



# SEV-TIO Firmware Interface Specification

## Technical Preview

Publication #	<b>58271</b>	Revision:	<b>0.91</b>
Issue Date:	<b>July 2025</b>		



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## Revision History

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Date	Revision	Description
July 2025	0.91	Global updates related to revisions of firmware support for ABI (commands, return codes, etc.). Revision of Theory-of-Operation.
May 2023	0.70	Initial release.



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# Chapter 1 Introduction

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## 1.1 Purpose

The purpose of this document is to specify the SEV Trusted I/O (SEV-TIO) extension to the SEV firmware. The SEV-TIO extension provides a mechanism for guests to bind to and use trusted devices within their guest private address space.

## 1.2 Scope

This document describes the software interface for functions supported by the AMD Secure Processor (ASP) for SEV-TIO trusted device management. It does not describe the x86 CPU or System-on-Chip (SoC) hardware support for SEV-TIO. While certain sections of this document may describe potential host software usage of the firmware interface, this document is not intended to prescribe any specific use or host software architecture.

This document is a technical preview. Future versions of this document may introduce backward compatibility-breaking changes.

## 1.3 Intended Audience

The intended audience of this document are host software developers and security architects. Host software developers supporting SEV-TIO must use the firmware functions described herein for device lifecycle management. Additionally, kernel developers and security architects must use the guest message functions to perform device attestation and system configuration to bring devices into the guest trust boundary.



## Chapter 2 Theory of Operation

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This interface specification extends the Secure Encrypted Virtualization (SEV) and SEV Secure Nested Paging (SEV-SNP) firmware interface specifications [1] [2] with a new set of host commands and SEV-TIO guest request messages, that allow a guest to establish trust in a device that supports TEE Device Interface Security Protocol (TDISP) [3] and then interact with the device via private memory. Host software is responsible for assigning device and host resources to the guest. Host software is also responsible for facilitating the flows necessary for supporting guests' assessment and usage of TDISP capable devices. For an overview of the feature, please see the AMD SEV-TIO whitepaper [4].

The AMD Security Processor (ASP) executes the SEV firmware that services all host commands and SEV-TIO guest request messages. Through this interface, host software orchestrates TDISP between the SEV firmware, which serves as the TEE Security Manager (TSM), and the Device Security Manager (DSMs) of TDISP capable devices.

The following sections describe the functionality of the SEV-TIO interface provided by the SEV firmware.

### 2.1 Feature Detection

Software can detect whether the host hardware supports SEV-TIO according to the AMD IOMMU specification [5]. To detect that the currently loaded SEV firmware supports SEV-TIO, software can retrieve bit 1 from Fn80000024\_EBX\_x00 using the FEATURE\_INFO command.

### 2.2 Platform Initialization

SEV-TIO is initialized by setting the TIO\_EN flag to 1 in the SNP\_INIT\_EX command. When TIO\_EN is 0, SNP\_INIT\_EX initializes the RMP entries for MMIO pages in the platform to HV-fixed, which prevents host software from assigning MMIO pages to SNP guests in the RMP. When TIO\_EN is 1, the command leaves the pages in the Hypervisor page state, which allows host software the ability to assign MMIO pages to guests. SNP\_INIT\_EX also initializes the SEV-TIO feature in the IOMMUs. Subsequent invocations of SNP\_INIT\_EX that do not request RMP re-initialization must have the same TIO\_EN value as the previous invocation.

### 2.3 Scatter Lists and Buffers

SEV-TIO uses buffers that can span multiple noncontiguous physical pages. Because the ASP accesses system physical addresses directly without address translation, SEV firmware uses a scatter list to reference noncontiguous physical pages. When host software allocates a buffer for SEV-TIO to use, software constructs a scatter list that points to each physical page of the buffer. Scatter lists are used to reference two new types of host-donated context buffers for devices and



their interfaces, as well as communication buffers for transmitting TDISP related data during the invocation of TIO commands.

The logical buffer constructed by scatter lists contains a header that describes the contents of the buffer. The remainder of the buffer is a sequence of data objects. Some data objects are intended to be constructed or parsed by host software, which are specified in Section 4.5. Other data objects contain implementation-specific data intended to be used only by SEV firmware that should be managed by host software as opaque objects. Buffers containing opaque objects are protected from software modification by the enforcement of RMP page states.

Buffers passed as parameters to commands may require resizing to successfully complete the command. Specifically, when SEV firmware is writing to a buffer, it may determine that the buffer is too small to complete the command. In this case, the firmware writes into the header of the buffer to indicate the minimum buffer size and returns a status code that indicates to host software that the buffer must be expanded in size. The status code returned is command specific.

## 2.4 Device Context Buffer

SEV firmware tracks the state of a device specific to SEV-TIO in a device context buffer. The host creates a device context buffer for each device by allocating the buffer, transitioning each page of the buffer to the Firmware page state, and then invoking the TIO\_DEV\_CREATE command. TIO\_DEV\_CREATE initializes the buffer and transitions the page to the Device-Context page state.

Device context buffers are fixed in size. Host software must allocate a buffer at least as large as the DEVCTX\_SIZE field returned by the TIO\_STATUS command. The minimum buffer size for context pages does not change until after one of these commands is invoked: SNP\_SHUTDOWN, SNP\_SHUTDOWN\_EX (IOMMU or x86), or DOWNLOAD\_FIRMWARE\_EX.

To reclaim a device context buffer, host software can invoke TIO\_DEV\_RECLAIM. Host software must invoke TIO\_TDI\_RECLAIM on all TDI context buffers of the device before reclaiming a device context buffer. TDI context buffers are described further in Section 2.6.

## 2.5 Device Connection

To use a TDISP capable device with SEV-TIO, host software must first arrange for the SEV firmware to establish a connection with the device by invoking the TIO\_DEV\_CONNECT command. The TIO\_DEV\_CONNECT command performs the following:

- Establishes a secure SPDML session using Secured Messages for SPDML.
- Constructs IDE selective streams between the root complex and the device.
- Checks the TDISP capabilities of the device.

SPDML is a request-response protocol in which the SEV firmware sends request messages to the device, and the device returns response messages back to the SEV firmware. The SPDML messages



are cryptographically protected and transported between the SEV firmware and the device via host software. For details on how the SEV firmware sends and receives SPDMM messages through host software, see Chapter 5.

## 2.6 TDI Context Buffer

Each TDISP capable device provides one or more TDIs that can be securely bound to SNP active guests. The SEV firmware tracks the state of a TDI specific to SEV-TIO with a TDI context buffer. The TDI context buffer size must meet the minimum size requirement reported in the TIO\_STATUS command. The host creates a TDI context buffer by allocating the buffer, transitioning each page of the buffer to the Firmware page state, and then invoking the TIO\_TDI\_CREATE command. TIO\_TDI\_CREATE initializes the buffer and transitions the page to the TDI-Context page state.

TDI context buffers are fixed in size. Host software must allocate a buffer at least as large as the TDICTX\_SIZE field returned by the TIO\_STATUS command. The minimum buffer size for context pages does not change until after one of these commands is invoked: SNP\_SHUTDOWN, SNP\_SHUTDOWN\_EX, or DOWNLOAD\_FIRMWARE\_EX.

To reclaim a TDI context buffer, host software can invoke TIO\_TDI\_RECLAIM.

## 2.7 Device Assignment and Binding

Host software binds a TDI to an SNP active guest by first mapping the MMIO ranges of the TDI to the private address space of the guest and transitioning the pages of the ranges to the Pre-Guest page state. Then host software invokes TIO\_TDI\_BIND.

TIO\_TDI\_BIND sends request messages to the device to transition the TDI from the CONFIG\_UNLOCKED state to the CONFIG\_LOCKED state and to the RUN state. Host hardware restricts DMA from the TDI into guest private memory until the guest sends the TIO\_MSG\_SDTE\_WRITE\_REQ guest request message to grant the TDI access. The guest also cannot access MMIO ranges of the TDI until the guest sets the RMP validated bits of the pages in the ranges using the TIO\_MSG\_MMIO\_VALIDATE\_REQ guest request message.

To unbind the TDI from a guest and return the TDI to the CONFIG\_UNLOCKED state, host software can invoke the TIO\_TDI\_UNBIND command.

## 2.8 Device Attestation

Before the guest enables DMA and MMIO for a TDI, the guest can retrieve attestation information about the device. The attestation objects available for the guest are the device certificate chain, the device attestation report, and the interface report. The policy used to validate these objects is beyond the scope of this specification.





The guest relies on host software to transfer the attestation objects. Host software can retrieve the certificate chain, device attestation report, and interface report using the TIO\_DEV\_CERTIFICATES, TIO\_DEV\_MEASUREMENTS, and TIO\_TDI\_REPORT commands, respectively. Additionally, the TIO\_DEV\_CONNECT command outputs the certificate chain, and the TIO\_TDI\_BIND command outputs the interface report to host software.

When the guest receives the attestation objects from host software, it can validate that the attestation objects were not tampered with by retrieving their cryptographic digests from the SEV firmware using the TIO\_TDI\_INFO\_REQ guest request message. This message gives the guest the digest of the attestation objects last retrieved by the SEV firmware.

The guest can ensure that the attestation report is fresh by checking that the MEAS\_DIGEST\_FRESH flag in the TIO\_MSG\_TDI\_INFO\_RSP guest message is 1. MEAS\_DIGEST\_FRESH indicates that the attestation report was retrieved after the TDI was locked. This may be important to guests to ensure that host software has not made security changes to the device that cause the device attestation report to become stale.

## 2.9 MMIO Validation

The guest can discover the location of the MMIO ranges of the TDI through existing guest PCIe enumeration. For instance, the guest can find the location of MMIO ranges by reading the Base Address Registers (BARs) out of the PCIe configuration space of the TDI. Because guest configuration space would be emulated by host software, the guest can validate the location and attributes of the MMIO ranges by examining the interface report.

The guest can examine the interface report to determine whether the MMIO range attributes agree with the security policy of the guest. For instance, the guest might wish to ensure that IS\_NON\_TEE\_MEM is 0 for sensitive MMIO ranges that must not be accessible to host software. The guest can also retrieve and update the MMIO range attributes with the TIO\_MSG\_MMIO\_CONFIG\_REQ guest message as desired.

After the guest has agreed with the location and security attributes of the MMIO range, the guest can send the TIO\_MSG\_MMIO\_VALIDATE\_REQ message. The guest provides the RangeID, base guest physical address, and length of the MMIO range in the message. The firmware checks that the MMIO range is correctly mapped into the guest address space and then sets the Validated bit. The guest can also clear the Validated bit for the MMIO range using this guest message.

Note that the PVALIDATE instruction triggers a #GP exception when used for MMIO ranges.

## 2.10 Enabling Direct Memory Access

The IOMMU rejects all access attempts of a device to guest private memory until the guest sends the TIO\_MSG\_SDTE\_WRITE\_REQ guest request message. This message sets the Secure Device



Table Entry (SDTE) for the TDI. To grant the device access to guest private memory, the guest can set the V bit of the SDTE to 1.

The SDTE contains the VMPL to assign to the TDI. On memory access by the TDI, the IOMMU uses the VMPL field of the SDTE for the RMP access check during address translation.

The guest can set the Virtual Top of Memory (vTOM) for the TDI in the SDTE. When vTOM is enabled, the IOMMU determines the C-bit of the TDI access using the provided vTOM address in the SDTE. All data accesses below vTOM are accessed with an effective C-bit of 1, and all addresses at or above vTOM are accessed with an effective C-bit of 0.

***Technical Preview Note:** This revision of the technical preview supports binding devices with guest paging mode disabled. In future revisions, guest paging support will be added, which will expand the definition of the SDTE with further fields associated with guest paging.*

## 2.11 Error Conditions

Each TDI of a TDISP capable device may enter the TDISP ERROR state. When a TDI is in the ERROR state, a TDISP capable device is expected to prevent further access to guest private memory via that TDI. The TIO\_TDI\_STATUS command can be used to retrieve the current state of the TDI to check whether the TDI has entered the ERROR state.

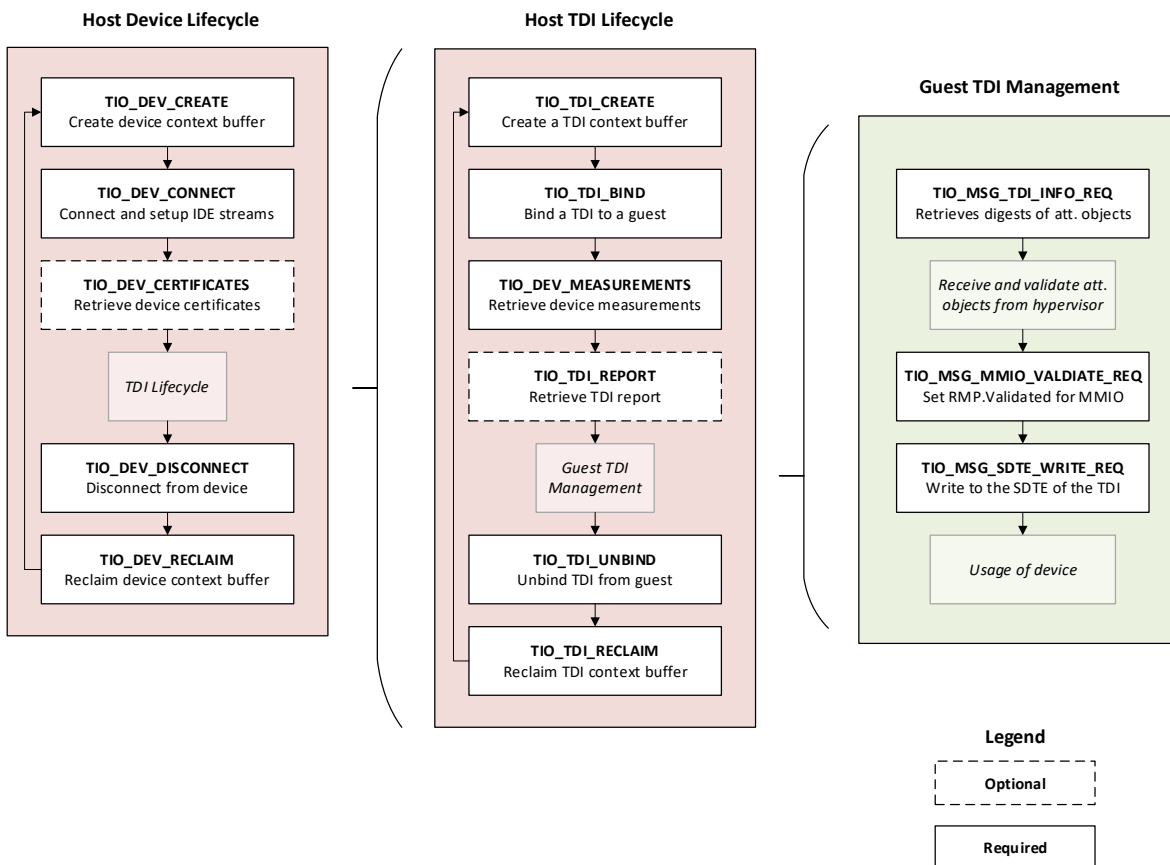
Host software can reclaim a TDI that has transitioned to the ERROR state by invoking TIO\_TDI\_UNBIND. This transitions the TDI back to the CONFIG\_UNLOCKED state. Note that unbinding a TDI from a guest destroys any guest context or data within the TDI.

If a bound TDI sends a request to the root complex and the IOMMU detects a fault caused by host configuration, then the root complex fences the ASID from all further I/O to or from that guest. A host fault is either a host page table fault or an RMP check violation. ASID fencing means that the IOMMU blocks all further I/O from the root complex to the guest that the TDI was bound, and the root complex blocks all MMIO accesses by the guest. When a guest writes to MMIO, the write is silently dropped. When a guest reads from MMIO, the guest reads all 1s.

Host software can clear the ASID fencing by unbinding all TDIs on the root complex from the guest. Then, the host software invokes the TIO\_ASID\_FENCE\_CLEAR command. The guest cannot interact with the TDIs until the host invokes TIO\_TDI\_BIND again. The Guest can re-attempt the TDI. The SNP\_DECOMMISSION command also clears the ASID fence.

## 2.12 Device Lifecycle

The commands and SEV-TIO guest request messages described in the previous sections are used together in the lifecycle of a TDISP capable device. Figure 1 illustrates the primary steps of this lifecycle.



**Figure 1: Lifecycle of a TDISP Capable Device**

Host software manages the lifecycles of devices and TDIs. As mentioned above, the device certificate chain and the interface reports are output by the `TIO_DEV_CONNECT` and `TIO_TDI_BIND` commands respectively, but host software can optionally retrieve them with `TIO_DEV_CERTIFICATES` and `TIO_TDI_REPORT`. The `TIO_DEV_MEASUREMENTS` command should be invoked after `TIO_TDI_BIND` to retrieve a fresh device attestation report for the guest to consume. Otherwise, the report may be stale, which is reported to the guest via `TIO_MSG_TDI_INFO_REQ`.

All irrecoverable errors can be cleared and reset by completing the lifecycle flow. For instance, if a guest shuts down unexpectedly, host software can recover the resources associated with the TDIs bound to the guest by invoking the `TIO_TDI_UNBIND` command. Similarly, device errors like reset, power failure, or physical removal can be handled by invoking `TIO_DEV_DISCONNECT`. Both commands succeed even if the device is unresponsive.



## Chapter 3 Mailbox Protocol

This specification extends the mailbox protocol with the SEV firmware defined in SEV ABI [1] and SEV-SNP ABI [2].

### 3.1 Command Identifiers

The command identifiers for SEV-TIO related commands are specified in Table 1.

**Table 1. Command Identifiers**

Command	ID	Description
TIO_STATUS	D0h	Retrieve status of the SEV-TIO feature.
TIO_INIT	D1h	Initialize the TIO feature.
TIO_DEV_CREATE	D2h	Create a device context buffer.
TIO_DEV_RECLAIM	D3h	Reclaim a device context buffer.
TIO_DEV_CONNECT	D4h	Connect the SEV firmware to a device.
TIO_DEV_DISCONNECT	D5h	Disconnect the SEV firmware from a device.
TIO_DEV_STATUS	D6h	Retrieve status of a device.
TIO_DEV_MEASUREMENTS	D7h	Retrieve the SPDM measurements from a device.
TIO_DEV_CERTIFICATES	D8h	Retrieve the SPDM certificate chain from a device.
TIO_TDI_CREATE	DAh	Create a TDI context page.
TIO_TDI_RECLAIM	DBh	Reclaim a TDI context page.
TIO_TDI_BIND	DCh	Bind a TDI to a guest.
TIO_TDI_UNBIND	DDh	Unbind a TDI from a guest.
TIO_TDI_REPORT	DEh	Retrieve the interface report of a TDI.
TIO_TDI_STATUS	DFh	Retrieve status about the TDI.
TIO_GUEST_REQUEST	E0h	Send SEV-TIO guest request messages capable of sending SPDM messages.
TIO_ASID_FENCE_CLEAR	E1h	Clear the ASID fencing of a root complex.
TIO_ASID_FENCE_STATUS	E2h	Retrieve the current ASID fencing status for a root port.
TIO_TDI_INFO	E3h	Retrieve TDISP related information about the TDI.
TIO_TDI_DIGESTS_REPORT	E4h	The Host OS retrieves a TDI attestation report.



## 3.2 Status Codes

The status codes for SEV-TIO related commands are specified in Table 2.

**Table 2. Status Codes**

Status	Code	Description
INCORRECT_BUFFER_LENGTH	30h	Buffer size does not match the buffer size provided by the TIO_STATUS command.
EXPAND_BUFFER_LENGTH_REQUEST	31h	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the BUFFER_CAPACITY field of BUFFER structure.
SPDM_REQUEST	32h	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	33h	Indicates an error in the SPDM channel.
INVALID_DATA_OBJECT	34h	Indicates that the data object is malformed.
ERROR_IN_DEV_CONNECTION	35h	Indicates that an unrecoverable error occurred in the SPDM secure session with the device.
INVALID_DEV_CTX	36h	Indicates that the provided page is not a valid device context page.
INVALID_TDI_CTX	37h	Indicates that the provided page is not a valid TDI context page.
INVALID_TDI	38h	Indicates that the identified TDI is invalid.
RECLAIM_REQUIRED	39h	Indicates that a reclaim of a context page is required before further use.
IN_USE	3Ah	The resource is in use.
INVALID_DEV_STATE	3Bh	The device state is invalid.
INVALID_TDI_STATE	3Ch	The TDI state is invalid.
DEV_CERT_CHANGED	3Dh	Digest of the certificate received in GET_CERTIFICATE does not match the digest previously saved digest.
RESYNC_REQUIRED	3Eh	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.
RESPONSE_TOO_LARGE	3Fh	The response buffer is not large enough.



## Chapter 4 Scatter Lists and Buffers

To represent a logical buffer across noncontiguous system physical pages, the interface requires software to pass a scatter list. This chapter describes scatter lists and the logical buffers they reference.

### 4.1 Scatter List Pointer

A Scatter Tree Address (SLA) is a 4 KB aligned System Physical Address (SPA) that uses the lower 12 bits of the address to store metadata about the page pointed to by the address. Table 3 describes the layout of an SLA.

**Table 3. Layout of the Scatter List Address (SLA)**

Byte Offset	Bits	Name	Description
0h	63:52	—	Reserved. Must be 0.
	51:12	SPA	Bit[51:12] of a system physical address.
	11:2	—	Reserved. Must be 0.
	1	PAGE_SIZE	0: The page pointed to by this SLA is 4 KB. 1: The page pointed to by this SLA is 2 MB.
	0	PAGE_TYPE	0: The page pointed to by this SLA is a data page. 1: The page pointed to by this SLA is a scatter tree node page.

The full system physical address encoded by the SLA is constructed by setting bits [63:52] and [11:0] to zero and setting bits [51:12] to the value in the SPA field of the SLA. That is, one can calculate the system physical address by masking the SLA with 000FFFFFF\_FFFFFFF000h.

If PAGE\_TYPE is 1, then PAGE\_SIZE must be 0.

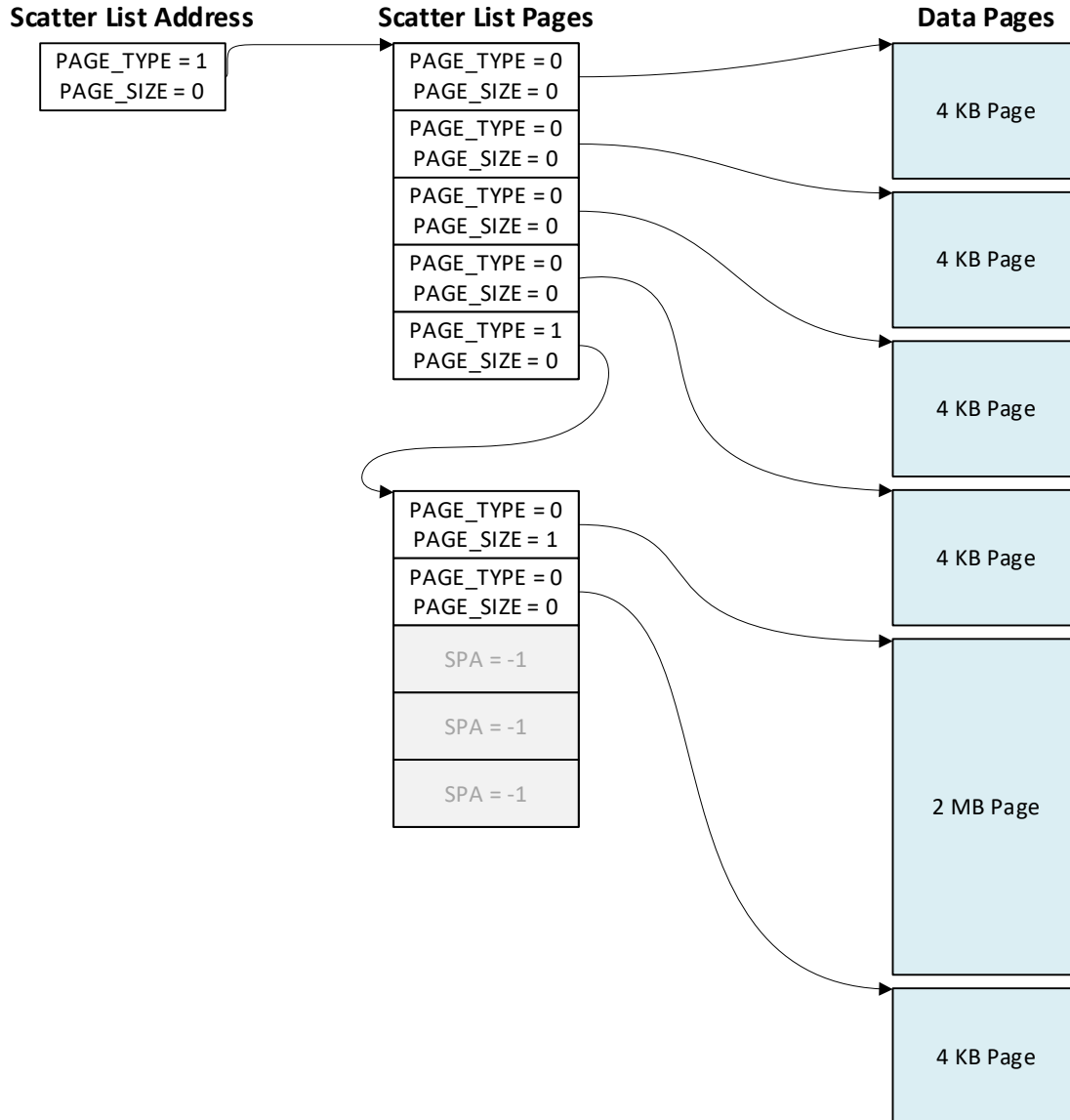
### 4.2 Scatter List

If the PAGE\_TYPE field of an SLA is 1, then the SLA points to a scatter list page, which is a page of memory formatted as specified in Table 4.

**Table 4. Layout of a Scatter Tree Node**

Byte Offset	Bits	Name	Description
0h–FFFh		SLA_ARRAY	Array of 512 SLAs.

If the SPA field of an SLA is all 1s, then the entry is invalid. The firmware reads each SLA\_ARRAY entry until it encounters an invalid entry or it encounters the end of the page.



**Figure 2: Scatter List and Its Formation of a Buffer**

The first 511 entries must have `PAGE_TYPE` cleared to 0 indicating that the SLA points to a data page. The last entry may have `PAGE_TYPE` cleared to 0 or set to 1. If `PAGE_TYPE` is 1, the last entry points to a subsequent scatter list that extends the buffer further. The firmware supports up to 512 total chained scatter lists unless otherwise stated.

For example, in Figure 2, a scatter list address points to the first scatter list page. Because the scatter list page is full of valid scatter list pointers, the last entry points to a second scatter list



page. The resulting logical buffer is made up of noncontiguous pages of both 4 KB and 2 MB sizes.

## 4.3 Page States

Because SEV firmware reads only from the scatter list pages, the scatter list pages may be in any page state. The data pages pointed to by the scatter list that form the logical buffer may be required to be in a specific RMP page state depending on the command accessing the buffer.

For instance, the scatter list page of a device context buffer may be in the Hypervisor page state, but each of the data pages that form the device context buffer must be in the Device-Context page state.

## 4.4 Buffer Layout

The sequence of data pages pointed to by a scatter list form a logical buffer. Every buffer is formatted with a header followed by one or more data objects. Table 5 specifies the structure of a logical buffer.

**Table 5. Layout of the BUFFER Structure**

Byte Offset	Bits	Name	Description
0h	31:0	BUFFER_CAPACITY	The capacity of the buffer in bytes.
4h	31:0	BUFFER_PAYLOAD_SIZE	The size of BUFFER_PAYLOAD in bytes.
8h	31:0	Reserved. Mbz.	
Ch	31:0	—	Reserved.
10h	127:0	BUFFER_IV	IV used for the encryption of this buffer.
20h	127:0	BUFFER_AUTHTAG	Authentication tag for this buffer.
30h	127:0	—	Reserved.
40h	—	BUFFER_PAYLOAD	BUFFER_PAYLOAD_SIZE bytes of data.

When the SEV firmware command needs to write to a buffer but the buffer is not large enough, the SEV firmware writes the desired buffer size into BUFFER\_CAPACITY and returns a status code indicating the buffer needs allocation from host software. The status code is determined by the command. See command descriptions for details.





## 4.5 Data Objects

Each data object stored in a logical buffer has a common header. Table 6 specifies the structure of the data object common header.

**Table 6. Layout of the DATA\_OBJECT\_HEADER Structure**

Byte Offset	Bits	Name	Description
0h	31:0	DOBJ_ID	Data object type identifier.
4h	31:0	DOBJ_LENGTH	Length of the data object in bytes, including this header.
8h	15:0	DOBJ_VERSION	Version of the data object structure. Bit[7:0]: Minor version. Bit[15:8]: Major version.

The following subsections specify each type of data object.

### 4.5.1 SPDM Request Object

A data object containing an SPDM request packet to be sent to a device. See Chapter 5 for a usage description of this object.

**Table 7. DATA\_OBJECT\_HEADER for SPDM Request Objects**

Byte Offset	Bits	Name	Description
0h	31:0	DOBJ_ID	1h.
4h	31:0	DOBJ_LENGTH	Length of the data object in bytes, including this header.
8h	15:0	DOBJ_VERSION	Version of the data object structure. Bit[7:0]: Minor version. Bit[15:8]: Major version.
Ah	7:0	SPDM_TYPE	0x00: Invalid 0x01: SPDM message 0x02: Secured SPDM message 0x03-0xFF: reserved
Bh–Fh		–	Reserved.
10h	–	DOBJ_PAYLOAD	SPDM request packet.



## 4.5.2 SPDM Response Object

A data object containing an SPDM response packet received from a device to be sent to the SEV firmware. See Chapter 5 for a usage description of this object.

**Table 8. DATA\_OBJECT\_HEADER for SPDM Response Objects**

Byte Offset	Bits	Name	Description
0h	31:0	DOBJ_ID	2h. Unique identifier for SPDM response objects.
4h	31:0	DOBJ_LENGTH	Length of the data object in bytes, including this header.
8h	15:0	DOBJ_VERSION	Version of the data object structure. Bit[7:0]: Minor version. Bit[15:8]: Major version.
Ah	7:0	SPDM_TYPE	0x00: Invalid 0x01: SPDM message 0x02: Secured SPDM message 0x03-0xFF: reserved
Bh–Fh		–	Reserved.
10h	–	DOBJ_PAYLOAD	SPDM request packet.

## 4.5.3 SPDM Certificate Object

A data object containing the certificate chain that was retrieved from a device. See TIO\_DEV\_CONNECT and TIO\_DEV\_CERTIFICATES command descriptions for the usage of this object.

**Table 9. DATA\_OBJECT\_HEADER for SPDM Certificate Objects**

Byte Offset	Bits	Name	Description
0h	31:0	DOBJ_ID	4h.
4h	31:0	DOBJ_LENGTH	Length of the data object in bytes, including this header.
8h	15:0	DOBJ_VERSION	Version of the data object structure. Bit[7:0]: Minor version. Bit[15:8]: Major version.
Ah–Fh		–	Reserved.
10h	15:0	DEVICE_ID	PCIe Routing ID of function 0 of the device.
12h	7:0	SEGMENT_ID	PCIe Segment ID.



Byte Offset	Bits	Name	Description
13h	7:0	CERT_TYPE	1h: SPDM certificate (see SPDM v1.2.1, Sec. 10.6.1, Table 28 for certificate format). 0h, 2h–FFh: Reserved.
14h–1Fh		–	Reserved.
20h	–	DOBJ_PAYLOAD	See Section 6.1.

#### 4.5.4 SPDM Measurement Object

A data object containing the SPDM attestation report retrieved from a device. See TIO\_DEV\_MEASUREMENTS command description for the usage of this object.

**Table 10. DATA\_OBJECT\_HEADER for SPDM Measurement Objects**

Byte Offset	Bits	Name	Description
0h	31:0	DOBJ_ID	5h.
4h	31:0	DOBJ_LENGTH	Length of the data object in bytes, including this header.
8h	15:0	DOBJ_VERSION	Version of the data object structure. Bit[7:0]: Minor version. Bit[15:8]: Major version.
Ah–Fh		–	Reserved.
10h	15:0	DEVICE_ID	PCIe Routing ID of function 0 of the device.
12h	7:0	SEGMENT_ID	PCIe Segment ID.
13h	7:0	MEAS_TYPE	1h: SPDM Measurement (see SPDM 1.2.1, Sec. 10.11, Table 43) 02h: SPDM Measurement Log L1/L2 (see SPDM 1.2.1, Sec. 10.11.2 for L1/L2 definition) 03h: SPDM Measurement Log L1/L2 and Signature (see SPDM 1.2.1, Sec. 10.11.2 for signature generation) 0h, 04h–FFh: Reserved
14h–1Fh		–	Reserved.
20h	–	DOBJ_PAYLOAD	See Section 6.2.

#### 4.5.5 SPDM Interface Report Object

A data object containing the certificate chain retrieved from a device. See TIO\_TDI\_BIND and TIO\_TDI\_REPORT command descriptions for the usage of this object.

**Table 11. DATA\_OBJECT\_HEADER for SPDMM Measurement Objects**

Byte Offset	Bits	Name	Description
0h	31:0	DOBJ_ID	6h.
4h	31:0	DOBJ_LENGTH	Length of the data object in bytes, including this header.
8h	15:0	DOBJ_VERSION	Version of the data object structure. Bit[7:0]: Minor version. Bit[15:8]: Major version.
Ah–Fh		–	Reserved.
10h	15:0	DEVICE_ID	PCIe Routing ID of function 0 of the device.
12h	7:0	SEGMENT_ID	PCIe Segment ID.
13h	7:0	MEAS_TYPE	1h: TDISP interface report. For more information, see section 11.3.11 of the TDISP specification as included in <i>PCIe Base Specification</i> , Rev 6.1. 0h, 2h–FFh: Reserved.
14h–1Fh		–	Reserved.
20h	–	DOBJ_PAYLOAD	See Section 6.3.



## Chapter 5 SPDM Transport

An SEV-TIO command can send SPDM requests to a device, receive an SPDM response from a device, and write objects like certificate chains and attestation reports to an output buffer.

### 5.1 SPDM Control Structure

Multiple SEV-TIO command buffers contain the SPDM control structure specified in Table 12.

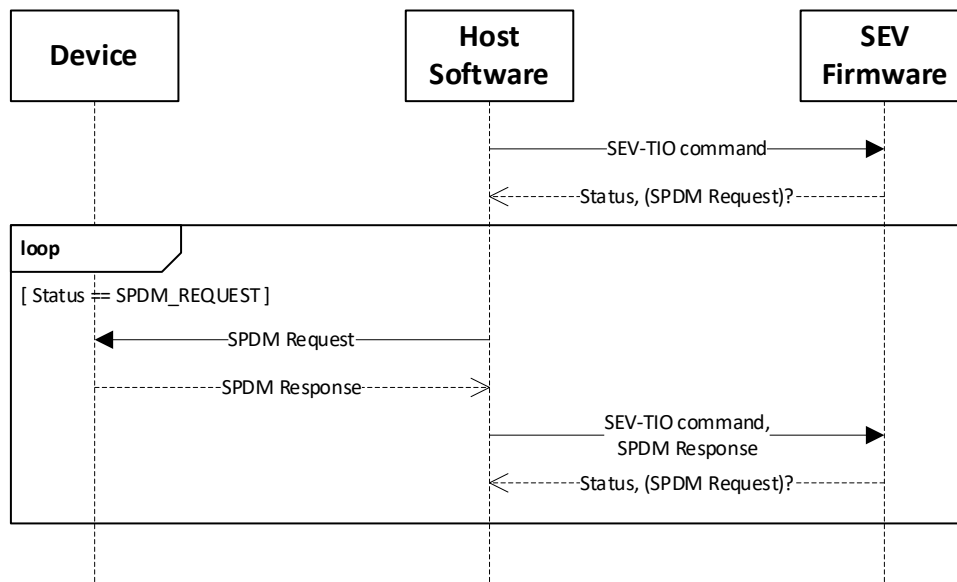
**Table 12. Layout of the SPDM\_CTRL Structure**

Byte Offset	Bits	Name	Description
0h	63:0	REQ_SLA	An SLA for the request buffer that contains an SPDM Request Object.
8h	63:0	RSP_SLA	An SLA for the response buffer that contains an SPDM Response Object.
10h	63:0	SCRATCH_SLA	An SLA for the scratch buffer that contains an SPDM Scratch Object.
18h	63:0	OUT_SLA	An SLA for the output buffer that may contain various data objects.

The request buffer, scratch buffer, and output buffer are written by SEV firmware. Each page of the request buffer and output buffer must be in the Firmware page state. Each page of the scratch buffer must be in the Firmware page state. The response buffer is read by SEV firmware and can be in any page state.

### 5.2 Control Flow

SEV-TIO introduces a new control flow scheme to support SPDM communication between SEV firmware and the device. Some commands might result in one or more SPDM sets of requests and responses transmitted between the SEV firmware and the device. For instance, the TIO\_DEV\_CONNECT command needs to trade multiple messages with the device to establish an SPDM connection and set up IDE streams. If a command requires SPDM communications, then the command must include an SPDM\_CTRL structure as defined in Section 5.1.



**Figure 3: Control Flow for Commands that Send and Receive SPD Messages**

If a command invoked by host software needs to send an SPD request, the command writes the request to the request buffer and returns the `SPDM_REQUEST` status code. When host software receives the `SPDM_REQUEST` status code, host software sends the message from the request buffer to the device. When the device returns a response, host software writes the response message into the response buffer and re-invokes the command so that SEV firmware can process the response. This process continues until the status code is no longer `SPDM_REQUEST`. Figure 3 illustrates the control flow. This sequence of reinvocation of commands is called an SPD action.

Some SPD actions produce output for host software to consume as part of the SPD request. For instance, a command may output the certificate chain of the device. In this case, the output buffer is filled with the certificate chain.

When host software reinvokes a command after an `SPDM_REQUEST` status code, host software must preserve the contents of the scratch and output buffers.

An SPD action operates on a single device. Only one SPD action may be pending for a device at a time. However, SPD actions for different devices may be interleaved. Commands that do not take `SPDM_CTRL` structures can be interleaved.

The SPD transport layer may require knowledge of whether the transferred SPD packets are secured. Host software can determine this via the `SPDM_TYPE` field of the SPD Request Object defined in Section 4.5.1.



## 5.3 SPDM Buffer Capacity

The firmware may return `SPDM_REQ_LENGTH`, `SPDM_SCRATCH_LENGTH`, or `SPDM_OUT_LENGTH` to indicate that the response buffer, scratch buffer, or output buffer are too small, respectively. In this case, the firmware writes the desired size into the `BUFFER_CAPACITY` field of the buffer header. Host software should allocate at least that many bytes for the buffer. Host software must ensure that the original buffer contents are preserved on reallocation. Host software may leave the newly allocated portion of the buffer uninitialized.

Host software can invoke `TIO_STATUS` to retrieve the minimum and maximum buffer sizes for the request buffer, scratch buffer, output buffer, and response buffers. If software provides a buffer size outside of these bounds, the firmware will respond with status code `INCORRECT_BUFER_LENGTH`.

## 5.4 SPDM Scratch Buffer Page State

The first command invoked as part of an SPDM action transitions the provided data pages of the scratch buffer to the SPDM-Scratch page state. The SPDM-Scratch page state protects the contents of the SPDM scratch buffer and is intended to be accessed only by SEV firmware. When the firmware requests for the host software to grow the buffer, the firmware transitions the newly added pages to the SPDM-Scratch page state.

If the command returns `SUCCESS` or any unrecoverable error, the firmware transitions the pages of the SPDM scratch buffer back to the Firmware page state.

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## Chapter 6      Attestation Objects

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TDISP capable devices provide attestation objects that allow the guest to validate the identity and configuration of the device, as well as the configuration of the TDI the guest is bound to. This validation occurs prior to allowing the TDI to access guest private memory. This section details the attestation object format that the SEV firmware outputs in the TIO\_DEV\_CERTIFICATES, TIO\_DEV\_MEASUREMENTS, and TIO\_TDI\_REPORT commands.

### 6.1      Certificates Object

TIO\_DEV\_CERTIFICATES returns a certificate chain retrieved from the device using the GET\_CERTIFICATES SPDM request message. The SEV firmware returns the X.509 certificate chain provided by the device unaltered.

### 6.2      Measurements Object

TIO\_DEV\_MEASUREMENTS returns an attestation report retrieved from the device using the GET\_MEASUREMENTS SPDM request message. Host software can request either the digest or the raw bitstream form of the attestation report.

The SEV firmware retrieves the attestation report through the cryptographically protected SPDM session. This provides the assurance that the attestation report came from the device and was not tampered with during transmission. Therefore, the SEV firmware does not request that the device sign the attestation report.

The measurement object is a MEASUREMENTS message as defined in the SPDM specification [6].

### 6.3      Interface Report Object

TIO\_TDI\_BIND and TIO\_TDI\_REPORT return an interface report object. The report object is specified as defined in Table 15 of the PCI TDISP specification [3]. The SEV firmware assists the guest in ensuring that the guest physical addresses of the MMIO are correctly mapped when the guest validates the range using the TIO\_MSG\_MMIO\_VALIDATE\_REQ guest message.





## Chapter 7 Command Reference

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This chapter provides information regarding the SEV-SNP modified commands, and the additional SEV-TIO commands. The status codes returned for these commands are specific to TIO; for all other SEV status codes (e.g. GUEST\_INVALID) please refer to the SEV-SNP specification.

*NOTE: Any command with LENGTH as an input field will be checked to match the specific size. INVALID\_LENGTH will be returned if the input command length does not match the version specific length.*

### 7.1 SNP\_INIT\_EX

The SNP\_INIT\_EX command is extended with a flag, TIO\_EN, at bit 4 of offset 0h.

When INIT\_RMP is 0, TIO\_EN must be set to the same value provided in the SNP\_INIT\_EX invocation that originally initialized the RMP. If not, the firmware returns RMP\_INIT\_REQUIRED.

When INIT\_RMP is 1 and TIO\_EN is 1, the firmware initializes the hardware to support TIO. All TIO commands require that TIO\_EN is 1. Software can invoke the TIO\_INIT command after the SNP\_INIT\_EX command to enable SEV-TIO in the IOMMUs and PCIe root ports.

### 7.2 SNP\_PLATFORM\_STATUS

The SNP\_PLATFORM\_STATUS command is extended to report the IS\_TIO\_EN and IS\_TIO\_INIT values.

### 7.3 SNP\_DECOMMISSION

The SNP\_DECOMMISSION command is extended to check that no TDIs are bound to the guest. If a TDI is bound to a guest, the command fails with IN\_USE. Software can invoke TIO\_TDI\_UNBIND on all TDIs bound to the guest to decommission the guest.

### 7.4 SNP\_SHUTDOWN

The SNP\_SHUTDOWN command is extended to require that all devices are disconnected via the TIO\_DEV\_DISCONNECT command before SNP\_SHUTDOWN or SNP\_SHUTDOWN\_EX succeeds. If a device is not yet disconnected, the SNP\_SHUTDOWN and SNP\_SHUTDOWN\_EX commands return RECLAIM\_REQUIRED.

## 7.5 TIO\_TDI\_DIGEST\_REPORT

The Host OS can directly request that the firmware construct a TDI attestation report.

The firmware generates a TDI attestation report by generating a Header, a “Guest Binding Tuple” (TUPLE) and a signature then placing the components into the specified Output buffer for the Host OS.

### 7.5.1 Guest (TVM) Identifier

There is a requirement to support a Guest (TVM) Identifier. This identifier is used to provide a logical binding of a guest (TVM) and device (TDI). The Guest Identifier is composed of the REPORT\_ID field from the Guest ATTESTATION\_REPORT structure and is included in the TDI Attestation Report.

### 7.5.2 Guest Binding Tuple (TUPLE)

The Guest Binding Tuple (TUPLE) is created by firmware and provides a cryptographic binding of the digests (hashes) of the following 3 objects:

- device certification
- measurements
- interface report information

Then the plaintext Guest (TVM) Identifier (REPORT\_ID) is added.

#### Header

The firmware generates a header consisting of two 32-bit fields. The first field is set to 0, and the second is set to the current version (1h).

#### Guest Binding Tuple (TUPLE) Generation

The Guest Binding Tuple (TUPLE) provides a binding of four objects to bind the guest and device cryptographically together.

The firmware uses the SHA-384 digests (hashes) previously generated to form the TUPLE:

- CertDigest := sha384 digest(leaf certificate retrieved via GET\_CERTIFICATES)
- DevAttDigest := sha384 digest(device attestation report retrieved via GET\_MEASUREMENTS)
- DevIntReportDigest := sha384 digest(interface report retrieved via INTERFACE\_REPORT\_REQUEST)

The REPORT\_ID value (Guest Identifier) is added to the TUPLE as the fourth member.

- REPORT\_ID (Guest Identifier)

TUPLE: All non-SIGNATURE fields listed in Table 14.



SIGNATURE := Signature(TUPLE, GuestAttKey)

GuestAttKey is the same key used to sign attestation reports (either VCEK or VLEK).

### Signature

The TIO\_TDI\_DIGESTS\_REPORT command has the firmware generate the Guest Binding TUPLE, adds a header object, and then signs both object sets.

The firmware signs the non-SIGNATURE fields in Table 14 with either the VLEK or the VCEK. If VLEK is installed it signs with VLEK, otherwise it signs with VCEK. The Signature is placed into the SIGNATURE field of the SNP\_TDI\_REPORT\_REQ Return Structure.

### 7.5.3 Parameters

**Table 13. Layout of the CMD\_TIO\_TDI\_DIGEST\_REPORT Request Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h	63:0	IN	GCTX_PADDR	Bits 63:00 of the sPA of the guest context page.
10h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
18h	63:0	IN	TDI_CTX_SLA	Scatter list address of the TDI context buffer.
20h-27h		IN	TDI_DIGEST_PADDR	Location for firmware to write the report.
28h	31:0	IN	FLAGS 31:2 Reserved 1:0 KEY_SEL	KEY_SEL: 0: If VCEK installed sign with VCEK otherwise sign with VLEK 1: Sign with VCEK 2: Sign with VLEK 3: Reserved
2ch – 3Fh		–	–	Reserved.

**Table 14. TIO\_TDI\_DIGEST\_REPORT Return Structure**

Byte Offset	Bits	Name	Description
0h	0:31	ZERO_FIELD	Mbz. Must be set to 0.
4h	0:31	VERSION	Set to 1h for this revision.
8h	0:63	-	Reserved. Mbz.



Byte Offset	Bits	Name	Description
10h	0:383	TUPLE_CERT_DIGEST	SHA-384 digest (hash) of the leaf certificate retrieved via GET_CERTIFICATES.
40h	0:383	TUPLE_MEAS_DIGEST	SHA-384 digest (hash) of the device attestation report retrieved via GET_MEASUREMENTS.
70h	0:383	TUPLE_INTER_DIGEST	SHA-384 digest (hash) of the interface report retrieved via INTERFACE_REPORT_REQUEST
A0h	0:63	TDI_REPORT_COUNT	TDIReportCount value in the TDI context.
A8h-AFh		-	Reserved.
B0h	0:255	TUPLE_GUEST_ID	REPORT_ID value from the guest attestation report
D0h	0:4095	SIGNATURE	VCEK or VLEK signature of the Header fields and the TUPLE values (from byte offset 0x0).

## 7.5.4 Actions

The firmware checks that the platform is in the INIT state. If not, the firmware returns `INVALID_PLATFORM_STATE`.

The firmware checks that the command buffer is aligned to a 16 byte boundary.

The firmware checks that `DEV_CTX_SLA` is a valid scatter list address. If not, firmware returns `INVALID_ADDRESS`.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns `INVALID_CONTEXT`.

The firmware checks that `TDI_CTX_SLA` points to a valid scatter list address. If not, firmware returns `INVALID_ADDRESS`.

The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns `INVALID_CONTEXT`.

The firmware checks that the `TDI_DIGEST_PADDR` is 8-byte aligned and not cross a 4k page boundary, if not the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page is in the Firmware or Default page state. If not, the firmware returns `INVALID_PAGE_STATE`.

Firmware checks that the TDI is bound to the guest. If the TDI is not bound to the guest, the firmware returns `INVALID_TDI_STATE`.



## 7.5.5 Status Codes

**Table 15. Status Codes for TIO\_TDI\_DIGEST\_REPORT**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PLATFORM_STATE	Not in the INIT state.
INVALID_TDI_STATE	The TDI state is invalid
INVALID_DEV_STATE	The device state is invalid

## 7.6 TIO\_STATUS

The TIO\_STATUS command returns status information about the SEV-TIO feature. SNP does not need to be initialized. This command does not generate SPDMM traffic with the device.

### 7.6.1 Parameters

**Table 16. Layout of the CMD\_TIO\_STATUS Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	In	LENGTH	Length of this command buffer in bytes.
4h	31:0	–	–	Reserved.
8h	63:0	In	STATUS_PADDR	SPA of the TIO_STATUS structure.

**Table 17. Layout of the TIO\_STATUS Structure**

Byte Offset	Bits	Name	Description
0h	31:0	LENGTH	Length of this structure in bytes.
4h	31:2	–	Reserved.
	1	TIO_INIT_DONE	Indicates TIO_INIT has been invoked.
	0	TIO_EN	Indicates if SEV-TIO is enabled.
8h	31:0	SPDM_REQ_SIZE_MIN	Minimum SPDMM request buffer size in bytes.
Ch	31:0	SPDM_REQ_SIZE_MAX	Maximum SPDMM request buffer size in bytes.
10h	31:0	SPDM_SCRATCH_SIZE_MIN	Minimum SPDMM scratch buffer size in bytes.



14h	31:0	SPDM_SCRATCH_SIZE_MAX	Maximum SPDM scratch buffer size in bytes.
18h	31:0	SPDM_OUT_SIZE_MIN	Minimum SPDM output buffer size in bytes.
1Ch	31:0	SPDM_OUT_SIZE_MAX	Maximum SPDM output buffer size in bytes.
20h	31:0	SPDM_RSP_SIZE_MIN	Minimum SPDM response buffer size in bytes.
24h	31:0	SPDM_RSP_SIZE_MAX	Maximum SPDM response buffer size in bytes.
28h	31:0	DEVCTX_SIZE	Size of a device context buffer in bytes.
2Ch	31:0	TDICTX_SIZE	Size of a TDI context buffer in bytes.
30h-33h		TIO_CRYPT_ALG	0x00: SHA2-384 0x01 – 0x33: Reserved
34h-3Fh		–	Reserved.

## 7.6.2 Actions

The firmware checks that STATUS\_PADDR is a valid address, is 8-byte aligned, and does not cross a page boundary. If not, the firmware returns INVALID\_ADDRESS. If SNP has been initialized, then the firmware checks that the page pointed at by STATUS\_PADDR is a Firmware or Default page. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware writes out the status information structure to STATUS\_PADDR.

## 7.6.3 Status Codes

**Table 18. Status Codes for TIO\_STATUS**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.

## 7.7 TIO\_INIT

Initialize the SEV-TIO feature. Successful completion of TIO\_INIT requires invocation of the SNP\_INIT\_EX command with the TIO\_EN flag set.

After successful completion of this command, the SEV-TIO feature will be enabled in the IOMMUs and PCIe root ports. It will remain enabled until the SNP\_SHUTDOWN\_EX command is invoked with the IOMMU\_SHUTDOWN flag set which will disable both SEV-SNP and SEV-TIO in the IOMMUs and PCIe root complexes.



### 7.7.1 Parameters

**Table 19. Layout of the TIO\_INIT Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	-	-	Reserved.
8h-Fh		-	-	Reserved.

### 7.7.2 Actions

The firmware checks that SNP\_INIT\_EX was invoked with the TIO\_EN flag set. If not, the firmware returns INVALID\_PLATFORM\_STATE.

The firmware enables TIO in the I/O subsystem of the SoC.

### 7.7.3 Status Codes

**Table 20. Status Codes for TIO\_INIT**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	SNP_INIT_EX was not invoked with TIO_EN set.

## 7.8 TIO\_DEV\_CREATE

Create a device context buffer that contains device-specific information related to SEV-TIO. The TIO\_STATUS command returns the minimum size of the device context buffer. The buffer may be reclaimed via the TIO\_DEV\_RECLAIM command. This command does not generate SPDMM traffic with the device.

### 7.8.1 Parameters

**Table 21. Layout of the CMD\_TIO\_DEV\_CREATE Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	—	—	Reserved.
8h	63:0	IN	DEV_CTX_SLA	A scatter list address pointing to a buffer to be used as a device context buffer.



10h	15:0	IN	DEVICE_ID	The PCIe Routing ID of the device to connect to.
12h	15:0	IN	ROOT_PORT_ID	The PCI Express Port number for the given PCI Express Link of the root port
14h	7:0	IN	SEGMENT_ID	The PCIe domain Segment Identifier of the device to connect to. This SEGMENT_ID is a PCI domain segment ID.
15h-1Fh		-	-	Reserved.

### 7.8.2 Actions

The firmware checks if TIO is enabled and is initialized. If not, the firmware returns NOT\_ENABLED.

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, the firmware returns INVALID\_ADDRESS.

The firmware checks that the data pages of the buffer pointed at by DEV\_CTX\_SLA are all in the Firmware page state. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the capacity of the provided buffer is large enough to hold a device context buffer. If not, the firmware returns INCORRECT\_BUFFER\_LENGTH.

The firmware transitions each data page to the Context-Device page state and initializes the contents of the device context buffer.

### 7.8.3 Status Codes

**Table 22. Status Codes for TIO\_DEV\_CREATE**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INCORRECT_BUFFER_LENGTH	A provided buffer was too small.
NOT_ENABLED	The TIO device is either not enable and initialized.
IN_USE	The resource is in use.

## 7.9 TIO\_DEV\_RECLAIM

Reclaim a device context buffer that was created by TIO\_DEV\_CREATE.

This command does not generate SPDMM traffic with the device.





## 7.9.1 Parameters

**Table 23. Layout of the CMD\_TIO\_DEV\_RECLAIM Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h	63:0	IN	DEV_CTX_SLA	Scatter list address of a device context buffer.

## 7.9.2 Actions

The firmware checks that the platform is in the INIT state. If not, the firmware returns `INVALID_PLATFORM_STATE`.

The firmware checks that `DEV_CTX_SLA` is a valid scatter list address. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the buffer is in the Device-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the buffer is a valid device context buffer. If not, the firmware returns `INVALID_CONTEXT`.

The firmware reclaims any system resources associated with this device context. Then, the firmware transitions the data pages of the device context buffer to the Reclaim page state.

## 7.9.3 Status Codes

**Table 24. Status Codes for TIO\_DEV\_RECLAIM**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
RECLAIM_REQUIRED	Resources must be reclaimed before invoking this command.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.

## 7.10 TIO\_DEV\_CONNECT

Request that the SEV firmware connect to the device by establishing a secure SPDm connection, set up IDE streams, and prepare the device for use as a TDISP device.



When the SPDM GET\_CAPABILITIES message is sent during the construction of the SPDM session, the firmware sets CTEExponent to 23, the maximum exponent allowed by PCI CMA. The firmware sets Flags, DataTransferSize, and MaxSPDMmsgSize in an implementation-specific manner.

When the NEGOTIATE\_ALGORITHMS message is sent, the firmware supports the following cipher suites:

- **Signature:** RSA-SSA 3072, ECDSA P-256, ECDSA P-384
- **Hash:** SHA-256, SHA-384
- **Diffie Hellman:** ECDH P-256, ECDH P-384
- **AEAD:** AES-128-GCM, AES-256-GCM

The firmware retrieves the certificate chain from the slot provided by host software in CERT\_SLOT and uses that certificate chain to authenticate the SPDM endpoint on the device. The firmware does not perform certificate chain validation but instead uses only the leaf key as if it is trustworthy. Each guest is responsible for retrieving the certificate chain and making its own decision to trust the device according to that certificate chain.

This command constructs one IDE selective stream between the device and the SoC per traffic class used by the device.

### 7.10.1 Parameters

**Table 25. Layout of the CMD\_TIO\_DEV\_CONNECT Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h–7h	–	–	–	Reserved.
8h–27h	–	IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h–2Fh	–	–	–	Reserved.
30h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
38h	7:0	IN	TC_MASK	Bitmask of the traffic classes to initialize for SEV-TIO usage. Setting the <i>k</i> th bit of the TC_MASK to 1 indicates that the traffic class <i>k</i> will be initialized.
39h	7:0	IN	CERT_SLOT	Slot number of the certificate requested for constructing the SPDM session.
3Ah–3Fh	–	–	–	Reserved.



Byte Offset	Bits	In/Out	Name	Description
40h	7:0	IN	IDE_STREAM_ID0	IDE stream ID 0 to be associated with this device. Valid only if TC_MASK bit 0 is set.
41h	7:0	IN	IDE_STREAM_ID1	IDE stream ID 1 to be associated with this device. Valid only if TC_MASK bit 1 is set.
42h	7:0	IN	IDE_STREAM_ID2	IDE stream ID 2 to be associated with this device. Valid only if TC_MASK bit 2 is set.
43h	7:0	IN	IDE_STREAM_ID3	IDE stream ID 3 to be associated with this device. Valid only if TC_MASK bit 3 is set.
44h	7:0	IN	IDE_STREAM_ID4	IDE stream ID 4 to be associated with this device. Valid only if TC_MASK bit 4 is set.
45h	7:0	IN	IDE_STREAM_ID5	IDE stream ID 5 to be associated with this device. Valid only if TC_MASK bit 5 is set.
46h	7:0	IN	IDE_STREAM_ID6	IDE stream ID 6 to be associated with this device. Valid only if TC_MASK bit 6 is set.
47h	7:0	IN	IDE_STREAM_ID7	IDE stream ID 7 to be associated with this device. Valid only if TC_MASK bit 7 is set.
48h-4FH	—	—	—	Reserved.

### 7.10.2 Actions

The firmware checks if TIO is enabled and is initialized. If not, the firmware returns `INVALID_PLATFORM_STATE`.

The firmware checks that `DEV_CTX_SLA` is a valid scatter list address. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the `SPDM_CTL` structure is correctly formed. See Section 5.1 for the structure of the `SPDM_CTL` structure. If a page in one of the buffers is not in the required page state, the firmware returns `INVALID_PAGE_STATE`.

`TC_MASK` must have bit 0 set. If not, the firmware returns `INVALID_PARAM`.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns `INVALID_CONTEXT`.

The firmware establishes the SPDM connection, constructs an SPDM secure session, and negotiates and programs the IDE streams for the device. The firmware constructs one IDE stream for each Traffic Class indicated in `TC_MASK`. If the firmware determines that the device does not



have sufficient capabilities to support an SPDm session, IDE streams, or TDISP functionality, the firmware returns INVALID\_CONFIG.

After this command successfully completes, the SPDm output buffer contains the certificate chain of the device used to construct the SPDm secure session. The SHA-384 digest of this certificate chain is also stored within the device context page.

If this command fails, the device context buffer is returned to the state it was in before TIO\_DEV\_CONNECT was called. If an SPDm session was established before the error was detected, the firmware resets the internal firmware host device state to the previous state prior to the TIO\_DEV\_CONNECT command.

### 7.10.3 Status Codes

**Table 26. Status Codes for TIO\_DEV\_CONNECT**

Status	Condition
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_CONFIG	The device is not sufficiently capable of supporting SPDm, IDE, or TDISP.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the TIO_STATUS command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the BUFFER_CAPACITY field of BUFFER structure.
SPDM_REQUEST	Indicates that firmware needs to send an SPDm message to the device, and the pending request is in the SPDm request buffer.
SPDM_ERROR	Indicates an error in the SPDm channel.
RESYNC_REQUIRED	The SPDm session needs to be resynced. This occurs when the SPDm generates resync required due to some inconsistency observed as defined in the spec.
RESPONSE_TOO_LARGE	The response buffer is not large enough.



## 7.11 TIO\_DEV\_DISCONNECT

Disconnects the SEV firmware from the device by destroying the IDE streams associated with the device and shutting down the SPDm channel.

### 7.11.1 Parameters

**Table 27. Layout of the CMD\_TIO\_DEV\_DISCONNECT Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:1	—	—	Reserved.
	0	IN	FORCE	Force a device disconnect without SPDm traffic.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.

### 7.11.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, the firmware returns INVALID\_ADDRESS.

The firmware checks that the SPDM\_CTL structure is correctly formed. See Section 5.1 for the structure of the SPDM\_CTL structure. If a page in one of the buffers is not in the required page state, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware checks that this device has no bound TDIs. If the device has a bound TDI, the firmware returns IN\_USE.

The firmware disables the IDE streams associated with this device and clears the keys in the root complex. Then, the firmware sends the END\_SESSION SPDm request to gracefully close the SPDm channel.

If the device is no longer capable of responding to SPDm messages, host software can set the FORCE flag. When host software either provides a valid SPDm response packet or sets the FORCE flag, the command returns SUCCESS.

After this, the device context buffer may be either reclaimed with TIO\_DEV\_RECLAIM or it may be used to connect to another device with TIO\_DEV\_CONNECT.



### 7.11.3 Status Codes

**Table 28. Status Codes for TIO\_DEV\_DISCONNECT**

Status	Condition
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
IN_USE	A TDI is still bound to the device.
SPDM_REQUEST	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	Indicates an error in the SPDM channel.
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the TIO_STATUS command.
RESYNC_REQUIRED	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.

## 7.12 TIO\_DEV\_STATUS

Return information about the device status.

This status command outputs the number of TDI contexts that exist as well as one of the TDI context page SPAs. This mechanism can be used by host software to identify and reclaim all TDI pages associated with a device by iteratively invoking this command and TIO\_TDI\_RECLAIM until all TDI context pages are reclaimed. After this, this device context page can be reclaimed.

This command provides the REQUEST\_PENDING, REQUEST\_COMMAND, and REQUEST\_TDI\_PADDR status fields. These fields can inform host software of whether an SPDM request message is pending, from which command the request originated, and the TDI related to the request, if applicable. Note that only one SPDM request can be pending at a time for a given device.

This command does not generate SPDM traffic with the device.



## 7.12.1 Parameters

**Table 29. Layout of the CMD\_TIO\_DEV\_STATUS Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved. Must be zero.
8h	63:0	IN	DEV_CTX_PADDR	SPA of a device context page.
10h	63:0	IN	STATUS_PADDR	SPA of the DEV_STATUS structure. See Table 30.
18h – 1Fh		-	-	Reserved.

**Table 30. Layout of the DEV\_STATUS Structure**

Byte Offset	Bits	Name	Description
0h	31:0	LENGTH	Length in bytes of this structure in bytes.
4h	7:0	DEVICE_STATE	0: Not connected. 1: Connected 2: Resync 3: Error 4 to FFh are reserved
5h	7:0	–	Reserved.
6h	7:2	–	Reserved.
	1	REQUEST_PENDING_TDI	If REQUEST_PENDING is 1, indicates that the pending request is associated with a TDI.
	0	REQUEST_PENDING	Flag indicating that the firmware has a pending SPDM message for this device.
7h	7:0	CERT_SLOT	SPDM SlotID for the certificate used to construct the SPDM channel.
8h	15:0	DEVICE_ID	PCIe Routing ID of the device.
Ah	7:0	SEGMENT_ID	PCIe Segment ID of the device.
Bh	7:0	TC_MASK	The traffic class mask provided to TIO_DEV_CONNECT.
Ch	15:0	REQUEST_PENDING_COMMAND	If REQUEST_PENDING is 1, then this field contains the command ID that is



Byte Offset	Bits	Name	Description
			expecting an SPDM response.
Eh - Fh		-	Reserved.
10h – 1Bh		REQUEST_PENDING_INTERFACE_ID	If REQUEST_PENDING_TDI is 1, then this field contains the TDISP interface ID of the TDI.
1Ch	7:2	–	Reserved.
	1	NO_FW_UPDATE	Indicates if firmware updates have been rejected by the device. This is 1 if any TDI is bound to a guest and the NO_FW_UPDATE flag was 1 in LOCK_INTERFACE_REQUEST.
	0	MEAS_DIGEST_VALID	Indicates that MEAS_DIGEST_NONCE contains the digest of a device attestation report and NONCE value retrieved since TIO_DEV_CONNECT was invoked.
1Dh–1Fh		–	Reserved.
20h–27h		IDE_STREAM_ID[]	Array of 8x 1-byte IDE stream IDs. Traffic class k is associated with IDE_STREAM_ID[k]. IDE_STREAM_ID[k] is valid only if bit k of TC_MASK is 1. Each IDE stream ID is 16 bits.
28h-2Fh		-	Reserved.
30h–5Fh		CERTS_DIGEST	Digest of the certificate chain used to construct the SPDM session.
60h–8Fh		MEAS_DIGEST	Digest of the latest measurement blocks retrieved by the SEV firmware. Valid only if MEAS_DIGEST_VALID is 1.
90h	31:0	TDI_CTX_COUNT	Number of TDIs with context buffers associated with this device.
94h	31:0	TDI_CTX_BOUND_COUNT	Number of TDIs bound to guests.
98h - 9Fh		SPDM_ALGORITHMS	Algorithms used to establish SPDM session. Refer to the SPDM_ALGOS Table 61 in this document for list of possible algorithms.





## 7.12.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the STATUS\_PADDR is 8-byte aligned and does not cross a 4k page boundary, if not the firmware returns INVALID\_PARAM. The firmware then checks that the page is in the Firmware or Default page state. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware fills the status buffer with status information of the device.

This command never sends SPDM messages (and thus may be invoked even when SPDM messages are pending) to query the current state of the device.

## 7.12.3 Status Codes

**Table 31. Status Codes for TIO\_DEV\_STATUS**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.

## 7.13 TIO\_DEV\_MEASUREMENTS

Retrieve the device attestation report using the GET\_MEASUREMENTS SPDM message.

The device attestation report is defined as the concatenation of all measurement blocks that can be retrieved by GET\_MEASUREMENTS. A measurement block is specified by Section 10.11.1 of [6].

Host software is expected to transfer the device attestation report to its guests. The guest can determine that the attestation is accurate and fresh by sending the TIO\_TDI\_INFO\_REQ message to retrieve MEAS\_DIGEST and MEAS\_DIGEST\_FRESH.

MEAS\_DIGEST is the digest with NONCE of the latest device attestation report that the firmware retrieved for this device. The guest can compare the digest of the report to MEAS\_DIGEST to ensure that the report has not been modified.

MEAS\_DIGEST\_FRESH indicates that the device attestation report has been retrieved since the TDI was locked and bound to the guest. The guest can use this in conjunction with the



NO\_FW\_UPDATE field in the TDI interface report to conclude that the device attestation report does not change while the TDI remains bound to the guest.

### 7.13.1 Parameters

**Table 32. Layout of Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:1	–	–	Reserved.
	0	IN	RAW_BITSTREAM	0: Requests the digest form of the attestation report. 1: Requests the raw bitstream form of the attestation report.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
30h	255:0	IN	MEAS_NONCE	NONCE to be associated with the measurements.

### 7.13.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the SPDM\_CTL structure is correctly formed. See Section 5.1 for the structure of the SPDM\_CTL structure. If a page in one of the buffers is not in the required page state, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware checks that the device is connected. If not, the firmware returns INVALID\_STATE.

The firmware sends the GET\_MEASUREMENTS request to the device to request all measurement blocks. The firmware fills the SPDM output buffer with an SPDM Measurement Object defined in Chapter 4. The firmware also stores the SHA-384 digest of the retrieved measurements in the device context page.

The firmware delegates all validation of the measurements to the guest.



### 7.13.3 Status Codes

**Table 33. Status Codes for TIO\_DEV\_MEASUREMENTS**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_STATE	The device is not connected.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
SPDM_REQUEST	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	Indicates an error in the SPDM channel.
RESYNC_REQUIRED	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the TIO_STATUS command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the BUFFER_CAPACITY field of BUFFER structure.
INVALID_DEV_STATE	The device state is invalid.
RESPONSE_TOO_LARGE	The response buffer is not large enough.

## 7.14 TIO\_DEV\_CERTIFICATES

Retrieve the certificate chain of the device. This retrieves the certificate of the slot used to construct the SPDM session.

### 7.14.1 Parameters

**Table 34. Layout of the CMD\_TIO\_DEV\_CERTIFICATES Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.



4h	31:0	–	–	Reserved.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.

### 7.14.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the SPDM\_CTL structure is correctly formed. See Section 5.1 for the structure of the SPDM\_CTL structure. If a page in one of the buffers is not in the required page state, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware sends the GET\_CERTIFICATES request to the device to request the certificate chain of the device using the SlotID used to establish the SPDM connection. The firmware fills the SPDM output buffer with an SPDM Certificates Object defined in Chapter 4. The firmware also stores the SHA-384 digest of the retrieved certificates in the device context page, replacing any previously saved digest.

### 7.14.3 Status Codes

**Table 35. Status Codes for TIO\_DEV\_CERTIFICATES**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
SPDM_REQUEST	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	Indicates an error in the SPDM channel.
RESYNC_REQUIRED	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the



Status	Condition
	TIO_STATUS command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the BUFFER_CAPACITY field of BUFFER structure.
INVALID_DEV_STATE	The device state is invalid.
RESPONSE_TOO_LARGE	The response buffer is not large enough.
DEV_CERT_CHANGED	Digest of the certificate received in GET_CERTIFICATE does not match the digest previously saved digest.

## 7.15 TIO\_TDI\_CREATE

Create a TDI context buffer that contains TDI-specific information related to SEV-TIO. The TIO\_STATUS command returns the minimum size of the TDI context buffer. The buffer may be reclaimed via the TIO\_TDI\_RECLAIM command. This command does not generate SPDH traffic with the device.

### 7.15.1 Parameters

**Table 36. Layout of the CMD\_TIO\_TDI\_CREATE Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h	63:0	IN	DEV_CTX_SLA	Scatter list address of a device context buffer.
10h	63:0	IN	TDI_CTX_SLA	Scatter list address of a buffer to be used as a TDI context page.
18h–23h		In	INTERFACE_ID	Interface ID of the TDI as defined by TDISP.
24h–2Fh		-	-	Reserved.

### 7.15.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.



The firmware checks that TDI\_CTX\_SLA is a valid scatter list address. If not, the firmware returns INVALID\_ADDRESS. The firmware checks that the data pages of the buffer pointed at by TDI\_CTX\_SLA are all in the Firmware page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the capacity of the provided TDI context buffer is large enough to hold a TDI context buffer. If not, the firmware returns INVALID\_BUFFER\_LENGTH.

The firmware checks that a TDI context has not already been created for the provided INTERFACE\_ID. If a context buffer already exists, the firmware returns IN\_USE.

The firmware transitions each data page of the TDI context buffer to the Context-TDI page state and initializes the contents of the TDI context buffer.

### 7.15.3 Status Codes

**Table 37. Status Codes for TIO\_TDI\_CREATE**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_BUFFER_LENGTH	The buffer was not large enough.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
IN_USE	The TDI is already in use.
INVALID_DEV_STATE	The device state is invalid.

## 7.16 TIO\_TDI\_RECLAIM

Reclaim a TDI context page. This command does not generate SPDM traffic with the device.

### 7.16.1 Parameters

**Table 38. Layout of the CMD\_TIO\_TDI\_RECLAIM Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	—	—	Reserved.
8h	63:0	IN	DEV_CTX_SLA	Scatter list address of a device context buffer.



10h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
18h – 1Fh	-	-	-	Reserved.

### 7.16.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware checks that TDI\_CTX\_SLA points to a valid TDI context page. If not, firmware returns INVALID\_CONTEXT.

The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns INVALID\_CONTEXT.

Firmware checks that the TDI is not bound to a guest. If the TDI is bound to a guest, the firmware returns IN\_USE.

The firmware transitions the page to the Reclaim page state.

### 7.16.3 Status Codes

**Table 39. Status Codes for TIO\_TDI\_RECLAIM**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
IN_USE	The TDI is already bound to a guest.
INVALID_DEV_STATE	The device state is invalid.

## 7.17 TIO\_TDI\_BIND

Bind a TDI to a guest. Host software uses this command to bind a guest and a TDI together.



The TIO\_TDI\_BIND command provides support for transitioning the TDI state via two different methods:

1. Transition TDI (CONFIG\_LOCKED or CONFIG\_UNLOCKED) directly to the RUN state
2. Transition TDI (CONFIG\_UNLOCKED or RUN) state to CONFIG\_LOCKED state

There are a set of command transition definitions to support these three transition actions.

**Table 40. Command Transition Definitions**

Current State	State Transition bit (STATE_TRANSITION)	Transition Requested	SPDM Output Buffer
CONFIG_UNLOCKED	1	CONFIG_UNLOCKED to RUN	Yes
CONFIG_UNLOCKED	0	CONFIG_UNLOCKED to CONFIG_LOCKED	Yes
CONFIG_LOCKED	1	CONFIG_LOCKED to RUN	Yes
CONFIG_LOCKED	0	CONFIG_LOCKED to RUN	No

In the CONFIG\_UNLOCKED state, the TIO\_TDI\_BIND command with STATE\_TRANSITION set to 1 is a command to transition the TDI state from CONFIG\_UNLOCKED to the RUN state, transitioning through the CONFIG\_LOCKED state.

In the CONFIG\_UNLOCKED state, the TIO\_TDI\_BIND command with STATE\_TRANSITION set to 0 is a command to transition the TDI state from CONFIG\_UNLOCKED to the CONFIG\_LOCKED state.

NOTE: Supporting transitioning into the persistent CONFIG\_LOCKED state provides an opportunity for the Host software to facilitate providing additional configuration elements to the TDI.

In the CONFIG\_LOCKED state, the TIO\_TDI\_BIND command with STATE\_TRANSITION set to 1 is a command to transition the TDI state from CONFIG\_LOCKED to the CONFIG\_RUN state.

In the CONFIG\_LOCKED state, the TIO\_TDI\_BIND command with STATE\_TRANSITION set to 0 is an invalid command and the firmware returns INVALID\_COMMAND.





After successful transition to the RUN state, the guest can assess the authenticity and configuration of the device to determine whether the guest wants to use the TDI.

The GUEST\_DEVICE\_ID is the GDeviceID chosen by host software and given to the guest. The guest uses the GUEST\_DEVICE\_ID to refer to the TDI in guest requests. See TIO\_GUEST\_REQUEST for more information.

All successful transition combinations of this command outputs the TDI interface report to the SPDM output buffer as a side effect of the command. Host software is expected to provide this SPDM output buffer to the guest. Host software may also invoke the TIO\_TDI\_REPORT command to retrieve the report.

### 7.17.1 Parameters

**Table 41. Layout of the CMD\_TIO\_TDI\_BIND Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
30h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
38h	63:0	IN	GCTX_PADDR	System physical address of a guest context page.
40h	15:0		GUEST_DEVICE_ID	The GDeviceID that the guest uses to refer to the TDI.
42h	15:5			Reserved. Must be 0.
	4		ALL_REQUEST_REDIRECT	Requires ATS translated requests to route through the root complex. Must be 1.
	3		BIND_P2P	Enables direct P2P. Must be 0.
	2		LOCK_MSIX	Lock the MSI-X table and PBA.
	1		–	Reserved. Must be 0.
	0		NO_FW_UPDATE	Indicates that no firmware updates are allowed while the interface is locked.



44h	15:1			Reserved. Must be 0.
	0	IN	STATE_TRANSITION	0: Drive TDI to CONFIG_LOCKED state 1: Drive TDI to RUN state
46h – 4Fh	–	–	–	Reserved.

## 7.17.2 Actions

### 7.17.2.1 Initial TDI state command transition validation

If the TDI state is CONFIG\_LOCKED and STATE\_TRANSITION is set to 0, the firmware returns INVALID\_STATE.

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware checks that TDI\_CTX\_SLA points to a valid TDI context page. If not, firmware returns INVALID\_CONTEXT.

The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware checks that the SPDM\_CTL structure is correctly formed. See Section 5.1 for the structure of the SPDM\_CTL structure. If a page in one of the buffers is not in the required page state, the firmware returns INVALID\_PAGE\_STATE.

Firmware checks that the TDI is not bound to a guest. If the TDI is bound to a guest, the firmware returns IN\_USE.

The firmware checks that GUEST\_INTERFACE\_ID is not used by another TDI already bound to this guest. If the ID is in use by another TDI for this guest, then the firmware returns IN\_USE.

### 7.17.2.2 CONFIG\_LOCKED state

If the current state is CONFIG\_LOCKED, then the following actions are performed:

The firmware transitions the TDI state to the RUN state, passing the provided flags to the LOCK\_INTERFACE\_REQUEST message.



The firmware retrieves the interface report of the TDI and then calculates and saves the digest of the interface report in the TDI context buffer. The firmware increments the TDIReportCount value in the TDI context.

The TIO\_TDI\_BIND command completes.

### 7.17.2.3 CONFIG\_UNLOCKED state

If the current state is CONFIG\_UNLOCKED then the following actions are performed.

If the STATE\_TRANSITION bit is unset, the firmware transitions the TDI to the CONFIG\_LOCKED state, passing the provided flags to the LOCK\_INTERFACE\_REQUEST message.

If the STATE\_TRANSITION bit is set, then transition the TDI state to the RUN state passing the provided flags to the LOCK\_INTERFACE\_REQUEST message.

The firmware retrieves the interface report of the TDI and then calculates and saves the digest of the interface report in the TDI context buffer. The firmware sets the TDIReportCount value in the TDI context to 1.

The TIO\_TDI\_BIND command completes.

### 7.17.3 Status Codes

**Table 42. Status Codes for CMD\_TIO\_TDI\_BIND**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
IN_USE	The guest device ID is already in use.
INVALID_STATE	Invalid state transition request.
SPDM_REQUEST	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	Indicates an error in the SPDM channel.
RESYNC_REQUIRED	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.



Status	Condition
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the TIO_STATUS command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the BUFFER_CAPACITY field of BUFFER structure.
RESPONSE_TOO_LARGE	The response buffer is not large enough.

## 7.18 TIO\_TDI\_UNBIND

Unbind a TDI from the guest to which it is bound.

### 7.18.1 Parameters

**Table 43. Layout of the CMD\_TIO\_TDI\_UNBIND Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
04	0	IN	FORCE	Indicates if device should be forcefully unbound regardless of the SPDM status
5h	30:0	—	—	Reserved.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
30h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
38h	63:0	IN	GCTX_PADDR	System physical address of a guest context page.

### 7.18.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_CONTEXT.

The firmware checks that TDI\_CTX\_SLA points to a valid TDI context page. If not, firmware returns INVALID\_CONTEXT.



The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns `INVALID_CONTEXT`.

The firmware checks that the `SPDM_CTL` structure is correctly formed. See Section 5.1 for the structure of the `SPDM_CTL` structure. If a page in one of the buffers is not in the required page state, the firmware returns `INVALID_PAGE_STATE`.

Firmware checks that the TDI is bound to the guest. If the TDI is not bound to the guest, the firmware returns `SUCCESS`.

Firmware checks if the `FORCE` bit is set to 1. If it is then it unbinds the TDI regardless of the `SPDM` state and releases TDI resources.

Firmware checks that each MMIO range in the interface report is in the Pre-Guest page state.

Firmware then transitions the TDI to the `CONFIG_UNLOCKED` state, regardless of what state the TDI was in at the time this command was invoked.

The firmware sets the `TDIReportCount` value in the TDI context to 0.

The `TIO_TDI_UNBIND` command completes successfully.

### 7.18.3 Status Codes

**Table 44. Status Codes for `TIO_TDI_UNBIND`**

Status	Condition
<code>SUCCESS</code>	Successful completion.
<code>INVALID_ADDRESS</code>	A provided address was invalid.
<code>INVALID_PAGE_STATE</code>	A provided page was not in the expected page state.
<code>INVALID_CONTEXT</code>	Context page was invalid.
<code>INVALID_PARAM</code>	A parameter is invalid or incorrectly formed.
<code>INVALID_PLATFORM_STATE</code>	The platform is not in the <code>INIT</code> state.
<code>INVALID_GUEST</code>	The guest is invalid.
<code>SPDM_REQUEST</code>	Indicates that firmware needs to send an <code>SPDM</code> message to the device, and the pending request is in the <code>SPDM</code> request buffer.
<code>SPDM_ERROR</code>	Indicates an error in the <code>SPDM</code> channel.
<code>RESYNC_REQUIRED</code>	The <code>SPDM</code> session needs to be resynced. This occurs when the <code>SPDM</code> generates resync required due to some inconsistency observed as defined in the spec.



Status	Condition
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the TIO_STATUS command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the BUFFER_CAPACITY field of BUFFER structure.
INVALID_TDI	Indicates that the identified TDI is invalid.

## 7.19 TIO\_TDI\_REPORT

Retrieve the TDI interface report.

### 7.19.1 Parameters

**Table 45. Layout of the CMD\_TIO\_TDI\_REPORT Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	—	—	Reserved.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
30h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
38h	63:0	IN	GCTX_PADDR	System physical address of a guest context page.

### 7.19.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_DEV\_CTX.

The firmware checks that TDI\_CTX\_SLA points to a valid TDI context page. If not, firmware returns INVALID\_PAGE\_STATE.



The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns `INVALID_TDI_STATE`.

The firmware checks that the `SPDM_CTL` structure is correctly formed. See Section 5.1 for the structure of the `SPDM_CTL` structure. If a page in one of the buffers is not in the required page state, the firmware returns `INVALID_PAGE_STATE`.

Firmware checks that the TDI is bound to the guest. If the TDI is not bound to the guest, the firmware returns `INVALID_PARAM`.

The firmware retrieves the interface report of the TDI. See Section 2.9 for explanation for how guests use the interface report. The firmware then calculates and saves the digest of the interface report in the TDI context buffer. The firmware increments the `TDIReportCount` value in the TDI context.

After this command successfully completes, the SPDM output buffer contains the TDI interface report for this TDI modified as described above.

### 7.19.3 Status Codes

**Table 46. Status Codes for TIO\_TDI\_REPORT**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
SPDM_REQUEST	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	Indicates an error in the SPDM channel.
RESYNC_REQUIRED	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the <code>TIO_STATUS</code> command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the <code>BUFFER_CAPACITY</code> field of <code>BUFFER</code> structure.



Status	Condition
RESPONSE_TOO_LARGE	The response buffer is not large enough.
INVALID_DEV_STATE	The device state is invalid.
INVALID_TDI_STATE	The TDI state is invalid.
INVALID_DEV_CTX	Indicates that the provided page is not a valid device context page.
INVALID_TDI_CTX	Indicates that the provided page is not a valid TDI context page.

## 7.20 TIO\_TDI\_INFO

Retrieve information about the TDI status. This command does not generate SPDMM traffic with the device.

### 7.20.1 Parameters

**Table 47. Layout of the CMD\_TIO\_TDI\_INFO Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
10h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
18h	63:0	IN	TDI_INFO_PADDR	System physical address of TDI_INFO structure. See Table 48.
20h – 2Fh		-	-	Reserved.

**Table 48. Layout of the TDI\_INFO Structure**

Byte Offset	Bits	Name	Description
0h	31:0	LENGTH	Length of this structure in bytes.
4h–Fh		INTERFACE_ID	TDISP interface identifier.





Byte Offset	Bits	Name	Description
10h	31:4	–	Reserved.
	3:2	TDI_STATUS	0: TDI_UNBOUND 1: TDI_BIND_LOCKED 2: TDI_BIND_RUN
	1	MEAS_DIGEST_FRESH	0: The measurement was retrieved before TIO_TDI_BIND. 1: The measurement was retrieved after TIO_TDI_BIND.
	0	MEAS_DIGEST_VALID	0: MEAS_DIGEST is not valid because host software has not yet invoked TIO_DEV_MEASUREMENTS. 1: MEAS_DIGEST is valid.
14h	15:5	–	Reserved.
	4	ALL_REQUEST_REDIRECT	Indicates whether ATS translated requests to route through the root complex is required.
	3	BIND_P2P	Indicates whether direct P2P is enabled.
	2	LOCK_MSIX	Indicates whether MSI-X table and PBA are locked.
	1	CACHE_LINE_SIZE	Indicates the cache line size. 0: 64B. 1: 128B.
	0	NO_FW_UPDATE	Indicates that no firmware updates are allowed while the interface is locked.
16h	15:0	–	Reserved.
18h–1Fh		SPDM_ALGOS	<b>Algorithms used to establish the SPDM session. See</b> Table 62. Layout of the SPDM_ALGOS Structure, for the format of this field.
20h	383:0	CERTS_DIGEST	Digest of the certificate chain of the TDI.
50h	383:0	MEAS_DIGEST	Digest of the measurements of the TDI.
80h	383:0	INTERFACE_REPORT_DIGEST	Digest of interface report.
B0h	63:0	TDI_REPORT_COUNT	TDIReportCount value in the TDI context.
B8h	31:0	ASID	ASID of the guest that this device is assigned to. Valid only if CTX_STATE is 1.
BCh–BFh		–	Reserved.



## 7.20.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_DEV\_CTX.

The firmware checks that TDI\_CTX\_SLA points to a valid TDI context page. If not, firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns INVALID\_TDI\_CTX.

The firmware checks that STATUS\_PADDR is a valid address, is 8-byte aligned, and does not cross a page boundary. If not, the firmware returns INVALID\_ADDRESS. The firmware then checks that the page pointed at by STATUS\_PADDR is a Firmware or Default page. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware fills the TDI\_INFO buffer with status information.

This command never sends SPDMM messages (and thus may be invoked even when SPDMM messages are pending) to query the current state of the TDI.

## 7.20.3 Status Codes

**Table 49. Status Codes for TIO\_TDI\_INFO**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_DEV_STATE	The device state is invalid.
INVALID_TDI_STATE	The TDI state is invalid.
INVALID_DEV_CTX	Indicates that the provided page is not a valid device context page.
INVALID_TDI_CTX	Indicates that the provided page is not a valid TDI context page.



## 7.21 TIO\_TDI\_STATUS

Retrieves the state and other TDISP related information about a TDI from the device.

### 7.21.1 Parameters

**Table 50. Layout of the CMD\_TIO\_TDI\_STATUS Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
30h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
38h	63:0	IN	STATUS_PADDR	System physical address of TDI_STATUS structure. See Table 48.

**Table 51. Layout of the TIO\_TDI\_STATUS Structure**

Byte Offset	Bits	Name	Description
0h	31:0	LENGTH	Length of this structure in bytes.
4h	7:0	TDISP_STATE	0: CONFIG_UNLOCKED. 1: CONFIG_LOCKED. 2: RUN. 3: ERROR. <i>All other encodings reserved.</i>
5h–Fh		–	Reserved.

### 7.21.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that the device context buffer is in the Device-Context page state. If not, the firmware returns INVALID\_PAGE\_STATE. The firmware checks that the device context buffer is a valid device context buffer. If not, the firmware returns INVALID\_DEV\_CTX.

The firmware checks that TDI\_CTX\_SLA points to a valid TDI context page. If not, firmware returns INVALID\_PAGE\_STATE.



The firmware checks that the TDI context buffer is in the TDI-Context page state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the TDI context buffer is a valid TDI context buffer. If not, the firmware returns `INVALID_TDI_CTX`.

The firmware checks that the `SPDM_CTL` structure is correctly formed. See Section 5.1 for the structure of the `SPDM_CTL` structure. If a page in one of the buffers is not in the required page state, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that `STATUS_PADDR` is a valid address, is 8-byte aligned, and does not cross a page boundary. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page pointed at by `STATUS_PADDR` is a Firmware or Default page. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware fills the `TDI_STATUS` buffer with status information retrieved from the device.

### 7.21.3 Status Codes

**Table 52. Status Codes for TIO\_TDI\_STATUS**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
SPDM_REQUEST	Indicates that firmware needs to send an SPDM message to the device, and the pending request is in the SPDM request buffer.
SPDM_ERROR	Indicates an error in the SPDM channel.
RESYNC_REQUIRED	The SPDM session needs to be resynced. This occurs when the SPDM generates resync required due to some inconsistency observed as defined in the spec.
INCORRECT_BUFFER_LENGTH	Buffer size does not match the buffer size provided by the <code>TIO_STATUS</code> command.
EXPAND_BUFFER_LENGTH_REQUEST	Indicates that a firmware write buffer is not large enough. Indicates that the firmware is asking to increase the data buffer size. The new buffer size is specified in the <code>BUFFER_CAPACITY</code> field of <code>BUFFER</code> structure.
INVALID_TDI_STATE	The TDI state is invalid.
RESPONSE_TOO_LARGE	The response buffer is not large enough.
INVALID_DEV_STATE	The device state is invalid.



Status	Condition
INVALID_DEV_CTX	Indicates that the provided page is not a valid device context page.
INVALID_TDI_CTX	Indicates that the provided page is not a valid TDI context page.

## 7.22 TIO\_ASID\_FENCE\_CLEAR

Clears the ASID fencing for a guest after an I/O abort caused by an RMP check failure or a host page table fault. See Section 2.11 for information about ASID fencing.

This command does not generate SPDMM traffic with the device.

### 7.22.1 Parameters

**Table 53. Layout of the CMD\_TIO\_ASID\_FENCE\_CLEAR Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer
10h	63:0	IN	GCTX_PADDR	System physical address of a guest context page.
18h–1Fh		–	–	Reserved.

### 7.22.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that GCTX\_PADDR is a valid guest context page. If not, the firmware returns INVALID\_GUEST.

The firmware checks that no TDIs are bound to the guest. If TDIs are bound to the guest, the firmware returns IN\_USE.

The firmware clears the ASID fence from the identified root port.



### 7.22.3 Status Codes

**Table 54. Status Codes for TIO\_ASID\_FENCE\_CLEAR**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	A provided address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_CONTEXT	Context page was invalid.
INVALID_PARAM	A parameter is invalid or incorrectly formed.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_GUEST	The guest is invalid (the provided guest context is invalid).
IN_USE	The resource is in use.
INVALID_DEV_STATE	The device state is invalid.
INVALID_DEV_CTX	Indicates that the provided page is not a valid device context page.

## 7.23 TIO\_ASID\_FENCE\_STATUS

Returns the ASID fencing status for a guest. See Section 2.11 for information about ASID fencing. This command does not generate SPDM traffic with the device.

### 7.23.1 Parameters

**Table 55. Layout of the CMD\_TStructure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	—	—	Reserved.
8h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer
Ch	31:0	IN	ASID	ASID of a guest to retrieve status.
14h	63:0	IN	STATUS_PADDR	SPA of an aligned 8B location to write the status. Bits 1:0 DMA fence status 2'b00: ASID is not fenced 2'b01: ASID is DMA fenced due to error 2'b02: reserved 2'b03: ASID is DMA fenced by default Bit 3:2 MMIO fence status 2'b00: ASID is not fenced



				2'b01: Reserved 2'b02: Reserved 2'b03: ASID is MMIO fenced.
1Ch–1Fh	–	–		Reserved.

### 7.23.2 Actions

The firmware checks that DEV\_CTX\_SLA is a valid scatter list address. If not, firmware returns INVALID\_ADDRESS.

The firmware checks that STATUS\_PADDR is a valid address, is 8-byte aligned, and does not cross a page boundary. If not, the firmware returns INVALID\_ADDRESS. The firmware then checks that the page pointed at by STATUS\_PADDR is a Firmware or Default page. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware writes to the system physical address STATUS indicating if the provided ASID is fenced by the provided root port.

### 7.23.3 Status Codes

**Table 56. Status Codes for TIO\_ASID\_FENCE\_STATUS**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	An address was invalid.
INVALID_PAGE_STATE	A provided page was not in the expected page state.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_DEV_STATE	The device state is invalid.
INVALID_DEV_CTX	Indicates that the provided page is not a valid device context page.

## 7.24 TIO\_GUEST\_REQUEST

Deliver an SEV-TIO related guest request to the firmware and receive the response.

Host software is expected to determine, through means outside of this interface, which TDI context page is associated with the guest request. For instance, the guest may provide host software with the guest request as well as the guest device ID that host software uses to look up the location of the TDI context page.

If host software provides the incorrect TDI context page to this command, the command returns a SUCCESS status code to the hypervisor and sends an error guest response message to the guest. This is to address the condition that the device has failed or has been removed from the system and the TDI context page is no longer available to communicate with. This also ensures that the



guest's request sequence numbers remain synchronized with the firmware. If host software cannot locate a TDI context page because the device was removed, host software should provide `INVALID_PADDR` for `TDI_CTX_PADDR`.

### 7.24.1 Parameters

**Table 57. Layout of the `CMD_TIO_GUEST_REQUEST` Structure**

Byte Offset	Bits	In/Out	Name	Description
0h	31:0	IN	LENGTH	Length in bytes of this command buffer.
4h	31:0	–	–	Reserved.
8h–27h		IN	SPDM_CTRL	SPDM control structure defined in Section 5.1.
28h	63:0	IN	DEV_CTX_SLA	Scatter list address of the device context buffer.
30h	63:0	IN	TDI_CTX_SLA	Scatter list address of a TDI context buffer.
38h	63:0	IN	GCTX_PADDR	System physical address of a guest context page.
40h	63:0	In	GUEST_REQUEST_PADDR	Bits 63:0 of the sPA of the request message.
48h	63:0	In	GUEST_RESPONSE_PADDR	Bits 63:0 of the sPA of the response message.

### 7.24.2 Actions

Firmware performs the same actions of delivering a guest request as `SNP_GUEST_REQUEST` specified in [2] except that a device context buffer, TDI context buffer, and an SPDM control block are provided.

The `GCTX_PADDR`, `GUEST_REQUEST_PADDR` and `GUEST_RESPONSE_PADDR` must be aligned on a 4k byte boundary, and the size of the buffer must not cross a 4k boundary. The firmware then checks that the pages pointed at by `GUEST_REQUEST_PADDR` and the `GUEST_RESPONSE_PADDR` are Firmware or Default pages. If not, the firmware returns `INVALID_PAGE_STATE`.

This command may also send and receive SPDM messages with the device. Host software must ensure that the data pointed at by `REQUEST_PADDR` and `RESPONSE_PADDR` are preserved on each re-invocation of this command.

The key used to encrypt the TIO guest messages must be `VMPCCK0`.





The SEV-TIO commands IDs are specified in Table 58.

**Table 58. Message Type Encodings**

Value	Message Type	Message Version
0	Invalid	-
19	TIO_MSG_TDI_INFO_REQ	1
20	TIO_MSG_TDI_INFO_RSP	1
21	TIO_MSG_MMIO_VALIDATE_REQ	1
22	TIO_MSG_MMIO_VALIDATE_RSP	1
23	TIO_MSG_MMIO_CONFIG_REQ	1
24	TIO_MSG_MMIO_CONFIG_RSP	1
25	TIO_MSG_SDTE_WRITE_REQ	1
26	TIO_MSG_SDTE_WRITE_RSP	1

The semantics of each guest message are specified in Chapter 8.

### 7.24.3 Status Codes

**Table 59. Status Codes for TIO\_GUEST\_REQUEST**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	An invalid parameter was provided.
INVALID_ADDRESS	An address is invalid for use by the firmware is misaligned.
INVALID_GUEST	The guest is invalid (the provided guest context is invalid).
INVALID_GUEST_STATE	The guest is not in the correct state.
INVALID_PAGE_SIZE	A page was not the correct size.
INVALID_PAGE_STATE	A page was in the incorrect state.
AEAD_OFLOW	The message sequence number was incorrect, or the guest's message count would overflow.
BAD_MEASUREMENT	The message failed to authenticate.
INVALID_DEV_STATE	The device state is invalid.
INVALID_DEV_CTX	Indicates that the provided page is not a valid device context page.



## Chapter 8 SEV-TIO Guest Messages

### 8.1 TDI Info

The guest sends this request to learn about the TDI.

Host software is expected to provide the guest the certificate chain, device measurements, and interface report through a protocol outside the scope of this interface. This message retrieves the digests of what the firmware saw of these objects. The guest can use these digests to determine whether host software tampered with the objects.

The guest can use MEAS\_DIGEST\_FRESH to determine that host software retrieved the device measurements object after this TDI was bound to the guest.

**Table 60. Layout of the TIO\_MSG\_TDI\_INFO\_REQ Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided identifier used by the guest to identify the TDI in guest messages.
2h–Fh		–	Reserved.

The firmware returns the TIO\_TDI\_INFO\_RSP message to the guest filled with information about the TDI.

**Table 61. Layout of the TIO\_MSG\_TDI\_INFO\_RSP Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided identifier used by the guest to identify the TDI in guest messages.
2h	15:0	TDI_STATUS	0: Success (Bound TDI) 1: Invalid TDI 2: Unbound TDI All other encoding is reserved.
4h - Fh		–	Reserved.



Byte Offset	Bits	Name	Description
10h	31:2	–	Reserved.
	1	MEAS_DIGEST_FRESH	0: The measurement was retrieved before TIO_TDI_BIND. 1: The measurement was retrieved after TIO_TDI_BIND.
	0	MEAS_DIGEST_VALID	0: MEAS_DIGEST is not valid because the host software has not yet invoked TIO_DEV_MEASUREMENTS. 1: MEAS_DIGEST is valid.
14h	31:5	–	Reserved.
	4	ALL_REQUEST_REDIRECT	Indicates if ATS translated requests to route through the root complex is required.
	3	BIND_P2P	Indicates if direct P2P is enabled.
	2	LOCK_MSIX	Indicates if MSI-X table and PBA are locked.
	1	CACHE_LINE_SIZE	Indicates the cache line size. 0: 64B. 1: 128B.
	0	NO_FW_UPDATE	Indicates that no firmware updates are allowed while the interface is locked.
18h–1Fh		SPDM_ALGOS	<b>Algorithms used to establish the SPDM session. See</b> Table 62 for the format of this field.
20h	383:0	CERTS_DIGEST	Digest of the certificate chain of the TDI.
50h	383:0	MEAS_DIGEST	Digest of the measurements of the TDI.
80h	383:0	INTERFACE_REPORT_DIGEST	Digest of interface report.
B0h	63:0	TDI_REPORT_COUNT	TDIReportCount value in the TDI context.
B8h–BFh	63:0	-	Reserved.

**Table 62. Layout of the SPDM\_ALGOS Structure**

Byte Offset	Bits	Name	Description
0h	7:0	DHE	0: secp256r1. 1: secp384r1. <i>All other encodings reserved.</i>
1h	7:0	AEAD	0: AES-128-GCM. 1: AES-256-GCM <i>All other encodings reserved.</i>
2h	7:0	ASYM	0: TPM_ALG_RSASSA_3072. 1: TPM_ALG_ECDSA_ECC_NIST_P256. 2: TPM_ALG_ECDSA_ECC_NIST_P384. <i>All other encodings reserved.</i>
3h	7:0	HASH	0: TPM_ALG_SHA_256. 1: TPM_ALG_SHA_384. <i>All other encodings reserved.</i>
4h	7:0	KEY_SCHED	0: SPDM key schedule. <i>All other encodings reserved.</i>
5h–7h		–	Reserved.

## 8.2 MMIO Validate

This message asks the SEV firmware to set the RMP. Validated bit to the guest-provided value for a subrange of an MMIO range. The SEV firmware also associates the range in the hardware with the specified TDI so that MMIO accesses are placed in the correct IDE stream.

**Table 63. Layout of the TIO\_MSG\_MMIO\_VALIDATE\_REQ Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided identifier used by the guest to identify the TDI in guest messages.
2h–Fh		–	Reserved.
10h	63:0	SUBRANGE_BASE	Guest physical address of the subrange.
18h	31:0	SUBRANGE_PAGE_COUNT	Number of 4 KB pages in the subrange.
1Ch	31:0	RANGE_OFFSET	Offset of the subrange within the MMIO range.



Byte Offset	Bits	Name	Description
20h	15:2	–	Reserved.
	1	FORCE_VALIDATED	0: If subrange does not have RMP. Validated set uniformly, fail. 1: If subrange does not have RMP. Validated set uniformly, force to requested value.
	0	VALIDATED	Desired value to set RMP. Validated for the range.
22h	15:0	RANGE_ID	RangeID of MMIO range.
24h – 2Fh		–	Reserved.

The firmware performs the following checks:

- The TDI is bound to the guest.
- The MMIO range ID is present in the interface report.
- All pages of the provided subrange are assigned to the guest.
- All pages of the provided subrange have the Immutable bit set in the RMP.
- If FORCE is 0, the Validated bit in the RMP is set uniformly for all pages of the provided subrange.
- The offset of the subrange matches the offset of the MMIO range in the interface report
- All pages of the provided MMIO range are I/O pages.

If any of the above checks fail, the firmware returns the appropriate error status code.

The firmware sets VALIDATED in response to the value of the Validated bits of the MMIO range. The firmware then returns the message without altering the RMP.

The firmware sets the Validated bits in the RMP as requested by the guest. The firmware sets VALIDATED to the new value and CHANGED to 1 if the firmware changed the Validated bit and 0 otherwise.

The firmware responds with the TIO\_MSG\_MMIO\_VALIDATE\_RSP message.

**Table 64. Layout of the TIO\_MSG\_MMIO\_VALIDATE\_RSP Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided PCIe Routing ID used by the guest to identify the TDI.
2h	15:0	STATUS	0: Success 1: Invalid TDI



Byte Offset	Bits	Name	Description
			2: TDI is not bound to this guest. 3: At least one page is not assigned to the guest. 4: At least one page is not an I/O page. 5: The Validated bit is not uniformly set for the MMIO subrange. 6: At least one page does not have immutable bit set when validated bit is clear 7: At least one page is not mapped to the expected MMIO pages 8: The provided MMIO range ID is not reported in the interface report 9: The subrange is not in the MMIO range in the interface report. 10: At least one page is not 4K page size. All other encodings reserved.
4h-Fh		-	Reserved.
10h	63:0	SUBRANGE_BASE	Guest physical address of the subrange.
18h	31:0	SUBRANGE_BASE_COUNT	Number of 4 KB pages in the subrange.
1Ch	31:0	RANGE_OFFSET	Offset of the subrange within the MMIO range.
20h	15:1	–	Reserved.
	0	CHANGED	Indicates that the Validated bit has changed due to this operation.
22h	15:0	RANGE_ID	Range of the MMIO.
24h – 2Fh		–	Reserved.

## 8.3 MMIO Configure

This message allows the guest to read and write TDISP-defined MMIO range attributes.

**Table 65. Layout of the TIO\_MSG\_MMIO\_CONFIG\_REQ Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided identifier used by the guest to identify the TDI in guest messages.
2h - 3h		–	Reserved.
4h	31:16	RANGE_ID	Identifier of the range.
	15:3	–	Reserved.
	2	IS_NON_TEE_MEM	0: Can be mapped only into guest private memory. 1: Can be mapped into either guest private memory or shared memory. Ignored if WRITE is 0.
	1:0	–	Reserved.
8h	31:1	–	Reserved.
	0	WRITE	0: Only retrieve configuration of range. 1: Write configuration of range.
Ch - Fh		-	Reserved.

When WRITE is 0, the firmware returns a message with the current attributes of the MMIO range indicated by RANGE\_ID. When WRITE is 1, the firmware sends the SET\_MMIO\_ATTRIBUTE\_REQUEST TDISP message to the device to alter the configuration.

**Table 66. Layout of the TIO\_MSG\_MMIO\_CONFIG\_RSP Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided identifier used by the guest to identify the TDI in guest messages.
2h	15:0	STATUS	0: Success. 1: Invalid TDI 2: TDI is not bound to the guest. 3: The provided MMIO range ID is not reported in the interface report. 4: One or more attributes could not be changed. <i>All other encodings reserved.</i>



Byte Offset	Bits	Name	Description
4h	31:16	RANGE_ID	Identifier of the range.
	15:4	–	Reserved.
	3	IS_MEM_ATTR_UPDATEABLE	Indicates certain TDISP flags can be updated.
	2	IS_NON_TEE_MEM	0: Can be mapped only into guest private memory. 1: Can be mapped into either guest private memory or shared memory. Ignored if WRITE is 0.
	1	MSIX_PBA	Indicates if this range maps MSI-X PBA.
	0	MSIX_TABLE	Indicates if the range maps MSI-X table.
8h	31:1	–	Reserved.
	0	WRITE	0: Only retrieve configuration of range. 1: Write configuration of range.
Ch-Fh		-	Reserved.

## 8.4 SDTE Write

Update the secure Device Table Entry (sDTE) for this TDI.

**Table 67. Layout of the TIO\_MSG\_SDTE\_WRITE\_REQ Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided PCIe Routing ID used by the guest to identify the TDI.
2h – Fh		-	Reserved.
10h	511:0	SDTE	sDTE to use to configure the guest-controlled fields. See Table 68.

**Table 68. Layout of the SDTE Structure**

Bits	Name	Description
511:350	–	Reserved.
351:321	VIRTUAL_TOM	vTOM applied to all TDI accesses.





Bits	Name	Description
320	VTOM_EN	0: vTOM not enabled. 1: vTOM enabled.
319:243	–	Reserved.
242:241	VMPL	VMPL applied to all accesses by this TDI.
240:1	–	Reserved.
62	IW	I/O write permission bit.
61	IR	I/O read permission bit.
60:1	-	Reserved.
0	V	0: TDI is not allowed to access guest private memory and this SDTE is not valid. 1: TDI is allowed to access guest private memory and this SDTE is valid.

The firmware sets the SDTE of the TDI to the value provided by the guest. The guest must send the TIO\_MSG\_TDI\_INFO\_REQ message before sending this message. This prevents the hypervisor from rebinding the TDI with the guest after the guest validated the attestation objects of the TDI.

**Table 69. Layout of the TIO\_MSG\_SDTE\_WRITE\_RSP Structure**

Byte Offset	Bits	Name	Description
0h	15:0	GUEST_DEVICE_ID	Hypervisor provided identifier used by the guest to identify the TDI in guest messages.
2h	15:0	STATUS	0: Success. 1: Invalid TDI 2. TDI is unbound. 3: Reserved fields were not 0. <i>All other encodings reserved.</i>
4h - Fh		-	Reserved.



## Chapter 9      References

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- [1] Advanced Microdevices, "Secure Encrypted Virtualization API," April 2020.
- [2] Advanced Microdevices, "SEV Secure Nested Paging Firmware ABI Specification," 2022.
- [3] PCI SIG, "TEE Device Interface Security Protocol (TDISP)," 2022.
- [4] Advanced Microdevices, "AMD SEV-TIO: Trusted I/O for Secure Encrypted Virtualization," 2023.
- [5] Advanced Microdevices, "AMD I/O Virtualization Technology (IOMMU) Specification," 2022.
- [6] Distributed Management Task Force, "Security Protocol and Data Model (SPDM) Specification," 2022.