlashAddress

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to a QoS Domain to interpret/parse the flash address. May be NULL if only the QoSDomainID is being returned.
struct SEFFlashAddress	flashAddress	In	The opaque address to be parsed
struct SEFQoSDomainID*	QoSDomainID	Out	A pointer to where to return the QoS Domain ID. A null pointer indicates that the QoS Domain ID is not to be returned
uint32_t *	blockNumber	Out	A pointer to where to return the block number. A null pointer indicates that the block number is not to be returned
uint32_t *	ADUOffset	Out	A pointer to where to return the ADU Offset. A null pointer indicates that the ADU Offset is not to be returned

Table 12.101: Return value of SEFParseFlashAddress

Type	Description
struct SEFStatus	Status and info summarizing result.

12.39 SEFCreateFlashAddress

```
struct SEFFlashAddress SEFCreateFlashAddress(SEFQoSHandle
    qosHandle, struct SEFQoSDomainID QoSDomainID, uint32_t
    blockNumber, uint32_t ADUOffset)
```


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This function is used to create an opaque flash address.
A generated flash address may be rejected by the device if it specifies an illegal ADUOffset, a super block number not owned by the QoSDomainID, or a QoSDomainID that has not been opened by the caller.

Table 12.102: Parameters of SEFCreateFlashAddress

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle of a QoS Domain to create a flash address for.
struct SEFQoSDomainID	QoSDomainID	In	The desired QoS Domain ID. It is not validated against the QoS Domain ID of the qosHandle.
uint32_t	blockNumber	In	The desired super block number.
uint32_t	ADUOffset	In	The desired ADU Offset.

Table 12.103: Return value of SEFCreateFlashAddress

Type	Description
struct SEFFlashAddress	The generated flash address or the NULL flashAddress if the qosHandle is invalid.

12.40 SEFReleaseSuperBlock

```
1 struct SEFStatus SEFReleaseSuperBlock(SEFQoSHandle qosHandle,
     struct SEFFlashAddress flashAddress)
```

Releases the specific super block to the free pool owned by the Virtual Device to which the specified QoS Domain belongs.
The target super block must have been assigned by a previous call to SEFAllocateSuperBlock() or as part of SEFWriteWithoutPhysicalAddress(). The super block may be in an open or closed state.

Table 12.104: Parameters of SEFReleaseSuperBlock

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain of the super block
struct SEFFlashAddress	flashAddress	In	Flash address of the super block to release

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Table 12.105: Return value of SEFReleaseSuperBlock

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.106: Return values of SEFReleaseSuperBlock

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EFAULT	The Flash Address is not valid

12.41 SEFAllocateSuperBlock

```
1 struct SEFStatus SEFAllocateSuperBlock(SEFQoSHandle qosHandle,
    struct SEFFlashAddress *flashAddress, enum SEFSuperBlockType
    type, const struct SEFAllocateOverrides *overrides)
```

Allocates a super block that will be assigned to the specified QoS Domain and returns the flash address of this super block.

The returned super block will be in the open state. These super blocks in turn can be used as part of the parameter set for the SEFNamlessCopy and SEFWriteWithoutPhysicalAddress functions. When allocating a super block, The SEF Unit intelligently selects a location in a manner designed to optimize the lifetime of flash memory and will return the flash address that was selected. Note that each open super block will allocate a write buffer and therefore consume memory, so there is a tradeoff in the number of open super blocks and the amount of memory consumed.

It's required that the total ADUs in the QoS Domain be less than its flash quota and its Virtual Device have an available super block. The ADUs in use by a QoS Domain can be known by summing the writableADUs of each super block in the QoS Domain.

See Also: SEFGetQoSDomainInformation

Table 12.107: Parameters of SEFAllocateSuperBlock

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFFlashAddress*	flashAddress	Out	The flash address of the allocated block
enum SEFSuperBlockType	type	In	kForWrite or kForPSLCWrite

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const struct SEFAllocateOverrides*	overrides	In	Overrides to scheduler parameters; pointer can be null for none required.

Table 12.108: Return value of SEFAllocateSuperBlock

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.109: Return values of SEFAllocateSuperBlock

Error Value	Description
0	The info member contains number of ADUs in allocated super block
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-ENOSPC	The QoS Domain is out of space

12.42 SEFFlushSuperBlock

```
1 struct SEFStatus SEFFlushSuperBlock(SEFQoSHandle qosHandle, struct
    SEFFlashAddress flashAddress, uint32_t
    *distanceToEndOfSuperBlock)
```

Flushes the target super block.

This command causes all written data for the super block that is still in the write buffer and not persisted to flash memory to be persisted to flash memory. The device will automatically append data if necessary to finish programming of all pending user data writes. This command will not return until all the data is persistent and all kAddressUpdate change notifications generated by the flush have been processed.

When a flush causes a super block to have no more writable ADUs, the super block will be closed and a QoS Domain notification of the close will be sent.

Table 12.110: Parameters of SEFFlushSuperBlock

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain of the super block

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struct SEFFlashAddress	flashAddress	In	Flash address of the super block to be flushed.
uint32_t *	distanceToEndOfSuperBlock	Out	Indicates remaining size in ADU after this flush operation. May be NULL.

Table 12.111: Return value of SEFFlushSuperBlock

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.112: Return values of SEFFlushSuperBlock

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

12.43 SEFCloseSuperBlock

```
struct SEFStatus SEFCloseSuperBlock(SEFQoSHandle qosHandle, struct
    SEFFlashAddress flashAddress)
```

Closes the target super block.
If there is remaining unwritten space in the super block, that space will be padded with dummy data. This can be used by the FTL as a means of closing a super block without invoking a Write command. This command will not return until all the data is persistent and all kAddressUpdate change notifications generated by the close have been processed ensuring that all addresses have either transitioned from tentative to permanent or have been updated.

Table 12.113: Parameters of SEFCloseSuperBlock

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain of the super block
struct SEFFlashAddress	flashAddress	In	Flash address of the super block to move to Closed state by filling data

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Table 12.114: Return value of SEFCloseSuperBlock

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 12.115: Return values of SEFCloseSuperBlock

Error Value	Description
0	The super block is was closed or was already closed
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EFAULT	The Flash Address is not valid

12.44 SEFReleaseSuperBlockAsync

```
1 void SEFReleaseSuperBlockAsync(SEFQoSHandle qosHandle, struct
    SEFReleaseSuperBlockIOCB *iocb)
```

This function is the asynchronous version of SEFReleaseSuperBlock().
See Also: SEFReleaseSuperBlock

Table 12.116: Parameters of SEFReleaseSuperBlockAsync

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFReleaseSuperBlockIOCB*	iocb	In/Out	For asynchronous response from SEF Library Unused fields should be set to 0.

12.45 SEFAllocateSuperBlockAsync

```
1 void SEFAllocateSuperBlockAsync(SEFQoSHandle qosHandle, struct
    SEFAllocateSuperBlockIOCB *iocb)
```

This function is the asynchronous version of SEFAllocateSuperBlock().
See Also: SEFAllocateSuperBlock

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Table 12.117: Parameters of SEFAllocateSuperBlockAsync

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFAllocateSuperBlockIOCB*	iocb	In/Out	For asynchronous response from SEF Library Unused fields should be set to 0.

12.46 SEFCloseSuperBlockAsync

```
1 void SEFCloseSuperBlockAsync(SEFQoSHandle qosHandle, struct
     SEFCloseSuperBlockIOCB *iocb)
```

This function is the asynchronous version of SEFCloseSuperBlock().
kSuperBlockStateChanged will have been sent before the completion routine is called and the iocb is marked as done.
See Also: SEFCloseSuperBlock

Table 12.118: Parameters of SEFCloseSuperBlockAsync

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFCloseSuperBlockIOCB*	iocb	In/Out	For asynchronous response from SEF Library

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13 | Data Access Commands

13.1 SEFWriteWithoutPhysicalAddress

```
struct SEFStatus SEFWriteWithoutPhysicalAddress(SEFQoSHandle
    qosHandle, struct SEFFlashAddress flashAddress, struct
    SEFPlacementID placementID, struct SEFUserAddress userAddress,
    uint32_t numADU, const struct iovec *iov, uint16_t iovcnt, const
    void *metadata, struct SEFFlashAddress *permanentAddresses,
    uint32_t *distanceToEndOfSuperBlock, const struct
    SEFWriteOverrides *overrides)
```

Writes data to the specified user address to an underlying physical flash page that is assigned for the QoS Domain.

If auto-allocate is enabled for the super block, when the assigned super block is filled and closed, the SEF Unit assigns a new super block for the remaining writes. If auto-allocate is not enabled, host software will know about the super block size as part of the allocation, and can use this information to construct appropriately-sized write commands. This call will not return until the data has been persisted, and will automatically pad the user data with dummy data if required to complete flash memory programming. The userAddress supplied here will be checked when reading the data back with SEFReadWithPhysicalAddress(). If storing a user address is not required, a userAddress of SEFUserAddressIgnore may be used. The check can optionally be disabled when reading and must be disabled to read data written with a user address of SEFUserAddressIgnore. In kSuperBlock mode and writing multiple ADUs, the LBA portion of the user address is incremented for each ADU. The write will fail if the userAddress is incremented to a value equal to SEFUserAddressIgnore. The userAddresses in a super block can be read using SEFGetUserAddressList.

Note: The synchronous and asynchronous versions differ in how data is committed to flash. As described above, the synchronous version flushes data to flash returning permanent flash addresses.

In contrast, the asynchronous version lazily flushes data to flash. The flash addresses returned are tentative instead. Once the SEF Unit eventually flushes a tentative address to flash, the original address may be discovered to be bad. When this happens, a kAddressUpdate QoS Domain notification is sent indicating the data has moved to a new permanent flash address. When the IOCB

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flag kSefIoFlagNotifyBufferRelease is set, the domain notification kBufferRelease will be sent for each piece of the IOCB iov as it becomes committed to flash. It is then the responsibility of the caller to maintain the lifetime of the iov buffers until the release notifications are sent. When not set, the commit state can be inferred instead by the kSuperBlockStateChanged QoS notification for the owning super block. Buffer lifetime is managed by library in this case by copying write data into library managed buffers.

Table 13.1: Parameters of SEFWriteWithoutPhysicalAddress

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFFlashAddress	flashAddress	In	Flash address of the super block. SEFAutoAllocate if auto allocate.
struct SEFPlacementID	placementID	In	Only valid if the flashAddress is auto allocated. A value from 0 to numPlacementIds–1 indicating what logical data group to place this data in.
struct SEFUserAddress	userAddress	In	FTL can store metadata related to this operation by this field. For example, storing LBA address to bind to this write operation such as data tags.
uint32_t	numADU	In	Total amount of write data size calculated in QoS Domain ADUs.
const struct iovec*	iov	In	A pointer to the scatter gather list
uint16_t	iovcnt	In	The number of elements in the scatter gather list

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const void *	metadata	In	Pointer to metadata to write with the data; The number of bytes per ADU required is SEFQoSDomain-Info::ADUsize.meta. May be NULL.
struct SEFFlashAddress*	permanentAddresses	Out	Must allocate space for returned permanent physical addresses equal to 8*length (i.e. 8*number of ADUs)
uint32_t *	distanceToEndOfSuperBlock	Out	Indicates remaining size in ADU after this write operation. May be NULL. This is not a guarantee as the block may be forced closed if too many super blocks are open. When this returns 0, the block was closed.
const struct SEFWriteOverrides*	overrides	In	Overrides to scheduler parameters; pointer can be null for none required.

Table 13.2: Return value of SEFWriteWithoutPhysicalAddress

Type	Description
struct SEFStatus	Status and info summarizing result. When .error is non-zero, .info is the number of ADUs written.

Table 13.3: Return values of SEFWriteWithoutPhysicalAddress

Error Value	Description
-ENODEV	The QoS Domain handle is not valid

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-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid
-ENOSPC	The QoS Domain is out of space

13.2 SEFReadWithPhysicalAddress

```
1 struct SEFStatus SEFReadWithPhysicalAddress(SEFQoSHandle qosHandle,
    struct SEFFlashAddress flashAddress, uint32_t numADU, const
    struct iovec *iov, uint16_t iovcnt, uint32_t iovOffset, struct
    SEFUserAddress userAddress, void *metadata, const struct
    SEFReadOverrides *overrides)
```

Reads data from a specified physical address.

While writes are expressed in terms of a placement ID or super block flash addresses, reads are expressed in terms of physical flash addresses. Read commands may interrupt other types of commands. When there is an in-flight flash memory command to the same flash die other than a read command, the in-flight command may be suspended in order to maintain deterministic read latency. If the target physical address is currently in the process of being programmed, data will instead be returned from the write buffer.

The userAddress must either match what was stored when the data was written or be SEFUserAddressIgnore to disable checking. In kSuperBlock mode, the LBA portion of the user address is incremented for each ADU in a multi-ADU write.

Note: When reading data that was just written, a read error will be returned when the data's original flash address has been updated but the notification has yet to be processed by the client. In this case, the caller must retry the read after the flash address change notification has been processed.

See Also: SEFSetRootPointer

Table 13.4: Parameters of SEFReadWithPhysicalAddress

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFFlashAddress	flashAddress	In	Physical address for the read command; When the QoS Domain ID and block number are 0, the ADU offset is the root pointer index for the flash address to read.
uint32_t	numADU	In	Length of data to read (in ADUs). Maximum allowed is superBlockCapacity.

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const struct iovec*	iov	In	A pointer to the scatter gather list
uint16_t	iovcnt	In	The number of elements in the scatter gather list
uint32_t	iovOffset	In	Starting byte offset into iov array
struct SEFUserAddress	userAddress	In	Stored data by the FTL. It will be validated with what was stored when the data was written except when SEFUserAddressIgnore is supplied
void *	metadata	In	Buffer to receive metadata stored with the data; The number of bytes per ADU required is SEFQoSDomainInfo::ADUsize.meta. May be NULL
const struct SEFReadOverrides*	overrides	In	Overrides to scheduler parameters; pointer can be null for none required.

Table 13.5: Return value of SEFReadWithPhysicalAddress

Type	Description
struct SEFStatus	Status and info summarizing result.

Table 13.6: Return values of SEFReadWithPhysicalAddress

Error Value	Description
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

13.3 SEFNamelessCopy

```
1 struct SEFStatus SEFNamelessCopy(SEFQoSHandle srcQosHandle, struct
    SEFCopySource copySource, SEFQoSHandle dstQosHandle, struct
    SEFFlashAddress copyDestination, const struct
    SEFUserAddressFilter *filter, const struct SEFCopyOverrides
    *overrides, uint32_t numAddressChangeRecords, struct
    SEFAddressChangeRequest *addressChangeInfo)
```

Performs Nameless Copy with map or list; optional user address filtering.

Copies ADUs as described by copySource to the copyDestination. Source addresses can only reference

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closed superblocks.

Table 13.7: Parameters of SEFNamelessCopy

Type	Name	Direction	Description
SEFQoSHandle	srcQosHandle	In	Handle to the source QoS Domain
struct SEFCopySource	copySource	In	Physical addresses to copy
SEFQoSHandle	dstQosHandle	In	Handle to the destination QoS Domain
struct SEFFlashAddress	copyDestination	In	Flash address of destination super block
const struct SEFUserAddressFilter*	filter	In	Pointer to user address filter parameters, null indicates no filtering
const struct SEFCopyOverrides*	overrides	In	Pointer to overrides to scheduler parameters; pointer can be null for none required.
uint32_t	numAddressChangeRecords	In	Maximum number of ADUs to copy (size of SEFAddressChangeRequest userAddress array)
struct SEFAddressChangeRequest*	addressChangeInfo	In	Filled with changed addresses

Table 13.8: Return value of SEFNamelessCopy

Type	Description
struct SEFStatus	Status and info summarizing result

Table 13.9: Return values of SEFNamelessCopy

Error Value	Description

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0	the info member contains: Destination super block has defective planes (kCopyDesinationDefectivePlanes), Read error was detected on source (kCopyReadErrorOnSource), Data that is out of User Address range is detected (kCopyFilteredUserAddresses), Destination super block was filled/closed (kCopyClosedDestination), Consumed entire source bitmap or list (kCopyConsumedSource)
-ENODEV	The QoS Domain handle is not valid
-EPERM	The QoS Domain Handle is not open
-EINVAL	The function parameter is not valid; info returns the parameter index that is not valid

13.4 SEFWriteWithoutPhysicalAddressAsync

```
void SEFWriteWithoutPhysicalAddressAsync(SEFQoSHandle qosHandle,
    struct SEFWriteWithoutPhysicalAddressIOCB *iocb)
```

This function is the asynchronous version of SEFWriteWithoutPhysicalAddress().
Note: When the kSefloFlagCommit flag is set in the IOCB's flag field, the returned tentative addresses will be permanent, potentially adding padding.
Note: Any kAddressUpdate and kSuperBlockStateChange QoS notifications for the returned tentative addresses will occur after the iocb completion routine has returned. When no completion routine is set, the caller must handle the race condition of acting on done being set and the notifications being sent.
See Also: SEFWriteWithoutPhysicalAddress

Table 13.10: Parameters of SEFWriteWithoutPhysicalAddressAsync

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFWriteWithoutPhysicalAddressIOCB*	iocb	In/Out	For asynchronous response from SEF Library. Unused fields should be set to 0.

13.5 SEFReadWithPhysicalAddressAsync

```
void SEFReadWithPhysicalAddressAsync(SEFQoSHandle qosHandle, struct
    SEFReadWithPhysicalAddressIOCB *iocb)
```

This function is the asynchronous version of SEFReadWithPhysicalAddress().

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See Also: SEFReadWithPhysicalAddress

Table 13.11: Parameters of SEFReadWithPhysicalAddressAsync

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the QoS Domain
struct SEFReadWithPhysicalAddressIOCB*	iocb	In/Out	For asynchronous response from SEF Library Unused fields should be set to 0.

13.6 SEFNamelessCopyAsync

```
1 void SEFNamelessCopyAsync(SEFQoSHandle qosHandle, struct
    SEFNamelessCopyIOCB *iocb)
```

This function is the asynchronous version of SEFNamelessCopy().

See Also: SEFNamelessCopy

Table 13.12: Parameters of SEFNamelessCopyAsync

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to the source QoS Domain
struct SEFNamelessCopyIOCB*	iocb	In/Out	For asynchronous response from SEF Library Unused fields should be set to 0.

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14 | Common Structures

14.1 SEFUserAddressLbaBits

Number of bits in a user address lba value.

Table 14.1: SEFUserAddressLbaBits

Name	Definition
SEFUserAddressLbaBits	40

14.2 SEFUserAddressMetaBits

Number of bits in a user address meta value.

Table 14.2: SEFUserAddressMetaBits

Name	Definition
SEFUserAddressMetaBits	(64-SEFUserAddressLbaBits)

14.3 SEFAutoAllocate

Flash address value to indicate device should allocate the super block while doing a write.
See Also: SEFWriteWithoutPhysicalAddress

Table 14.3: SEFAutoAllocate

Name	Definition
SEFAutoAllocate	((struct SEFFlashAddress) {UINT64_C(0xffffffffffffffff)})

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14.4 SEFUserAddressIgnore

User address value to indicate it should not be validated by the SEF device.
See Also: *SEFReadWithPhysicalAddress*

Table 14.4: SEFUserAddressIgnore

Name	Definition
SEFUserAddressIgnore	((struct SEFUserAddress) {UINT64_C(0xffffffffffffffff)})

14.5 SEFNullFlashAddress

Flash address value indicating empty.

Table 14.5: SEFNullFlashAddress

Name	Definition
SEFNullFlashAddress	((struct SEFFlashAddress){(int64_t)0x0})

14.6 SEFIsNullFlashAddress

```
1 static int SEFIsNullFlashAddress(struct SEFFlashAddress
    flashAddress)
```

Checks whether the flash address is null.

Table 14.6: Parameters of SEFIsNullFlashAddress

Type	Name	Direction	Description
struct SEFFlashAddress	flashAddress	In	The opaque address to be checked

Table 14.7: Return value of SEFIsNullFlashAddress

Type	Description
int	Returns 1 if the flashAddress is null

14.7 SEFIsEqualFlashAddress

```
1 static int SEFIsEqualFlashAddress(struct SEFFlashAddress
```


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```
    flashAddress1, struct SEFFlashAddress flashAddress2)
```

Checks whether two flash addresses are equal.

Table 14.8: Parameters of SEFIsEqualFlashAddress

Type	Name	Direction	Description
struct SEFFlashAddress	flashAddress1	In	The opaque address to be compared
struct SEFFlashAddress	flashAddress2	In	The opaque address to be compared

Table 14.9: Return value of SEFIsEqualFlashAddress

Type	Description
int	Returns 1 if the flashAddress1 equals flashAddress2

14.8 SEFNextFlashAddress

```
1 struct SEFFlashAddress SEFNextFlashAddress(SEFQoSHandle qosHandle,
    struct SEFFlashAddress flashAddress)
```

Returns the next flash address by incrementing the ADU Offset.
Doesn't guarantee that the returned flash address is valid

Table 14.10: Parameters of SEFNextFlashAddress

Type	Name	Direction	Description
SEFQoSHandle	qosHandle	In	Handle to a QoS Domain to interpret/parse the flash address.
struct SEFFlashAddress	flashAddress	In	The opaque address to be incremented

Table 14.11: Return value of SEFNextFlashAddress

Type	Description
struct SEFFlashAddress	Returns the next flash address if the qosHandle is valid, otherwise it returns SEFNullFlashAddress.

14.9 SEFStatus

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Table 14.12: Members of SEFStatus

Type	Name	Description
int32_t	error	Status information
int32_t	info	Additional context-based descriptive information

14.10 SEFVirtualDeviceID

Table 14.13: Members of SEFVirtualDeviceID

Type	Name
uint16_t	id

14.11 SEFQoSDomainID

Table 14.14: Members of SEFQoSDomainID

Type	Name
uint16_t	id

14.12 SEFPlacementID

Table 14.15: Members of SEFPlacementID

Type	Name
uint16_t	id

14.13 SEFADUsize

Table 14.16: Members of SEFADUsize

Type	Name	Description
uint32_t	data	ADU data size in bytes
uint16_t	meta	ADU meta data size in bytes
uint16_t	reserved	Reserved/unused

14.14 SEFInfo

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Table 14.17: Members of SEFInfo

Type	Name	Description
const char *	name	Device Name from O/S
char[8]	vendor	Vendor field
char[20]	serialNumber	Device serial number
char[8]	FWVersion	Device firmware version
char[8]	HWVersion	Device hardware version
uint16_t	unitNumber	Unit number of the SEFInfo struct
uint16_t	APIVersion	API Version
uint64_t	supportedOptions	Supported features - see kSupported defines
uint16_t	maxQoSDomains	Hardware version specific, may be less than 65535 defined by architecture
uint16_t	maxRootPointers	Firmware version specific, may be less than 8 defined by architecture
uint16_t	maxPlacementIDs	Firmware version specific, max number of auto opened super blocks per QoS Domain
uint16_t	maxOpenSuperBlocks	Firmware version specific, max number of open super blocks for the device. When 0, the limit is per Virtual Device instead. SEFVirtualDeviceInfo
uint16_t	numReadQueues	Firmware version specific, max number of read queues total
uint16_t	numVirtualDevices	Number of currently defined virtual devices
uint16_t	numQoSDomains	Number of currently defined QoS Domains
uint16_t	numBanks	Number of banks per channel
uint16_t	numChannels	Number of channels per SEF Unit
uint16_t	numPlanes	Number of planes per die
uint32_t	pageSize	Physical page size
uint32_t	numPages	Number of pages per block
uint32_t	numBlocks	Number of blocks per die
uint32_t	totalBandWidth	Total bandwidth in MiBs corresponding to the underlying flash component on this device
uint32_t	readTime	Read time in microseconds corresponding to the underlying flash components on this device
uint32_t	programTime	Program time in microseconds corresponding to the underlying flash components on this device
uint32_t	eraseTime	Erase time in microseconds corresponding to the underlying flash components on this device

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uint16_t	minReadWeight	Advisory minimum read weight to allow timely house keeping internal I/O
uint16_t	minWriteWeight	Advisory minimum write weight to allow timely house keeping internal I/O
uint32_t	openExpirationPeriod	Granularity in seconds for entire block
uint16_t	reserved_0	Reserved/unused
uint16_t	numADUSizes	Size of ADUsize array that follows at end of structure
struct SEFADUsize[]	ADUsize	Array of supported ADU sizes

14.15 SEFVirtualDeviceList

Table 14.18: Members of SEFVirtualDeviceList

Type	Name	Description
uint16_t	numVirtualDevices	Number of virtual devices
struct SEFVirtualDeviceID[]	virtualDeviceID	An Array of all Virtual device IDs

14.16 SEFQoSDomainList

Table 14.19: Members of SEFQoSDomainList

Type	Name	Description
uint16_t	numQoSDomains	Number of QoS domains
struct SEFQoSDomainID[]	QoSDomainID	An Array of all QoS Domain IDs

14.17 SEFUserAddress

Structure of SEFUserAddress may be redefined by user.
The limitations for redefining the structure are:

- size must be 8 bytes
- multi-adu writes will auto increment the LBA value and must not equal SEFUserAddressIgnore. However SEFUserAddressIgnore is supported as a starting user address.

For kSuperBlock, the LBA is limited to 40 bits and the meta to 24. The unformatted member is in little endian format.

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Table 14.20: Members of SEFUserAddress

Type	Name
uint64_t	unformatted

14.18 SEFFlashAddress

Opaque flash address value parsable by SEFParseFlashAddress()

Table 14.21: Members of SEFFlashAddress

Type	Name
uint64_t	bits

14.19 SEFDieList

Table 14.22: Members of SEFDieList

Type	Name	Description
uint16_t	numDies	Number of dies in dieIDs
uint16_t[]	dieIDs	List of dies by ID

14.20 SEFWeights

Relative die time weights for write type of I/O operations.

Table 14.23: Members of SEFWeights

Type	Name	Description
uint16_t	eraseWeight	Default weight for an erase operation by SEFAllocateSuperBlock, SEFFlushSuperBlock and SEFCloseSuperBlock
uint16_t	programWeight	Default weight for a program operation by the Nameless Write and Nameless Copy commands

14.21 SEFVirtualDeviceConfig

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Table 14.24: Members of SEFVirtualDeviceConfig

Type	Name	Description
struct SEFVirtualDeviceID	virtualDeviceID	Virtual Device ID
uint8_t	numReadQueues	Number of read queues to define for this Virtual Device
uint8_t	reserved	Reserved, must be initialized to zero
uint16_t[SEFMaxReadQueues]	readWeights	Default weight for read operations for each possible read queue
uint16_t	superBlockDies	Number of dies in a super block, 0 uses dieList.numDies
struct SEFDieList	dieList	List of dies in ascending order for the Virtual Device

14.22 SEFVirtualDeviceUsage

Table 14.25: Members of SEFVirtualDeviceUsage

Type	Name	Description
uint32_t	eraseCount	Count of super blocks erased. Used to populate eraseOrder in SEFSuperBlockInfo
uint32_t	numUnallocatedSuperBlocks	Number of unallocated super blocks
uint32_t	numSuperBlocks	Number of allocated super blocks
uint32_t	numUnallocatedPSLCSuperBlocks	Number of unallocated pSLC super blocks
uint32_t	numPSLCSuperBlocks	Number of allocated pSLC super blocks
struct SEFVirtualDeviceID	vdID	Virtual device ID of the handle
uint8_t	averagePEcount	Average program/erase count
uint8_t	maxPEcount	Max program/erase count
uint16_t	patrolCycleTime	Recommended Patrol Cycle in minutes
uint16_t	reserved	Reserved, must be initialized to zero

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14.23 SEFVirtualDeviceSuspendConfig

Configuration for Erase/Program suspend.
The weights supplied with i/o represents virtual time. These parameters control how often, and for how long an erase/program can be interrupted by reads.

Table 14.26: Members of SEFVirtualDeviceSuspendConfig

Type	Name
uint32_t	maxTimePerSuspend
uint32_t	minTimeUntilSuspend
uint32_t	maxSuspendInterval

14.24 SEFVirtualDeviceInfo

Table 14.27: Members of SEFVirtualDeviceInfo

Type	Name	Description
uint64_t	flashCapacity	Flash capacity in 4k ADUs
uint64_t	flashAvailable	Available flash capacity in 4k ADUs
uint64_t	pSLCFlashCapacity	pSLC Flash capacity in 4k ADUs
uint64_t	pSLCFlashAvailable	pSLC Available flash capacity in 4k ADUs
uint32_t	superBlockCapacity	Super block capacity in 4k ADUs
uint32_t	pSLCSuperBlockCapacity	pSLC super block capacity in 4k ADUs
uint32_t	maxOpenSuperBlocks	Maximum number of open super blocks per Virtual Device. When 0, the limit is per device instead. See SEFInfo
uint32_t	numPSLCSuperBLocks	Number of pSLC super blocks
struct SEFVirtualDeviceSuspendConfig	suspendConfig	
uint16_t	superBlockDies	Number of dies used for a super block
uint8_t	aduOffsetBitWidth	Number of bits that make up the adu offset in a flash address

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uint8_t	superBlockIdBitWidth	Number of bits that make up the super block id in a flash address
uint16_t[SEFMaxReadQueues]	readWeights	Default weight for read operations for each possible read queue
uint8_t	numReadQueues	Number of read queues defined for the Virtual Device
uint8_t[5]	reserved	Reserved, must be initialized to zero
struct SEFQoSDomainList	QoSDomains	List of domains

14.25 SEFSuperBlockInfo

Table 14.28: Members of SEFSuperBlockInfo

Type	Name	Description
struct SEFFlashAddress	flashAddress	Flash address where this super block resides
uint32_t	eraseOrder	Indication of when a super block was erased. Can be used to determine the order blocks were allocated or to version a super block. Values only increase over time and are unique at the Virtual Device level
uint32_t	writableADUs	For a fresh, unwritten, open super block, this how much QoS Domain quota is being used by the super block. It will decrease if defects are encountered while writing
uint32_t	writtenADUs	This field increases as ADUs in the super block are written. For kPerfect and kPacked, it will equal writableADUs when the block is closed. For kFragmented, it will equal super block capacity because it includes defective portions of the flash
struct SEFPlacementID	placementID	When auto-allocated, indicates the placement id supplied to SEFWriteWithoutPhysicalAddress(). Otherwise it will be SEFPlacementIdUnused
uint16_t	numDefects	Number of defective planes per super page. This may increase as the super block is written
uint16_t	timeLeft	Time in minutes left to handle an integrity that is not kIntegrityGood before risking data loss

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uint8_t	PEIndex	This is the block's erase count normalized to be between 0 and 255
enum SEFSuperBlockType	type	This is the type of the super block, normal or pSLC
enum SEFSuperBlockState	state	This is the block's current state
enum SEFDataIntegrity	integrity	This is the integrity of the super block, If not kIntegrity-Good, the super block requires a SEFCheckSuperBlock to patrol or refresh
uint8_t[]	defects	This is a bitmap indicating which planes are dective. SEFQoSDomainInfo::defectMapSize is the size of this field.

14.26 SEFSuperBlockRecord

Entry in a SEFSuperBlockList.

Table 14.29: Members of SEFSuperBlockRecord

Type	Name	Description
struct SEFFlashAddress	flashAddress	Flash address where this super block resides
uint8_t[6]	reserved	Reserved
uint8_t	PEIndex	This is the block's erase count normalized to be between 0 and 255
enum SEFSuperBlockState	state	This is the block's current state

14.27 SEFSuperBlockList

Table 14.30: Members of SEFSuperBlockList

Type	Name	Description
uint32_t	numSuperBlocks	Number of super blocks in use by the QoS Domain
uint32_t	reserved	Reserved
struct SEFSuperBlockRecord[]	superBlockRecords	List of super block records

14.28 SEFQoSDomainInfo

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Table 14.31: Members of SEFQoSDomainInfo

Type	Name	Description
struct SEFVirtualDeviceID	virtualDeviceID	Virtual device ID
uint16_t	numPlacementIDs	Specifies the number of Placement IDs corresponding to this QoS Domain
uint8_t	encryption	0 for disabled, non-zero for enabled
enum SEFErrorRecoveryMode	recoveryMode	Specifies the recovery mode for this QoS Domain
enum SEFDefectManagementMethod	defectStrategy	Defect management strategy for the QoS Domain
enum SEFAPIIdentifier	api	Specifies the API Identifier for this QoS Domain
uint64_t	flashCapacity	Reserved capacity of the QoS Domain in QoS Domain ADUs
uint64_t	flashQuota	Number of QoS Domain ADUs that can be allocated by the QoS Domain
uint64_t	pSLCFlashCapacity	Reserved pSLC capacity of the QoS Domain in QoS Domain ADUs
uint64_t	pSLCFlashQuota	Number of pSLC QoS Domain ADUs that can be allocated by the QoS Domain
struct SEFFlashAddress[SEFMaxRootPointer]	rootPointers	List of root pointers
struct SEFADUsize	ADUsize	Size of QoS Domain ADUs, data and metadata in bytes
uint32_t	superBlockCapacity	Super block capacity in QoS Domain ADUs

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uint32_t	pSLCSuperBlockCapacity	pSLC super block capacity in QoS Domain ADUs
uint16_t	maxOpenSuperBlocks	Maximum number of open super blocks for the QoS Domain
uint16_t	defectMapSize	Size of a super block defect map
struct SEFWeights	weights	Default i/o weights for erase and program
enum SEFDeadlineType	deadline	Deadline type for the QoS Domain
uint8_t	defaultReadQueue	Default read queue assignment
uint8_t	numReadQueues	Number of read queues as defined by the Virtual Device
uint8_t[5]	reserved	Reserved

14.29 SEFWearInfo

Table 14.32: Members of SEFWearInfo

Type	Name	Description
uint32_t	numSuperBlocks	Number of super blocks
uint32_t	reserved_0	Reserved, must be initialized to zero
struct SEFSuperBlockRecord[]	superBlockRecords	List of super block records

14.30 SEFRefreshInfo

Table 14.33: Members of SEFRefreshInfo

Type	Name	Description
uint32_t	numSuperBlocks	Number of super blocks
uint32_t	reserved_0	Reserved, must be initialized to zero
struct SEFSuperBlockRecord[]	superBlockRecords	List of super block records

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14.31 SEFCheckInfo

SuperBlocks returned by SEFGetCheckList()

Table 14.34: Members of SEFCheckInfo

Type	Name	Description
uint32_t	numSuperBlocks	Number of super blocks
uint32_t	reserved_0	Reserved, must be initialized to zero
struct SEFSuperBlockRecord[]	superBlockRecords	List of super block records

14.32 SEFUserAddressList

Table 14.35: Members of SEFUserAddressList

Type	Name	Description
uint32_t	numADUs	Number of ADUs
uint32_t	reserved_0	Reserved, must be initialized to zero
struct SEFUserAddress[]	userAddressesRecovery	User addresses

14.33 SEFProperty

Table 14.36: Members of SEFProperty

Type	Name	Description
union		5 Members
¬ int	intVal	Valid when type is kSefPropertyTypeInt
¬ void *	ptr	Valid when type is kSefPropertyTypePtr
¬ struct SEFQoSDomainID	qosID	Valid when type is kSefPropertyTypeQoSDomainID
¬ struct SEFVirtualDeviceID	vdID	Valid when type is kSefPropertyTypeVirtualDeviceID
¬ void(*)(void *, struct SEFQoSNotification)	qosNotify	Valid when type is kSefPropertyTypeQoSNotify
enum SEFPropertyType	type	Denotes the property type

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14.34 SEFWriteOverrides

Supplied to override default write weights.
May be used when calling SEFWriteWithoutPhysicalAddress() or SEFWriteWithoutPhysicalAddressAsync().

Table 14.37: Members of SEFWriteOverrides

Type	Name	Description
uint16_t	programWeight	Weight to use for program instead of the QoS domain default. 0 will use the QoS Domain default.

14.35 SEFReadOverrides

Supplied to override default read weight.
May be used when calling SEFReadWithPhysicalAddress() or SEFReadWithPhysicalAddressAsync().

Table 14.38: Members of SEFReadOverrides

Type	Name	Description
uint16_t	readWeight	Weight to use for read instead of the read queue's default. 0 will use the read queue's default.
uint8_t	readQueue	Read queue to use for read instead of QoS Domain's default. A value of 0 or greater than number of read queues defined for the QoS Domain will use the default read queue for the QoS Domain.
uint8_t	reserved	Reserved, must be initialized to zero.

14.36 SEFAllocateOverrides

Supplied to override default super block allocation weight.
May be used when calling SEFAllocateSuperBlock() or SEFAllocateSuperBlockAsync().

Table 14.39: Members of SEFAllocateOverrides

Type	Name	Description
uint16_t	eraseWeight	Weight to use for erase instead of the QoS Domain default. 0 will use the QoS Domain default.

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14.37 SEFCopySource

Source addresses for SEFNamelessCopy().
The Source addresses format controls if the validBitmap or list of flash addresses is used.SEFNamelessCopy()SEFUserAddres

Table 14.40: Members of SEFCopySource

Type	Name	Description
enum SEFCopySourceType	format	Specifies the format to use
uint8_t[3]	reserved_0	Reserved, must be initialized to zero
uint32_t	arraySize	Number of items in bitmap array or Flash Address List (QWORD count)
union		2 Members
¬ const struct SEFFlashAddress*	flashAddressList	pointer to flash address list
¬ struct		2 Members
¬ ¬ struct SEFFlashAddress	srcFlashAddress	flash address of source block. ADU & 0x3f indicates the ADU of bit 0 of validBitmap and ADU & 0x3f is the starting bit in validBitMap
¬ ¬ const uint64_t *	validBitmap	pointer to COPY of valid bitmap array (little endian)

14.38 SEFUserAddressFilter

Optional filtering on user address data during copy.

Table 14.41: Members of SEFUserAddressFilter

Type	Name	Description
struct SEFUserAddress	userAddressStart	Starting user address of filter
uint64_t	userAddressRangeLength	Length of filter range (0 indicates no filtering)
uint32_t	userAddressRangeType	Zero to copy data in range; non-zero to copy outside of range

14.39 SEFAddressChangeRequest

Detailed information about results of the SEFNamelessCopy() request.

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Table 14.42: Members of SEFAddressChangeRequest

Type	Name	Description
uint32_t	numProcessedADUs	The number of processed ADUs including errors
uint32_t	nextADUOffset	Given a bitmap source, it indicates the next ADU offset of the source flash address; Given a list source, it indicates the next entry number in the source flash address list
uint32_t	numReadErrorADUs	The number of ADUs that couldn't be processed due to errors
uint32_t	numADUsLeft	The number of remaining ADUs in the destination super block
uint8_t	copyStatus	A bit array denoting the results of the request
uint8_t[7]	reserved	Reserved, must be initialized to zero
struct []	addressUpdate	3 Members; An array of information about copied ADUs
¬ struct SEFUserAddress	userAddress	The user address
¬ struct SEFFlashAddress	oldFlashAddress	The old flash address
¬ struct SEFFlashAddress	newFlashAddress	The new flash address

14.40 SEFCopyOverrides

Scheduling Queue overrides for SEFNamelessCopy()

Table 14.43: Members of SEFCopyOverrides

Type	Name	Description
uint16_t	programWeight	Weight to use for program instead of the QoS domain default. 0 will use the QoS Domain default

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15 | Callback Structures

15.1 SEFCommonIOCB

Table 15.1: Members of SEFCommonIOCB

Type	Name	Direction	Description
struct SEFStatus	status	Out	Library sets error field to a non-zero value to indicate any error when a command completes
int16_t	opcode	In	Should never be accessed - for internal use by library
int16_t	flags	In/Out	SEFIOCBFlags
int32_t	reserved	In	Reserved, must be initialized to zero
void *	param1	In	Ignored by the library; the caller can store context information that may be accessed from the completion function
void(*)(struct SEFCommonIOCB *)	complete_func	In	If non-zero, treated as the address of a function to be called when a command completes

15.2 SEFWriteWithoutPhysicalAddressIOCB

Table 15.2: Members of SEFWriteWithoutPhysicalAddressIOCB

Type	Name	Direction	Description
struct SEFCommonIOCB	common	In/Out	Common fields for all IOCBs

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struct SEFFlashAddress	flashAddress	In	Address of the super block for this write; -1 for auto-allocate, or can use value from previous super block allocation call
struct SEFUserAddress	userAddress	In	Contains LBA information
struct SEFFlashAddress*	tentativeAddresses	Out	List of tentative physical addresses return
const void *	metadata	In	Metadata to write with data; The number of bytes per ADU required is SEFQoSDomainInfo::ADUsize.meta. May be NULL
const struct iovec*	iov	In	A pointer to the scatter gather list
uint16_t	iovcnt	In	The number of elements in the scatter gather list
struct SEFPlacementID	placementID	In	Only valid if the flashAddress is auto allocated. A value from 0 to numPlacementIds – 1 indicating what logical data group to place this data in
uint32_t	numADU	In	Length in QoS Domain ADUs
uint32_t	distanceToEndOfSuperBlock	Out	Return value in units of ADUs
struct SEFWriteOverrides	overrides	In	Override parameters for scheduling purposes. Must set kSefIoFlagOverride in flags to apply

15.3 SEFReadWithPhysicalAddressIOCB

Table 15.3: Members of SEFReadWithPhysicalAddressIOCB

Type	Name	Direction	Description
struct SEFCommonIOCB	common	In/Out	Common fields for all IOCBs

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struct SEFFlashAddress	flashAddress	In	Physical address for the read command; When the QoS Domain ID and block number are 0, the ADU offset is the root pointer index for the flash address to read.
struct SEFUserAddress	userAddress	In	Contains LBA information
const struct iovec*	iov	In	A pointer to the scatter gather list
void *	metadata	In	Receives ADU metadata; The number of bytes per ADU required is SEFQoSDomainInfo::ADUsize.meta. May be NULL
uint32_t	iovOffset	In	Starting byte offset into iov array
uint32_t	numADU	In	Number of ADUs to be read, maximum is superBlockCapacity
uint16_t	iovcnt	In	The number of elements in the scatter gather list
struct SEFReadOverrides	overrides	In	Override parameters for scheduling purposes. Must set kSefIoFlagOverride in flags to apply

15.4 SEFReleaseSuperBlockIOCB

Table 15.4: Members of SEFReleaseSuperBlockIOCB

Type	Name	Direction	Description
struct SEFCommonIOCB	common	In/Out	Common fields for all IOCBs
struct SEFFlashAddress	flashAddress	In	Address of super block

15.5 SEFAllocateSuperBlockIOCB

IOCB for SEFAllocateSuperBlockAsync()

Table 15.5: Members of SEFAllocateSuperBlockIOCB

Type	Name	Direction	Description
struct SEFCommonIOCB	common	In/Out	Common fields for all IOCBs
struct SEFFlashAddress	flashAddress	Out	Address of super block
struct SEFAllocateOverrides	overrides	In	Override parameters for scheduling purposes. Must set kSefIoFlagOverride in flags to apply
enum SEFSuperBlockType	type	In	kForWrite or kForPSLCWrite

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15.6 SEFCloseSuperBlockIOCB

IOCB for SEFCloseSuperBlockAsync()

Table 15.6: Members of SEFCloseSuperBlockIOCB

Type	Name	Direction	Description
struct SEFCommonIOCB	common	In/Out	Common fields for all IOCBs
struct SEFFlashAddress	flashAddress	In	Address of the super block

15.7 SEFNamelessCopyIOCB

Table 15.7: Members of SEFNamelessCopyIOCB

Type	Name	Direction	Description
struct SEFCommonIOCB	common	In/Out	Common fields for all IOCBs
SEFQoSHandle	dstQosHandle	In	Handle to the destination QoS Domain
struct SEFFlashAddress	copyDestination	In	Flash address of destination super block
uint32_t	reserved_0	In	Reserved, must be initialized to zero
uint32_t	numAddressChangeRecords	In	Maximum number of ADUs to copy (size of addressChangeRequest userAddress array)
struct SEFAddressChangeRequest*	addressChangeInfo	Out	Output of changed addresses
struct SEFCopySource	copySource	In	Physical addresses to copy
const struct SEFUserAddressFilter*	filter	In	Pointer to user address filter parameters, null for no filtering

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struct SEFCopyOverrides	overrides	In	Override parameters for scheduling purposes. Must set kSeFloFlagOverride in flags to apply

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16 | Events

16.1 SEFQoSNotification

This event is issued at the QoS Domain level.

Table 16.1: Members of SEFQoSNotification

Type	Name	Description
enum SEFNotificationType	type	See union below...
uint8_t[5]	reserved_0	Reserved, must be initialized to zero
struct SEFQoSDomainID	QoSDomainID	QoSDomainID for this notification
union		7 Members
¬ struct SEFFlashAddress	maintenanceFlashAddress	Valid when type is kRequireMaintenance
¬ struct		3 Members
¬ ¬ struct SEFUserAddress	changedUserAddress	User address that moved
¬ ¬ struct SEFFlashAddress	oldFlashAddress	Old flash address
¬ ¬ struct SEFFlashAddress	newFlashAddress	New flash address
¬ struct SEFFlashAddress	patrolFlashAddress	Valid when type is kRequirePatrol
¬ struct		2 Members
¬ ¬ char *	userData	pointer to buffered data
¬ ¬ struct SEFUserAddress	unflushedUserAddress	affected user address
¬ struct SEFFlashAddress	unreadableFlashAddress	Valid when type is kUnreadable
¬ struct SEFFlashAddress	changedFlashAddress	Valid when type is kSuperBlockStateChanged (open=>closed)
¬ struct		2 Members
¬ ¬ const struct iovec*	iov	A pointer to the scatter gather list
¬ ¬ int16_t	iovcnt	The number of elements in the scatter gather list

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16.2 SEFVDNotification

This event indicates to the host that it should respond in some appropriate manner to the reduced capacity condition.
This event is issued at the Virtual Device level. Due to failure of blocks, actual available capacity may fall below the allocated capacity of the attached QoS Domains. The host should take action to release super blocks back to the Virtual Device's free pool before it is entierly consumed.

Table 16.2: Members of SEFVDNotification

Type	Name	Description
enum SEFNotificationType	type	Is kReducedCapacity, kOutOfCapacity or kOutOfP-SLCCapacity
uint8_t	reserved_0	Reserved, must be initialized to zero
struct SEFVirtualDeviceID	virtualDeviceID	Virtual Device for this notification
uint32_t	numADUs	kReducedCapacity - Amount of space that is no longer available

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17 | Enumerated Types

17.1 SEFDefectManagementMethod

Table 17.1: Members of SEFDefectManagementMethod

Member	Description
kPacked	Offset address in a super block is consecutive. Size of super block is reduced with defected block(s). This results in slower reads due to the extra level of indirection incurred.
kFragmented	Defective blocks are left in place, and are simply marked as non-addressable. Over time, this can result in a device with a gradually decreasing usable size. This scheme has the fastest read performance, but comes at the cost of additional management complexity that the host will be responsible for.
kPerfect	Offset address is consecutive. Size of super block is fixed. Number of super blocks is reduced with defected block(s). This has the slowest read performance because this remapping has the potential to cross block boundaries

17.2 SEFAPIIdentifier

Table 17.2: Members of SEFAPIIdentifier

Member	Description
kSuperBlock	Currently the only mode supported by the API
kInDriveGC	Reserved for future use
kVirtualSSD	Reserved for future use

17.3 SEFErrorRecoveryMode

Table 17.3: Members of SEFErrorRecoveryMode

Member	Description

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kAutomatic	Automatic recovery mode
kHostControlled	Host is responsible for recovery

17.4 SEFDeadlineType

Table 17.4: Members of SEFDeadlineType

Member	Description
kFastest	Does not attempt a corrective action, but instead sends a notification to allow higher layer to read from a separate redundant store.
kTypical	Attempts to perform basic error recovery in the event of a read error condition
kLong	Attempts to perform more advanced error recovery in the event of a read error condition
kHeroic	Attempts to perform full recovery in the event of a read error condition

17.5 SEFNotificationType

Asynchronous notifications from SEF.

Table 17.5: Members of SEFNotificationType

Member	Description
kAddressUpdate	The flash address has changed
kUnflushedData	The super block data was flushed to the Flash Memory
kRequirePatrol	The super block requires to be patrolled; A list of super blocks requiring patrol can be retrieved using SEFGetCheckList <linebreak />
kRequireMaintenance	The super block requires maintenance; In other words, the data should be copied off and the super block should be freed
kReducedCapacity	The Virtual Device's capacity has been reduced
kUnreadableData	The data stored at the flash address cannot be read
kSuperBlockStateChanged	The super block's state has changed
kOutOfCapacity	The Virtual Device is full
kOutOfPSLCCapacity	The Virtual Device is out of pSLC
kBufferRelease	The buffer pointed to by iov can be freed

17.6 SEFSuperBlockType

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Table 17.6: Members of SEFSuperBlockType

Member	Description
kForWrite	Super block is for writes
kForPSLCWrite	Super block is for pSLC writes

17.7 SEFSuperBlockState

Table 17.7: Members of SEFSuperBlockState

Member	Description
kSuperBlockClosed	This is the state of super blocks which retain effective data after all super pages have been programmed
kSuperBlockOpenedByErase	This is the state of super blocks in the middle of being programmed and were allocated by SEFAllocateSuperBlock()
kSuperBlockOpenedByPlacementId	This is the state of super blocks in the middle of being programmed and were allocated automattically by placement id

17.8 SEFDataIntegrity

Integrity of a super block.

Table 17.8: Members of SEFDataIntegrity

Member	Description
kSefIntegretyUnknown	The block needs to be patrolled
kSefIntegretyGood	Reading the block requires little to no error correction
kSefIntegretyAllowable	Reading the block requires an acceptable amount of error correction
kSefIntegretyMarginal	The data in the block needs to be relocated

17.9 SEFPropertyID

Table 17.9: Members of SEFPropertyID

Member	Description
kSefPropertyQoSDomainID	Get QoS Domain ID in qosID
kSefPropertyVirtualDeviceID	Get Virtual Device ID as vdID
kSefPropertyUnitNumber	Get Unit number as intVal
kSefPropertyQoSNotify	Get QoS notification fnc as qosNotify

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kSefPropertyPrivateData	Get/Set private data
kSefPropertyNumActiveRequests	Get Number of active requests as intVal

17.10 SEFPropertyType

Table 17.10: Members of SEFPropertyType

Member	Description
kSefPropertyTypeInvalid	The SEFPropertyID is not supported
kSefPropertyTypeNull	The Property has no value (not set)
kSefPropertyTypeInt	The intVal member is valid
kSefPropertyTypePtr	The ptr member is valid
kSefPropertyTypeQoSDomainID	The qosID member is valid
kSefPropertyTypeVirtualDeviceID	The vdID member is valid
kSefPropertyTypeQoSNotify	The qosNotify member is valid

17.11 SEFCopySourceType

The source format to be used when copying a super block.

Table 17.11: Members of SEFCopySourceType

Member	Description
kBitmap	Use validBitmap as the copy source
kList	Use flashAddressList as the copy source

17.12 SEFIOCBFlags

Table 17.12: Members of SEFIOCBFlags

Member	Description
kSefIoFlagDone	Flag for polled I/O - library sets this bit to a 1 value once the command completes
kSefIoFlagNotifyBufferRelease	Flag set to indicate caller is managing buffer lifetime. See Also: SEFWriteWithoutPhysicalAddress()
kSefIoFlagCommit	Flag set to force data to flash before completing, potentially adding padding
kSefIoFlagOverride	Flag set to apply weight override to i/o

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