



# SEV Secure Nested Paging Firmware ABI Specification

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## Revision History

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August 2020	0.9	<b>Updates and Additions:</b> <ul style="list-style-type: none"> <li>•</li> </ul>
August 2020	0.8	<b>Updates and Additions:</b> <ul style="list-style-type: none"> <li>• Updated Section 3.2 Platform State Machine.</li> <li>• Updated Table 11. Command Identifiers.</li> <li>• Updated Section 7.3 Attestation.</li> <li>• Updated Table 21. ATTESTATION_REPORT Structure.</li> <li>• Updated Section 8.3.2 Actions for SNP_PLATFORM_STATUS.</li> <li>• Updated Table 38. Layout of the STRUCT_PLATFORM_STATUS Structure.</li> <li>• Added Section 8.4 SNP_.</li> </ul> <p>Updated Section 8.6.2 Actions for SNP_INIT</p> <ul style="list-style-type: none"> <li>• Updated Table 42. Status Codes for SNP_INIT.</li> <li>• Updated Section 8.11.2 Actions for SNP_DF_FLUSH.</li> <li>• Updated Table 52. Status Codes for SNP_DF_FLUSH.</li> <li>• Updated Section 8.12.2 Actions for SNP_SHUTDOWN.</li> </ul>
April 2020	0.7	Initial public release.



# Chapter 1 Introduction

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## 1.1 Purpose

The purpose of this document is to provide details of the Platform Security Processor (PSP) firmware support for the Secure Nested Paging (SEV-SNP) enhancement to SEV. The PSP exposes a set of functions to the hypervisor for guest lifecycle management of SNP-enabled guests.

## 1.2 Scope

This document describes the software interface for the functions supported by the PSP for SNP VM management. It does not describe the x86 CPU or System-on-Chip (SOC) hardware support for SNP. While certain sections of this document may describe potential hypervisor usage of the firmware ABI, this document is not intended to prescribe any specific use or hypervisor architecture. Please refer to [APM] for the x86 ISA mechanisms related to SEV-SNP and to the whitepaper [SNP-WP] for a high-level description of SEV-SNP and the features it provides.

## 1.3 Intended Audience

The intended audience of this document is hypervisor developers, kernel developers, and security architects. Hypervisor developers supporting SNP will need to use the firmware functions described herein for VM lifecycle management. Additionally, kernel developers and security architects will need to use the guest message functions to perform secure attestation, key management, and migration.

## 1.4 References

**Table 1. External References**

Reference	Document
APM	AMD64 Architecture Programmer's Manual (Volumes 1–5) #s 24592, 24593, 24594, 26568, and 26569
PPR	Processor Programming Reference
SNP-WP	AMD SEV-SNP: Strengthening VM Isolation with Integrity Protection and More
SEV	Secure Encrypted Virtualization API, #55766



## Chapter 2 Data Structures and Encodings

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This section describes data structures that are common to multiple commands.

### 2.1 Metadata Entries (MDATA)

Table 2 describes a metadata entry within a metadata page. Metadata entries describe security attributes of pages that have been swapped out. When pages are swapped back in, the firmware uses the metadata entries to ensure the SNP security properties are not violated.

**Table 2. Layout of the MDATA Structure**

Byte Offset	Bits	Name	Description
00h	63:0	SOFTWARE_DATA	Software available data supplied by the hypervisor.
08h	63:0	IV	Initialization vector used to encrypt the swapped-out page.
10h	127:0	AUTH_TAG	Authentication tag of the swapped-out page.
20h	63:12	GPA	Bits 63:12 of the gPA of the swapped-out page.
	11:5	-	Reserved.
	4	PAGE_SIZE	Indicates the size of the swapped-out page. If set to 0, the page is 4 KB. If set to 1, the page is 2 MB.
	3	METADATA	Indicates that the swapped-out page is a metadata page.
	2	VMSA	Contains RMP.VMSA of the page at the time the page was swapped out.
	1	PAGE_VALIDATED	Contains RMP.Validated of the page at the time the page was swapped out.
	0	VALID	Indicates this metadata entry is valid.
28h	31:24	VMPL3	The permission mask RMP.VMPL3 of the page at the time the page was swapped out.
	23:16	VMPL2	The permission mask RMP.VMPL2 of the page at the time the page was swapped out.
	15:8	VMPL1	The permission mask RMP.VMPL1 of the page at the time the page was swapped out.
	7:0	VMPL0	The permission mask RMP.VMPL0 of the page at the time the page was swapped out.
2Ch	31:0	-	Reserved.
30h	63:0	-	Reserved.
38h	63:0	-	Reserved.

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## 2.2 TCB\_VERSION

The TCB version is a version string that represents the version of the firmware. The TCB version is described in Table 3.

**Table 3. Structure of the TCB\_VERSION Version String**

Bits	Field	Description
63:56	MICROCODE	Lowest current patch level of all the cores.
55:48	SNP	Version of the SNP firmware Security Version Number (SVN) of SNP firmware.
47:16	-	Reserved.
15:8	TEE	Current PSP OS version SVN of PSP operating system.
7:0	BOOT_LOADER	Current bootloader version SVN of PSP bootloader.

## 2.3 VCEK

The Versioned Chip Endorsement Key (VCEK) is a root key derived from chip-unique secrets and the current TCB version. The VCEK can be computed for previous versions of the TCB, allowing for migrations of secrets from previous version to the current version.

## 2.4 Invalid Physical Address (PADDR\_INVALID)

The value PADDR\_INVALID represents an invalid value for sPA and gPA fields in this specification. PADDR\_INVALID is defined as two's-complement  $-1$  with a width of the field to which it is assigned. Note that 0h is a valid sPA and gPA.

# Chapter 3 Platform Management

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Before SNP VMs can be launched, the platform must be properly configured and initialized. Platform initialization is accomplished via the SNP\_INIT command, which verifies that SNP has been enabled across all CPUs and configured correctly. Further, the platform contains a state machine that restricts which commands may be executed at certain times throughout execution.

## 3.1 Feature Detection and Enablement

On initialization, the SNP\_INIT command will check that the SEV-SNP feature is available and globally enabled. See [APM] Volume 2, Section 15.36, for information on feature detection and enablement.

## 3.2 Platform State Machine

The SNP firmware may exist in two states: UNINIT and INIT. Certain commands may be executed only in each of these states.

**Table 4. Commands Available in Each State**

State	Encoding	Description	Allowed Platform Commands
UNINIT	0h	The platform is uninitialized. This is the reset state of the PSP firmware.	SNP_INIT SNP_PLATFORM_STATUS DOWNLOAD_FIRMWARE GET_ID
INIT	1h	The platform is initialized	All SNP commands except SNP_INIT, DOWNLOAD_FIRMWARE

# Chapter 4 Guest Management

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The lifecycles of SNP-enabled guests are managed through the guest management ABI functions. SNP-enabled guests are identified via their guest context pages, and may be launched, attested, migrated, etc. via the appropriate ABI calls. An SNP-enabled guest is created by first allocating a context page, then activating the guest on a specific ASID, and then adding an initial set of plaintext pages into the guest address space. After the guest has begun execution, it may request attestation reports, derived keys, and assist in scenarios such as live migration directly through a trusted channel with the PSP firmware.

## 4.1 Guest Context

The guest context (represented as GCTX throughout this specification) contains all the information, keys, and metadata associated with the guest that the firmware tracks to implement the SEV and SNP features. The guest context is specified in Table 5.

**Table 5. Fields of the Guest Context (GCTX)**

Field	Migrated?	Description
ASID	No	The ASID that the guest's keys are installed on, if at all.
State	Yes	The current state of the guest.
MsgCount0	Yes	The number of guest messages that the firmware has sent to or received from VMPL0.
MsgCount1	Yes	The number of guest messages that the firmware has sent to or received from VMPL1.
MsgCount2	Yes	The number of guest messages that the firmware has sent to or received from VMPL2.
MsgCount3	Yes	The number of guest messages that the firmware has sent to or received from VMPL3.
Policy	Yes	The guest's security policy.
MA	No	The migration agent of the guest, if the guest is associated with a migration agent.
LD	Yes	The launch digest context used to measure the guest during the launch command flow.
OEK	Yes	The offline encryption key associated with this guest.
OeklvCount	Yes	The IV counter used for encryption with the OEK
VEK	No	The VM encryption key used to encrypt the guest's memory.
VMPCK0, VMPCK1, VMPCK2, VMPCK3	Yes	The VM communication keys.
VMRK	Yes	The VM root key provided by the MA at guest launch or guest import.

Field	Migrated?	Description
HostData	Yes	Host data provided by the hypervisor during guest launch. This firmware includes this value in all attestation reports for this guest.
IDBlockEn	Yes	Indicates whether an ID block was associated with the guest.
IDBlock	Yes	The associated ID block, if any.
IDKeyDigest	Yes	The ID key digest, if any.
AuthorKeyEn	Yes	Indicates whether an Author key signed the ID key.
AuthorKeyDigest	Yes	The Author key digest, if any.
ReportID	Yes	Attestation report ID.
RootMDEntry	Yes	The root metadata entry.
IMD	Yes	The measurement of the Incoming Migration Image (IMI).
IMIEn	No	Indicates whether the current launch flow is an IMI migration or not. Used only when the guest is in the GSTATE_LAUNCH state.
GOSVW	Yes	Guest OS visible workarounds. Provided in SNP_LAUNCH_START by the hypervisor.

The firmware stores the guest context in a page donated by the hypervisor. The hypervisor donates the page through the SNP\_GCTX\_CREATE command and reclaims it with SNP\_PAGE\_RECLAIM command. Because the guest context page is in the Context state (see Chapter 5 for details on the page state machine), the hypervisor cannot write to the page. The firmware prevents the hypervisor from reading from the page by encrypting the guest context.

## 4.2 Guest State Machine

The commands that can be successfully issued for a guest are restricted according to an internal guest state machine. The guest state machine ensures that commands are executed in the correct order. The current guest state is stored in GCTX.State.

**Table 6. Guest State Definition**

State	Encoding	Description	Allowed Guest Commands
GSTATE_INIT	0h	The initial state of the guest.	SNP_LAUNCH_START SNP_GUEST_REQUEST (VM_IMPORT) SNP_PAGE_RECLAIM SNP_DECOMMISSION

State	Encoding	Description	Allowed Guest Commands
GSTATE_LAUNCH	1h	The guest is being launched.	SNP_GCTX_CREATE SNP_LAUNCH_UPDATE SNP_LAUNCH_FINISH SNP_ACTIVATE SNP_DECOMMISSION SNP_PAGE_RECLAIM SNP_PAGE_MOVE SNP_PAGE_SWAP_OUT SNP_PAGE_SWAP_IN SNP_PAGE_UNSMASH
GSTATE_RUNNING	2h	The guest is currently running.	SNP_ACTIVATE SNP_DECOMMISSION SNP_PAGE_RECLAIM SNP_PAGE_MOVE SNP_PAGE_SWAP_OUT SNP_PAGE_SWAP_IN SNP_PAGE_UNSMASH SNP_GUEST_REQUEST

**Table 7. Guest State Transitions**

Command	Start State	End State
SNP_LAUNCH_START	GSTATE_INIT	GSTATE_LAUNCH
SNP_LAUNCH_FINISH	GSTATE_LAUNCH	GSTATE_RUNNING
VM_ABSORB	GSTATE_LAUNCH	GSTATE_RUNNING
VM_IMPORT	GSTATE_INIT	GSTATE_RUNNING

## 4.3 Guest Policy

The firmware associates each guest with a guest policy that the guest owner provides. The firmware restricts what actions the hypervisor can take on this guest according to the guest policy. The policy also indicates the minimum firmware version to for the guest.

The guest owner provides the guest policy to the firmware during launch. The firmware then binds the policy to the guest. The policy cannot be changed throughout the lifetime of the guest. The policy is also migrated with the guest and enforced by the destination platform firmware.

The guest policy is an 8-byte structure with the fields shown in Table 8.

**Table 8. Guest Policy Structure**

Bit(s)	Name	Description
63:20	-	Reserved. MBZ.

Bit(s)	Name	Description
19	DEBUG	0: Debugging is disallowed. 1: Debugging is allowed.
18	MIGRATE_MA	0: Association with a migration agent is disallowed. 1: Association with a migration agent is allowed.
17	-	Reserved. Must be one.
16	SMT	0: SMT is disallowed. 1: SMT is allowed.
15:8	ABI_MAJOR	The minimum ABI major version required for this guest to run.
7:0	ABI_MINOR	The minimum ABI minor version required for this guest to run.

The policy bits for a given guest are referenced with the format `POLICY.<FLAG_NAME>`. For instance, the flag indicating that SMT is allowed is referred to as `POLICY.SMT`.

## 4.4 Guest Activation

The processor associates each guest memory transaction with the Address Space Identifier (ASID) specified in the guest's VMCB. The ASID of a guest selects the key used by the memory controller to encrypt that guest's memory. The hypervisor must inform the firmware on which ASID it will execute the guest with using the VMRUN instruction. The firmware then installs the guest's VEK in the key slot associated with that ASID. To inform the firmware of the guest-ASID binding, the hypervisor calls `SNP_ACTIVATE`.

All guest data in the caches and data fabric write buffers are unencrypted. Guests with different ASIDs have logically separate caches. However, guests with the same ASID share cache lines. To ensure that a previously decommissioned guest's data are not accessible to a new guest, `SNP_ACTIVATE` will require that the caches are invalidated and that the data fabric write buffers are flushed. In this case, the hypervisor must first invoke `WBINVD` on all cores. Following the `WBINVD` completion, the hypervisor must invoke the `SNP_DF_FLUSH` command. This ensures that no plaintext data owned by another guest exist in the caches or in the write buffers before activation.

The hypervisor can activate a guest on a subset of core complexes using `SNP_ACTIVATE_EX`. If a guest is activated on a core complex, the hypervisor may execute the guest with that ASID on only that core complex.

Guest activation must always occur before any memory is assigned to the guest by the hypervisor using the `RMPUPDATE` instruction.

## 4.5 Launching a Guest

The hypervisor starts an SNP guest by launching the guest. The hypervisor uses the commands `SNP_LAUNCH_START`, `SNP_LAUNCH_UPDATE`, and `SNP_LAUNCH_FINISH` to launch the guest.

`SNP_LAUNCH_START` begins the launch process. Through this command, the firmware initializes a cryptographic digest context used to construct the measurement of the guest. If the guest is expected to be migrated, `SNP_LAUNCH_START` also binds a Migration Agent (MA) to the guest. (See 4.11 for further information about migration.)

`SNP_LAUNCH_UPDATE` inserts data into the guest's memory. The firmware extends the cryptographic digest context with the data to bind the measurement of the guest with all operations that the hypervisor took on the guest's memory contents.

`SNP_LAUNCH_UPDATE` can insert two special pages into the guest's memory: the secrets page and the CPUID page. The secrets page contains encryption keys used by the guest to interact with the firmware. Because the secrets page is encrypted with the guest's memory encryption key, the hypervisor cannot read the keys. The CPUID page contains hypervisor provided CPUID function values that it passes to the guest. The firmware validates these values to ensure the hypervisor is not providing out-of-range values.

`SNP_LAUNCH_FINISH` finalizes the cryptographic digest and stores it as the measurement of the guest at launch. This measurement is a critical part of the guest's attestation report produced by the firmware. This command also takes identity keys to be associated with guest used as part of the attestation report. For further information about the identity bloc, see 4.6. For attestation, see 4.9.

After `SNP_LAUNCH_FINISH` completes successfully, the hypervisor may invoke `VMRUN` on the x86 CPU to execute the guest.

## 4.6 Identity Block

As part of the input to the `SNP_LAUNCH_FINISH` command, the hypervisor may provide an optional data structure called the identity block. The identity block contains the expected launch digest of the guest, information uniquely identifying the guest, the guest policy bitfield, and a signature by the guest owner. The provided launch digest is checked against the computed launch digest, and the provided policy is checked against the policy used to launch the guest. The identifying information is stored in the guest context to be used during key derivation and attestation. Finally, the firmware will check that the signature is valid.

The firmware stores the keys used to sign the identity block in the guest context. Attestation reports for the guest contain the public keys to reflect the binding of the guest to the guest owner. A guest owner that sees its public keys in the attestation report knows that the launch process used an identity block provided by that guest owner to validate the guest.



## 4.7 Decommissioning a Guest

The hypervisor may decommission a guest by calling `SNP_DECOMMISSION` on the guest context page. The firmware prevents the hypervisor from running a decommissioned guest by marking the guest's ASID as unusable. Further, the firmware transitions the guest context page to a Firmware page, thus rendering the context page unusable.

## 4.8 Guest Messages

During the launch sequence, a special secrets page may be inserted that contains VM Platform Communication Keys (VMPCCKs) that may be used by the guest to send and receive secure messages to the PSP. Guests encrypt messages as described in the `SNP_GUEST_REQUEST` function before presenting the encrypted payload to the hypervisor. The hypervisor in turn calls `SNP_GUEST_REQUEST` and returns the result (also encrypted with the VMPCCK) to the guest. Guest messages are used for getting attestation reports, derived keys, handling migration, and other uses.

## 4.9 Remote Attestation

Guests may ask the PSP to generate an attestation report on their behalf via a `SNP_GUEST_REQUEST` call. The guest may ask for an attestation report at any time and multiple reports can be generated. When the guest asks for a report, it supplies 512 bits of arbitrary data to be included in the report. The resulting report will contain this data, identity information about the guest (from the launch sequence), migration, and policy information. The report is signed by VCEK, a chip-unique key specific to the current TCB version.

Guests may supply attestation reports to 3rd parties to establish trust. The 3rd party should verify the authenticity of the report based on its signature. A successful signature verification proves that the 512 bits of guest data supplied in the report came from the guest whose identity is described. For instance, this may be used to securely associate a public key with a particular VM instance.

## 4.10 Guest Keys

Guests may ask the PSP to derive keys for them based on various information via a `SNP_GUEST_REQUEST` call. Keys are either rooted in a VM Root Key (VMRK) that is supplied as part of the launch flow (and migrates with the guest), or in the VCEK, which is machine specific. When asked for a key, the PSP uses a key derivation function (KDF) to generate the requested key based on the root value and additional parameters. Certain pieces of guest information are always mixed into the derived key while others may be optionally mixed when requested by the guest. Keys may be used to seal information to the identity of the guest, or for other purposes.

## 4.11 Migration

Migration is supported in the SNP architecture through Migration Agents (MAs). A Migration Agent is itself an SNP VM that is bound to the primary VM during the launch process. A VM may be associated only with a single MA, but a single MA may manage multiple primary VMs. The MA is responsible for supplying the VMRK during the launch process and for enforcing the guest migration policy.

The MA is considered part of the guest VM's TCB. Consequently, when a guest generates an attestation report, the report includes information about the MA associated with the guest (if one exists). A 3rd party verifying the attestation report of a guest should also verify the report of the guest's MA.

The hypervisor may migrate a guest with or without the assistance of the guest. 4.12 describes how a hypervisor migrates with the assistance of the guest. When the hypervisor wishes to migrate a guest without the assistance of the guest, it first swaps all guest memory and associated metadata pages using the `SNP_PAGE_SWAP_OUT` command (see Chapter 5 for additional details). Swapped pages are encrypted using the OEK (Offline Encryption Key). Because each swapped page must be associated with a metadata entry, eventually there will be a single metadata page remaining after all other pages are swapped. When the hypervisor swaps this page, it can choose to store its metadata entry in the special `RootMDEntry` field in the guest context.

After all the guest memory is swapped, the hypervisor asks the MA to perform the `VM_EXPORT` function via `SNP_GUEST_REQUEST`. This function sends the context page of the guest to be migrated to the MA via an encrypted channel. At this point, the primary VM is no longer runnable.

The MA sends the VM context to a trusted location, such as a MA on a new machine. The mechanism that the MA uses to transfer this data and enforce security on it is outside the scope of this document.

In a typical scenario, a MA will have started on the destination machine to receive the guest context information. After the hypervisor creates a guest context (as described earlier) it may ask the MA to perform the `VM_IMPORT` function (via `SNP_GUEST_REQUEST`), which installs the provided guest context on the new machine. At this point, the hypervisor may proceed with swapping in guest memory (via `SNP_PAGE_SWAP_IN`) and begin executing the guest.

The use of an MA is optional and SNP guests may be started without a MA. Guests that are started without a MA may not be exported and therefore cannot be migrated without shutting themselves down.

## 4.12 Guest Assisted Migration

If the guest has an Initial Migration Image (IMI), the guest may assist the hypervisor during the migration process to increase migration throughput. An IMI is software measured during the guest launch process that can reconstruct a guest on the receiving platform from pages it is sent by the sending guest.

On launch, a subset of the pages launched may be marked as part of the IMI. The launch process measures the IMI separately into the Initial Migration Digest (IMD) and is stored in the guest context. To start a migration operation, the cloud provider performs a modified launch flow on the receiving platform. This launch flow differs from normal launch in two important ways:

- Only the IMI pages are launched via `SNP_LAUNCH_UPDATE`
- `SNP_LAUNCH_FINISH` is replaced by the absorb guest message

The absorb guest message takes a guest context exported by the sending machine using the export guest message. The absorb message differs from the import message mainly by overwriting the IMI context with the incoming guest context. However, the absorb message requires that the launch digest of the IMI matches the IMD of the migrated guest. This ensures that the receiving IMI is exactly the IMI that was launched with the guest.

When the guest is exported on the sending platform for the purpose of guest assisted migration, the guest remains runnable. This allows the guest to send its own memory contents to the IMI.

# Chapter 5 Page Management

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## 5.1 Page Security Attributes

The Reverse Map Table (RMP) is a structure that resides in DRAM and maps system physical addresses (sPAs) to guest physical addresses (gPAs). There is only one RMP for the entire system, which is configured using x86 model specific registers (MSRs). See [APM] volume 2, Section 15.36, for details.

Each RMP entry is indexed by the sPA the page. The RMP, combined with all guests' nested page tables, creates a global one-to-one mapping between sPAs and gPAs. That is, the RMP ensures that a page cannot be mapped into multiple guests at once, and it cannot be mapped multiple times into a single guest at once.

The RMP also contains various security attributes of each that are managed by the hypervisor through hardware-mediated and firmware-mediated controls. The fields of an RMP entry are described in [APM] volume 2, Section 15.36.3.

## 5.2 Page States

A page's state is completely determined by the fields in the page's RMP entry. Specifically, the page state depends on the Assigned, Validated, ASID, Immutable, GPA, and VMSA RMP entry fields. Table 9 enumerates and defines each of the page states. Note that (-) in a cell indicates that the page state is not dependent on that field.

**Table 9. Page State Definitions**

Page State	Assigned	Validated	ASID	Immutable	GPA	VMSA
Hypervisor	0	0	0	0	-	-
Reclaim	1	0	0	0	-	-
Firmware	1	0	0	1	0	0
Context	1	0	0	1	0	1
Metadata	1	0	0	1	>0	-
Pre-Guest	1	0	>0	1	-	-
Guest-Invalid	1	0	>0	0	-	-
Pre-Swap	1	1	>0	1	-	-
Guest-Valid	1	1	>0	0	-	-
Default	See discussion below.					

A Hypervisor page is used by the hypervisor for its normal execution. SNP places no restrictions on the use of Hypervisor pages for purposes outside of managing SNP guests. A Default page is a page that does not have an RMP entry. Pages do not have an RMP entry if the sPA indexes to an

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entry past the end of the RMP table—that is, past RMP\_END. Default pages have the same access permissions as a Hypervisor page but cannot be transitioned to any other page state.

Pages in the Firmware state are owned by the firmware. Because the RMP.Immutable bit is set, the hypervisor cannot write to Firmware pages nor alter the RMP entry with the RMPUPDATE instruction. A Firmware page is used by the hypervisor to donate writeable memory to the firmware to operate on. Such pages may be used to output data to the hypervisor, or to transition into a special page state, such as Metadata pages or Context pages.

When an immutable page is returned to the hypervisor by the firmware, the page is transitioned into the Reclaim page state. The Reclaim page state can then be transitioned to other non-immutable pages by the hypervisor using RMPUPDATE.

A Context page is a firmware-owned page that contains all context information of a guest. The format of the Context page is implementation specific. The content of a Context page is encrypted and integrity protected so that the hypervisor cannot not read or write to it.

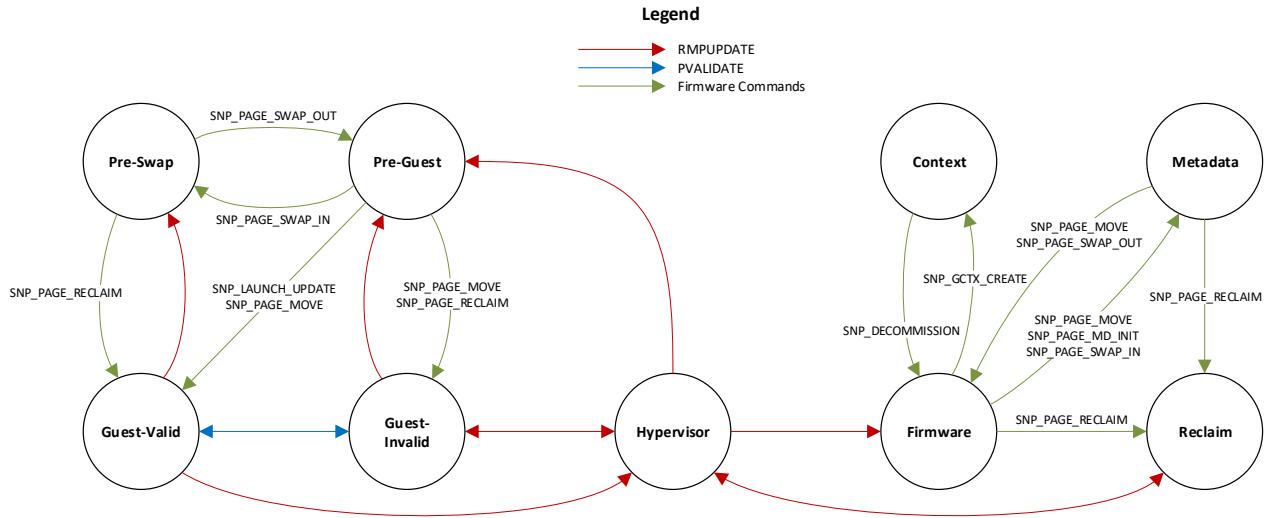
A Metadata page is a firmware-owned page that contains the metadata of a swapped-out page. Metadata pages have a well-defined format. The firmware converts a Firmware into a Metadata page by making the GPA field non-zero.

A Guest-Invalid page has been donated to the guest but has not yet been validated by the guest. If the hypervisor wishes to have the firmware operate on them, the hypervisor transitions the page into a Pre-Guest page.

Similarly, a Guest-Valid page has been donated to the guest, and the guest has validated the page. If the hypervisor wishes to have the firmware operate on them, the hypervisor transitions the page into a Pre-Swap page.

## 5.3 Page State Transitions

The only ways in which a page can transition between states are by invoking the RMPUPDATE and PVALIDATE instructions or by issuing firmware commands described in this specification. The hardware and firmware mediate all page state transitions to ensure that only secure state transitions occur.



**Figure 1. SNP Page State Machine**

Red edges in Figure 1 represent hypervisor actions. Blue edges represent guest actions. Green edges represent firmware commands specified in this document. Note that the some transitive RMPUPDATE edges are omitted for clarity.

Actions that trigger a page state transition are depicted in Figure 1. The following subsections describe the transitions in further detail. Notably, the following subsections do not describe the Default page state because Default pages cannot transition to other page states.

### 5.3.1 RMPUPDATE

The RMPUPDATE instruction may be used by the hypervisor to alter the RMP entries of pages. This allows the hypervisor to directly alter the state of most pages.

Notably, RMPUPDATE can invalidate a page but cannot validate a page. This means that the hypervisor cannot produce pages in the Pre-Swap or Guest-Valid states without assistance from a guest or from the PSP firmware.

Also, RMPUPDATE cannot affect the page state of an immutable page. A hypervisor can produce pages in the Pre-Guest or Pre-Swap states with RMPUPDATE. However, once in those states, the hypervisor must rely on the PSP firmware to transition them.

### 5.3.2 PVALIDATE

The PVALIDATE instruction may be used by a guest to alter the Validated flag of a page. This allows a guest to signal to the hardware and firmware that the page at a specified gPA is validated—that is, the guest expects the hardware and firmware to protect the integrity of the page.

Because PVALIDATE can be executed only within the guest, PVALIDATE can operate only on pages addressable within the guest's physical address space. Further, Pre-Guest, and Pre-Swap pages have their RMP.Immutable flags equal to 1, which prevents the guest from transitioning them.

### **5.3.3 Page Management Commands**

The hypervisor can invoke the commands described in this specification to manage memory without violating the security provided by SNP.

The hypervisor must perform these actions using RMPUPDATE. This restriction allows RMPUPDATE to mediate all re-assignments of pages so that the appropriate TLB and cache operations happen.

### **5.3.4 Launch Commands**

The SNP\_GCTX\_CREATE command transitions a page from the Firmware state to the Context state. This is the only way a Context page can be created.

The launch commands, specifically SNP\_LAUNCH\_UPDATE, take unencrypted guest pages and convert them into encrypted pages. In doing so, this command also transitions the launched pages to Guest-Valid pages.

### **5.3.5 Guest Request Commands**

Neither the SNP\_GUEST\_REQUEST command itself nor any of the guest messages alter the state of the pages passed to it.

### **5.3.6 Platform Commands**

SNP\_INIT initializes the state of all pages within the system by initializing the RMP. Other platform commands do not alter the state of any pages.

### **5.3.7 SEV Legacy Commands**

The behavior of the SEV-legacy commands is altered when the SNP firmware is in the INIT state. In this case, the SEV-legacy commands require any page that the SEV-legacy command writes to be a Firmware or Default page.

When the RMP has been initialized, as reported by SNP\_PLATFORM\_STATUS, any invocation of the SEV-legacy commands INIT and INIT\_EX require that TMR\_PADDR must be 2MB aligned instead of 1MB, and TMR\_LENGTH must be 2MB instead of 1MB.

## 5.4 Metadata Entries

A metadata entry contains security attributes associated with a swapped-out page. A Metadata page can describe three types of swapped-out pages: Data pages, Metadata pages, or VMSA pages. Each page type determines how the metadata entry is constructed.

Table 10 describes the contents of a metadata entry. All references to RMP fields or addresses refer to the attributes of the page at the time the hypervisor swapped it out.

**Table 10. Contents of Metadata Entries for Swapped-Out Data Pages, VMSA Pages, and Metadata Pages**

Field	Data Page	VMSA Page	Metadata Page
SOFTWARE_DATA	Software-provided data	Software-provided data	Software-provided data
IV	Initialization vector	Initialization vector	Initialization vector
AUTH_TAG	Authentication tag	Authentication tag	Authentication tag
PAGE_SIZE	RMP.Page_Size	RMP.Page_Size	RMP.Page_Size
VALID	1	1	1
METADATA	0	0	1
VMSA	0	1	0
GPA	gPA of the page	gPA of the page	PADDR_INVALID
PAGE_VALIDATED	RMP.Validated	RMP.Validated	0
VMPL0	RMP.VMPL0 if VMPLs are enabled. 0h otherwise.	RMP.VMPL0 if VMPLs are enabled. 0h otherwise.	0h
VMPL1	RMP.VMPL1 if VMPLs are enabled. 0h otherwise.	RMP.VMPL1 if VMPLs are enabled. 0h otherwise.	0h
VMPL2	RMP.VMPL2 if VMPLs are enabled. 0h otherwise.	RMP.VMPL2 if VMPLs are enabled. 0h otherwise.	0h
VMPL3	RMP.VMPL3 if VMPLs are enabled. 0h otherwise.	RMP.VMPL3 if VMPLs are enabled. 0h otherwise.	0h
Reserved fields	0h	0h	0h

The hypervisor may request that the firmware place data into SOFTWARE\_DATA for its own purposes. The firmware never interprets this field. Because the hypervisor can read the metadata entries in Metadata pages, the hypervisor can use SOFTWARE\_DATA for its own bookkeeping purposes.

An entry with VALID set to 0h is invalid and does not refer to any swapped-out page. When VALID is 0, the firmware does not interpret any other fields of the entry.





# Chapter 6 Mailbox Protocol

Software on the x86 CPUs communicate with the PSP through a set of MMIO registers, referred to as mailbox registers. This ABI used the mailbox protocol defined in Chapter 4 of [SEV]. This ABI adds new commands and status codes, which extend the SEV mailbox protocol. These command and status codes are described in the following sections.

## 6.1 Command Identifier

This ABI adds many new commands to be handled by the mailbox protocol. Table 11 summarizes the additional commands and their identifiers. See the command definitions for further details.

**Table 11. Command Identifiers**

Command	ID	Description
SNP_INIT	81h	Initialize platform for SNP.
SNP_SHUTDOWN	82h	Un-initialize platform for SNP.
SNP_PLATFORM_STATUS	83h	Query platform information.
SNP_DF_FLUSH	84h	Flush data fabric buffers.
SNP_INIT_EX	85h	Initialize platform for SNP with extended parameters.
SNP_DECOMMISSION	90h	Destroy a guest context.
SNP_ACTIVATE	91h	Assign an ASID to a guest.
SNP_GUEST_STATUS	92h	Query guest information.
SNP_GCTX_CREATE	93h	Create a guest context.
SNP_GUEST_REQUEST	94h	Process a guest request.
SNP_ACTIVATE_EX	95h	Assign an ASID to a guest on select cores.
SNP_LAUNCH_START	A0h	Begin to launch a new guest.
SNP_LAUNCH_UPDATE	A1h	Add memory to a launching guest.
SNP_LAUNCH_FINISH	A2h	Complete launching a guest.
SNP_DBG_DECRYPT	B0h	Decrypt guest memory for debugging.
SNP_DBG_ENCRYPT	B1h	Encrypt guest memory for debugging.
SNP_PAGE_SWAP_OUT	C0h	Swap a page out of guest memory.
SNP_PAGE_SWAP_IN	C1h	Swap a page into guest memory.
SNP_PAGE_MOVE	C2h	Move a Memory page.
SNP_PAGE_MD_INIT	C3h	Initialize a Metadata page.
SNP_PAGE_RECLAIM	C7h	Clear the immutable bit on a page.
SNP_PAGE_UNSMASH	C8h	Convert a sequence of 4 k pages into a 2 MB page.
SNP_CONFIG	C9h	Set the system wide configuration values

## 6.2 Status Codes

This ABI introduces several new status codes to the mailbox protocol. Table 12 summarizes the additional status codes added by this ABI.

**Table 12. Status Codes**

Status	Code	Description
INVALID_PAGE_SIZE	19h	The RMP page size is incorrect.
INVALID_PAGE_STATE	1Ah	The RMP page state is incorrect.
INVALID_MDATA_ENTRY	1Bh	The metadata entry is invalid.
INVALID_PAGE_OWNER	1Ch	The page ownership is incorrect.
AEAD_OFLOW	1Dh	The AEAD algorithm would have overflowed.
RMP_INIT_REQUIRED	20h	The RMP must be reinitialized

# Chapter 7 Guest Messages

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Guest messages provide the guest a mechanism to communicate with the PSP without risk from a malicious hypervisor who wishes to read, alter, drop, or replay the messages sent. A guest may issue requests of firmware via the `SNP_GUEST_REQUEST` command. This command constructs a trusted channel between the guest and the PSP firmware. The hypervisor cannot alter the messages without detection nor read the plaintext of the messages.

The firmware constructs the channel using a Virtual Machine Platform Communication key (VMPCCK). Each guest has four VMPCCKs, which the firmware generates and provides to the guest in a special secrets page as part of the guest launch process (see `SNP_LAUNCH_UPDATE` in Section 8.14 details). Only the guest and the firmware possess the VMPCCKs.

Each message contains a sequence number per VMPCCK. The sequence number is incremented with each message sent. Messages sent by the guest to the firmware and by the firmware to the guest must be delivered in order. If not, the firmware will reject subsequent messages by the guest when it detects that the sequence numbers are out of sync.

Each message is protected with an Authenticated Encryption with Associated Data algorithm (AEAD), namely AES-256 GCM.

Details on how to send a message via the `SNP_GUEST_REQUEST` command can be found in Section 8.23.

## 7.1 CPUID Reporting

*Note: This guest message may be removed in future versions as it is redundant with the CPUID page in `SNP_LAUNCH_UPDATE` (see Section 8.14).*

The firmware provides a service to the guest to validate CPUID function values provided by the hypervisor. This ensures that CPUID function values provided by the hypervisor are within range of the hardware. To use this service, the guest constructs an `MSG_CPUID_REQ` message.

The guest constructs an `MSG_CPUID_REQ` message as defined in Table 13. This message contains an array of CPUID function structures as defined in Table 13. The guest fills the structure with the information the guest received from the CPUID instruction from the hypervisor.

The message contains enough space for `COUNT_MAX` function structures, but only `COUNT` function structures are valid. `COUNT_MAX` is 64.

**Table 13. `MSG_CPUID_REQ` Structure**

Byte Offset	Bits	Name	Description
00h	31:0	COUNT	Number of CPUID functions to validate. Must be less

Byte Offset	Bits	Name	Description
			than COUNT_MAX.
04h	31:0	-	Reserved. Must be zero.
08h	63:0	-	Reserved. Must be zero.
10h		CPUID_FUNCTION[]	COUNT_MAX number of CPUID_FUNCTION records. Only the first COUNT records are valid.

**Table 14. CPUID\_FUNCTION Structure**

Byte Offset	Bits	Name	Description
00h	31:0	EAX_IN	EAX input parameter to CPUID.
04h	31:0	ECX_IN	ECX input parameter to CPUID.
08h	63:0	XCRO_IN	XCRO at the time of CPUID execution.
10h	63:0	XSS_IN	IA32_XSS MSR at the time of CPUID execution.
18h	31:0	EAX	EAX output parameter of CPUID.
1Ch	31:0	EBX	EBX output parameter of CPUID.
20h	31:0	ECX	ECX output parameter of CPUID.
24h	31:0	EDX	EDX output parameter of CPUID.
28h	63:0	-	Reserved. Must be zero.

The firmware returns an MSG\_CPUID\_RSP message as defined in Table 15. The message contains the same CPUID function structures that may be altered by the firmware. The firmware will alter the function structure when the hypervisor has provided an insecure value.

If firmware encounters a CPUID function that is not in the standard range (Fn0000\_0000 through Fn0000\_FFFF) or the extended range (Fn8000\_0000 through Fn8000\_FFFF), the firmware does not perform any checks on the function output.

If firmware encounters a CPUID function that is in the standard or extended ranges, then the firmware performs a check to ensure that the provided output would not lead to an insecure guest state. If insecure function output is identified, the firmware sets the field in the response message with to an acceptable value. Note that some functions have multiple acceptable values, and the firmware may choose any one of them. The firmware then returns INVALID\_PARAM in the STATUS field of the response message.

The policy used by the firmware to assess CPUID function output can be found in [PPR].

**Table 15. MSG\_CPUID\_RSP Structure**

Byte Offset	Bits	Name	Description
00h	31:0	STATUS	The status of key derivation operation. 0h: Success. 16h: Invalid parameters.
04h	31:0	COUNT	Number of CPUID functions that have been validated.
08h	63:0	-	Reserved.
10h		CPUID_FUNCTION[]	COUNT_MAX number of CPUID_FUNCTION records. Only the first COUNT records are valid.

## 7.2 Key Derivation

The guest can ask the firmware to provide a key derived from a root key. This key may be used by the guest for any purpose it chooses, such as sealing keys or communicating with external entities.

The data that the firmware mixes into the derived key is described in Table 16. The firmware unconditionally mixes some of the fields into the key while the guest may optionally select and even supply other data to mix into the key.

**Table 16. Data Mixed into the Derived Guest Key**

Data	Description	Mix Type	Provided in Message
VCEK/VMRK	VCEK or VMRK of the guest. The guest selects which of the keys is used.	Always	No
VMPL	The VMPL selected by the guest.	Always	Yes
Host Data	The host data provided at launch.	Always	No
ID key/ Author key	The author key provided at launch. If an author key was not provided, then the firmware uses the ID key instead.	Always	No
Guest Field Selection	A bitmask describing which of the fields in this table are mixed into the key. This covers the guest-selectable fields as well as other field selection done by the firmware.	Always	Yes
TCB Version	The TCB version selected by the guest.	Optional	Yes
Guest SVN	SVN of the guest.	Optional	Yes
Measurement	The measurement of the guest at launch.	Optional	No
Family ID	The family ID provided at launch.	Optional	No
Image ID	The image ID provided at launch.	Optional	No

Data	Description	Mix Type	Provided in Message
Guest Policy	The guest policy provided at launch.	Optional	No

Table 17 describes the MSG\_KEY\_REQ message structure that the guest sends to the firmware to request a derived key.

**Table 17. MSG\_KEY\_REQ Message Structure**

Byte Offset	Bits	Name	Description
0h	31:1	-	Reserved. Must be zero.
	0	ROOT_KEY_SELECT	Selects the root key to derive the key from. 0 indicates VCEK. 1 indicates VMRK.
4h	31:0	-	Reserved. Must be zero.
8h	63:0	GUEST_FIELD_SELECT	Bitmask indicating which data will be mixed into the derived key. See Table 16 for the structure of this bitmask.
10h	31:0	VMPL	The VMPL to mix into the derived key. Must be greater than or equal to the current VMPL.
14h	31:0	GUEST_SVN	The guest SVN to mix into the key. Must not exceed the guest SVN provided at launch.
18h	63:0	TCB_VERSION	The TCB version to mix into the derived key. Must not exceed the current TCB version.

The MSG\_KEY\_REQ described in Table 17 describes the MSG\_REQ message structure that the guest sends to the firmware to request a derived key. GUEST\_FIELD\_SELECT indicates which guest-selectable fields will be mixed into the key that is described in Table 18.

**Table 18. Structure of the GUEST\_FIELD\_SELECT Field**

Bits	Field	Description
63:6	-	Reserved. Must be zero.
5	TCB_VERSION	Indicates that the guest-provided TCB version string will be mixed into the key.
4	GUEST_SVN	Indicates that the guest-provided SVN will be mixed into the key.
3	MEASUREMENT	Indicates the measurement of the guest during launch will be mixed into the key.
2	FAMILY_ID	Indicates the family ID of the guest will be mixed into the key.
1	IMAGE_ID	Indicates that the image ID of the guest will be mixed into the key.
0	GUEST_POLICY	Indicates that the guest policy will be mixed into the key.

The firmware returns the MSG\_KEY\_RSP message defined Table 19 to the guest.

**Table 19. MSG\_KEY\_RSP Message Structure**

Byte Offset	Bits	Name	Description
00h	31:0	STATUS	The status of key derivation operation. 0h: Success. 16h: Invalid parameters.
04h–1Fh		-	Reserved.
20h	255:0	DERIVED_KEY	The requested derived key if STATUS is 0h.

## 7.3 Attestation

The guest can request that the firmware construct an attestation report. External entities can use an attestation report to assure the identity and security configuration of the guest.

A guest requests an attestation report by constructing an MSG\_REPORT\_REQ as specified in Table 20. The message contains data provided by the guest in REPORT\_DATA to be included into the report; the firmware does not interpret this data.

**Table 20. MSG\_REPORT\_REQ Message Structure**

Byte Offset	Bits	Name	Description
00h	511:0	REPORT_DATA	Guest-provided data to be included into the attestation report
40h	31:0	VMPL	The VMPL to put into the attestation report. Must be greater than or equal to the current VMPL and at most three.
44h–5Fh		-	Reserved. Must be zero.

The guest may generate attestation reports for VMPLs that are greater than or equal to the current VMPL. The desired VMPL is provided by the guest in the request message.

Upon receiving a request for an attestation report, the firmware constructs the report according to Table 21.

The firmware generates a report ID for each guest that persists with the guest instance throughout its lifetime. In each attestation report, the report ID is placed in REPORT\_ID. If the guest has a migration agent associated with it, the REPORT\_ID\_MA is filled in with the report ID of the migration agent.

The firmware signs the attestation report with its VCEK. The firmware uses the system wide ReportedTcb value as the TCB version to derive the VCEK. This value is set by the hypervisor. The firmware guarantees that the ReportedTcb value is never greater than the installed TCB version.



**Table 21. ATTESTATION\_REPORT Structure**

Byte Offset	Bits	Name	Description
00h	31:0	VERSION	Version number of this attestation report. Set to 1h for this specification.
04h	31:0	GUEST_SVN	The guest SVN.
08h	63:0	POLICY	The guest policy. See Table 8 for a description of the guest policy structure.
10h	127:0	FAMILY_ID	The family ID provided at launch.
20h	127:0	IMAGE_ID	The image ID provided at launch.
30h	31:0	VMPL	The request VMPL for the attestation report.
34h	31:0	SIGNATURE_ALGO	The signature algorithm used to sign this report. 102h indicates ECDSA P-384 with SHA-384. All other encodings are reserved.
38h	63:0	PLATFORM_VERSION	The install version of firmware.
40h	63:0	PLATFORM_INFO	Information about the platform. See Table 22.
48h	31:1	-	Reserved. Must be zero.
	0	AUTHOR_KEY_EN	Indicates that the digest of the author key is present in AUTHOR_KEY_DIGEST. Set to the value of GCTX.AuthorKeyEn.
4Ch	31:0	-	Reserved. Must be zero.
50h	511:0	REPORT_DATA	Guest-provided data.
90h	383:0	MEASUREMENT	The measurement calculated at launch.
C0h	255:0	HOST_DATA	Data provided by the hypervisor at launch.
E0h	383:0	ID_KEY_DIGEST	SHA-384 digest of the ID public key that signed the ID block provided in SNP_LAUNCH_FINISH.
110h	383:0	AUTHOR_KEY_DIGEST	SHA-384 digest of the Author public key that certified the ID key, if provided in SNP_LAUNCH_FINISH. Zeroes if AUTHOR_KEY_EN is 1.
140h	255:0	REPORT_ID	Report ID of this guest.
160h	255:0	REPORT_ID_MA	Report ID of this guest's migration

Byte Offset	Bits	Name	Description
			agent.
180h	63:0	REPORTED_TCB	Reported TCB version used to derive the VCEK that signed this report.
188h – 19Fh		-	Reserved.
1A0h-1DFh	511:0	CHIP_ID	If MaskChipId is set to 0, Identifier unique to the chip. Otherwise, set to 0h.
1E0h-29Fh		-	Reserved.
2A0h-49Fh		SIGNATURE	Signature of bytes 0h to 29Fh inclusive of this report. The format of the signature is described in Table 23.

**Table 22. Structure of the PLATFORM\_INFO Field**

Byte Offset	Bits	Name	Description
0h	63:1	-	Reserved.
	0	SMT_EN	Indicates that SMT is enabled in the system.

**Table 23. Format for an ECDSA P-384 with SHA-384 Signature (Used when SIGNATURE\_ALGO is 102h)**

Byte Offset	Bits	Name	Description
000h	575:0	R	R component of this signature. Value is zero-extended little-endian encoded.
048h	575:0	S	S component of this signature. Value is zero-extended little-endian encoded.
090h–1FFh		-	Reserved.

The firmware constructs an MSG\_REPORT\_RSP message containing the generated attestation report as defined in Table 24.

**Table 24. MSG\_REPORT\_RSP Message Structure**

Byte Offset	Bits	Name	Description
00h	31:0	STATUS	The status of key derivation operation. 0h: Success. 16h: Invalid parameters.
04h	31:0	REPORT_SIZE	Size in bytes of the report.
08h–1Fh		-	Reserved.

20h	REPORT	The attestation report generated by the firmware.
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## 7.4 VM Export

When the hypervisor wishes to migrate a guest, it sends a request to that guest or its migration agent. The guest (or its migration agent) then sends the PSP a request message to export the guest's data. The format of this request is defined in Table 25.

**Table 25. MSG\_EXPORT\_REQ Message Structure**

Byte Offset	Bits	Name	Description
00h	63:12	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page for the target guest to be exported
	11:0	-	Reserved. Must be zero.
08h	31:1	-	Reserved. Must be zero.
	0	IMI_EN	Indicates that an IMI is used to migrate the guest.
0Ch	31:0	-	Reserved. Must be zero.

The firmware checks that GCTX\_PADDR is a valid sPA. If not, the firmware returns a status of INVALID\_ADDRESS.

The firmware checks that GCTX\_PADDR is a Context page. The firmware checks that either

- The guest sending the message is the migration agent of the exported guest. That is, GCTX.MA of the provided guest context page matches the sPA of the requesting guest's guest context page, or
- The guest sending the message has no migration agent and is exporting itself. That is, GCTX\_PADDR matches the sPA of the requesting guest's context page, and GCTX.MA of the requesting guest is PADDR\_INVALID.

In summary, the guest can export itself if it has no migration agent. Otherwise, only its migration agent can export it. If either check fails, the firmware returns a status of INVALID\_GUEST.

The firmware checks that the guest to be exported is in the GSTATE\_RUNNING state. If not, the firmware returns INVALID\_GUEST\_STATE.

The firmware responds with a MSG\_EXPORT\_RSP message containing the guest context defined in Table 26. The size of the payload is such that HDR\_SIZE + MSG\_SIZE is 4096. That is, the message fills a 4 KB page.

**Table 26. MSG\_EXPORT\_RSP Message Structure**

Byte Offset	Bits	Name	Description
00h	31:0	STATUS	The status of the attestation request. 0h: Success 16h: Invalid parameters
04h	31:0	GCTX_SIZE	Size in bytes of the guest context stored in GCTX
08h	31:0	GCTX_VERSION	Version of the GCTX field. Set to 2h for this ABI version.
0Ch–1Fh		-	Reserved.

20h–2AFh	GCTX	Guest context. See Table 27 for the format of this field.
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**Table 27. GCTX Field Structure**

Byte Offset	Bits	Name	Description
000h	383:0	LD	See 4.1 for description of this field.
030h	255:0	OEK	
050h	255:0	VMPCK0	
070h	255:0	VMPCK1	
090h	255:0	VMPCK2	
0B0h	255:0	VMPCK3	
0D0h	255:0	VMRK	
0F0h	255:0	HostData	
110h	383:0	IDKeyDigest	
140h	383:0	AuthorKeyDigest	
170h	255:0	ReportID	
190h	383:0	IMD	
1C0h	63:0	MsgCount0	
1C8h	63:0	MsgCount1	
1D0h	63:0	MsgCount2	
1D8h	63:0	MsgCount3	
1E0h		RootMDEntry	See 5.1 for description of this field. If IMI_EN is set, then this field is set to 0h.
220h	61:2	-	Reserved. Must be zero.
	1	IDBlockEn	See 4.1 for description of this field.
	0	AuthorKeyEn	See 4.1 for description of this field.
228h	63:0	Policy	See 4.1 for description of this field.
230h	7:0	State	See 4.1 for description of this field.
238h	63:0	OeklvCount	See 4.1 for description of this field.
240h–29Fh		IDBlock	See 8.1 for the description of this field and Table 51 for the format of the field.
2A0h	127:0	GOSVW	See 4.1 for description of this field.
2B0h – 2FFh		-	Reserved. Must be zero.

If IMI\_EN message parameter is 0, the firmware makes the exported guest unable to run on this platform.

If IMI\_EN message parameter is 1, the firmware allows the exported guest to continue running on this platform. The IMI within the guest is expected to make itself not runnable after it has completed migration.

If IMI\_EN message parameter is 1, the firmware does not export the RootMDEntry. Instead, it writes 0h to the RootMDEntry field.

## 7.5 VM Import

When the hypervisor wishes to receive a migrated guest from another system, it first constructs a guest context with SNP\_GCTX\_CREATE. The hypervisor then passes the new guest context sPA to the migration agent. The migration agent then sends the PSP a request message to import the guest's data to the migration agent. The format of this request is defined in Table 28.

A hypervisor should ensure that all pages of the guest have been swapped out before invoking this command. The RootMDEntry in the guest contest should contain the root metadata entry of the guest that covers all pages of the guest.

**Table 28. MSG\_IMPORT\_REQ Message Structure**

Byte Offset	Bits	Name	Description
00h	63:12	GCTX_PADDR	Bits 63:12 of the sPA of a page donated to the firmware by the hypervisor to contain the guest context.
	11:0	-	Reserved. Must be zero.
08h	31:0	GCTX_SIZE	Size in bytes of the guest context stored in GCTX
0Ch	31:0	GCTX_VERSION	Version of the GCTX field. Set to 2h for this ABI version.
10h–1Fh		-	Reserved. Must be zero.
20h–2AFh		INCOMING_GCTX	Incoming guest context. See Table 27 for the format of this field.

The firmware checks that GCTX\_PADDR is a valid sPA. If not, the firmware returns the status INVALID\_ADDRESS. The firmware then checks that GCTX\_PADDR is a Context page. If not, the firmware returns the status INVALID\_GUEST.

The firmware checks that the guest is in the GSTATE\_INIT state. If not, the firmware returns INVALID\_GUEST\_STATE.

The firmware checks that RootMDEntry of the incoming guest context has its VALID field set to 1. If not, the firmware returns INVALID\_MDATA\_ENTRY.

The firmware copies the incoming guest context into the context page at GCTX\_PADDR. The firmware then sets the fields of the guest context page according to Table 29.

**Table 29. Guest Context Initialized by the MSG\_IMPORT\_REQ Guest Message**

Field	Value
MA	The GCTX_PADDR of the migration agent that sent this message.
IMIEn	0

The firmware transitions the guest to the GSTATE\_RUNNING state.

The firmware responds with a message containing the status of the import. The response message is defined in Table 30.

**Table 30. MSG\_IMPORT\_RSP Message Structure**

Byte Offset	Bits	Name	Description
0h	31:0	STATUS	Status of the import operation
4h–Fh		-	Reserved.

## 7.6 VM Absorb

When an IMI is used to accelerate guest migration, a migration agent imports the new guest using the MSG\_ABSORB\_REQ message. This message requests that, after the hypervisor has launched the IMI, the firmware replace the guest's context with the context migrated from another machine.

The migration agent sends the firmware an MSG\_ABSORB\_REQ message as described in Table 31.

**Table 31. MSG\_ABSORB\_REQ Message Structure**

Byte Offset	Bits	Name	Description
00h	63:12	GCTX_PADDR	Bits 63:12 of the sPA of a page donated to the firmware by the hypervisor to contain the guest context.
	11:0	-	Reserved. Must be zero.
08h	31:0	IN_GCTX_SIZE	Size in bytes of the guest context stored in GCTX.
0Ch	31:0	IN_GCTX_VERSION	Version of the GCTX field. Set to 2h for this ABI version.
10h–1Fh		-	Reserved.
20h–28Fh		IN_GCTX	Incoming guest context. See Table 26 for the format of this field.

The firmware checks that GCTX\_PADDR is a valid sPA. If not, the firmware returns the status INVALID\_ADDRESS. The firmware then checks that GCTX\_PADDR is a Context page. If not, the firmware returns the status INVALID\_GUEST.

The firmware checks that the guest is in the `GSTATE_LAUNCH` state. The firmware also checks that `GCTX.IMIEn` is 1. If either check fails, the firmware returns the status `INVALID_GUEST_STATE`.

The firmware checks that the `IN_GCTX.IMD` is equal to `GCTX.LD`. If not, the firmware returns the status `BAD_MEASUREMENT`.

The firmware checks that it supports the `IN_GCTX_VERSION` and that the `IN_GCTX_SIZE` is compatible with this version. If not, the firmware returns the status `INVALID_PARAM`.

The firmware checks that `RootMDEntry` of the incoming guest context has its `VALID` field set to 0. If not, the firmware returns `INVALID_MDATA_ENTRY`.

Because the guest that sent this message is the new migration agent of the incoming guest, the firmware sets the `GCTX.MA` of the incoming guest context to `GCTX_PADDR`.

The firmware overwrites the guest context at `GCTX_PADDR` with the guest context in the `IN_GCTX` field. The firmware then sets the state of the guest to the `GSTATE_RUNNING` state.

The firmware responds with a message containing the status of the import. The response message is defined in Table 32.

**Table 32. MSG\_ABSORB\_RSP Message Structure**

Byte Offset	Bits	Name	Description
0h	31:0	STATUS	Status of the absorb operation
4h–Fh		-	Reserved. Must be zero.

## 7.7 VM Absorb – No Migration Agent

This message is similar in use to the `MSG_ABSORB_REQ` except that it allows a guest to import its own guest context. This can be used with the `MSG_EXPORT_REQ` message to allow a guest to manage its migration without a migration agent.

**Table 33. MSG\_ABSORB\_NOMA\_REQ Message Structure**

Byte Offset	Bits	Name	Description
00h	63:0	-	Reserved. Must be zero.
08h	31:0	IN_GCTX_SIZE	Size in bytes of the guest context stored in <code>GCTX</code> .
0Ch	31:0	IN_GCTX_VERSION	Version of the <code>GCTX</code> field. Set to 2h for this ABI version.
10h–1Fh		-	Reserved.
20h–28Fh		IN_GCTX	Incoming guest context. See Table 26 for the format of this field.



The firmware checks that GCTX.MA is INVALID\_PADDR. That is, the guest sending this message has no migration agent. If this check fails, the firmware returns the status INVALID\_GUEST.

The firmware checks that the IN\_GCTX.IMD is equal to GCTX.LD and IN\_GCTX.IMD is equal to GCTX.IMD. If not, the firmware returns the status BAD\_MEASUREMENT.

The firmware checks that it supports the IN\_GCTX\_VERSION and that the IN\_GCTX\_SIZE is compatible with this version. If not, the firmware returns the status INVALID\_PARAM.

The firmware checks that RootMDEntry of the incoming guest context has its VALID field set to 0. If not, the firmware returns INVALID\_MDATA\_ENTRY.

The firmware overwrites the guest context at GCTX\_PADDR with the guest context in the IN\_GCTX field excluding the following fields.

- HostData
- IDKeyDigest
- AuthorKeyDigest
- ReportId
- IDBlockEn
- AuthorKeyEn
- State
- IDBlock

The firmware responds with a message containing the status of the import. The response message is defined in Table 32.

**Table 34. MSG\_ABSORB\_NOMA\_RSP Message Structure**

Byte Offset	Bits	Name	Description
0h	31:0	STATUS	Status of the absorb operation
4h–Fh		-	Reserved. Must be zero.

## 7.8 VMRK Message

During launch, the migration agent of the guest sends the VMRK to use for the guest. It must be encrypted with the migration agent's VMPCCK0. If not, the firmware returns INVALID\_PARAM.

The structure of the VMRK message is defined in Table 35.

**Table 35. Structure of the MSG\_VMRK\_REQ Guest Message**

Byte Offset	Bits	Name	Description
0h	63:12	GCTX_PADDR	Bits 63:12 of the sPA of a page donated to the firmware by the hypervisor to contain the guest context.
	11:0	-	Reserved. Must be zero.
4h–1Fh		-	Reserved. Must be zero.
20h	255:0	VMRK	A VMRK generated by a migration agent.

The firmware checks that GCTX\_PADDR is a valid sPA. If not, the firmware returns the status `INVALID_ADDRESS`. The firmware then checks that GCTX\_PADDR is a Context page. If not, the firmware returns the status `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` state. The firmware also checks that `GCTX.IMIEn` is 0. If either check fails, the firmware returns the status `INVALID_GUEST_STATE`.

The firmware checks that `GCTX.MA` of the guest matches the `GCTX_PADDR` of the migration agent—that is, the guest sending the `MSG_VMRK_REQ` message. If not, the firmware returns the status `INVALID_GUEST`.

The firmware installs the VMRK into the guest's `GCTX.VMRK`.

The firmware responds with a message containing the status. The response message is defined in Table 36.

**Table 36. MSG\_VMRK\_RSP Message Structure**

Byte Offset	Bits	Name	Description
0h	31:0	STATUS	Status of the VMRK operation.
4h–Fh		-	Reserved.

# Chapter 8 Command Reference

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## 8.1 DOWNLOAD\_FIRMWARE

This command allows the hypervisor to install new SNP firmware newer than the currently active firmware. This command is a legacy SEV command and documented in Section 5 of [SEV].

In addition to the checks performed in [SEV], the SNP platform state must be UNINIT. If not, the firmware returns INVALID\_PLATFORM\_STATE.

## 8.2 GET\_ID

This command returns a unique ID for the system that can be used to obtain a certificate for the VCEK from AMD's Key Distribution Server. This command is a legacy SEV command and documented in Section 5 of [SEV].

In addition to the checks in [SEV], the firmware also checks that, if the SNP firmware state is INIT, the 16 B buffer pointed at by ID\_PADDR resides entirely in Firmware or Default pages. Otherwise, the firmware returns INVALID\_PAGE\_STATE.

## 8.3 SNP\_PLATFORM\_STATUS

This command returns information about the current status and capabilities of the platform.

### 8.3.1 Parameters

**Table 37. Layout of the CMDBUF\_SNP\_PLATFORM\_STATUS Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:0	In	STATUS_PADDR	sPA to write the platform status structure. See Table 38.

### 8.3.2 Actions

The platform may be in any state when this command is called.

The firmware checks that STATUS\_PADDR is a valid sPA. If not, the firmware returns INVALID\_ADDRESS.

If the SNP firmware state is INIT, the page must be either a Firmware or Default page. If not, the firmware returns INVALID\_PAGE\_STATE.

If the platform state is UNINIT, the firmware does not check the state or size of the page.

The following data structure is written to memory at STATUS\_PADDR

**Table 38. Layout of the STRUCT\_PLATFORM\_STATUS Structure**

Byte Offset	Bits	Name	Description
00h	7:0	API_MAJOR	Major API version.
01h	7:0	API_MINOR	Minor API version.
02h	7:0	STATE	The current platform state, zero extended. See 3.2 for encodings.
03h	7:1	-	Reserved.
	0	IS_RMP_INIT	Set to the value of IsRmpInitializied.
04h	31:0	BUILD	Firmware build ID for this API version.
08h	31:1	-	Reserved.
	0	MASK_CHIP_ID	Set to the value of MaskChipId.
0Ch	31:0	GUEST_COUNT	The number of guests currently managed by the firmware.
10h	63:0	PLATFORM_VERSION	The installed TCB version.
18h	63:0	REPORTED_TCB	The reported TCB version in guest attestation reports.

### 8.3.3 Status Codes

**Table 39. Status Codes for SNP\_PLATFORM\_STATUS**

Status	Condition
SUCCESS	Successful completion.
INVALID_ADDRESS	The address is invalid for use by the firmware.
INVALID_PARAM	MBZ fields are not zero.
INVALID_PAGE_STATE	The page at STATUS_PADDR is not in the correct RMP page state.

## 8.4 SNP\_CONFIG

This command sets the system wide configuration values for SNP.

### 8.4.1 Parameters

**Table 40. Layout of the CMDBUF\_SNP\_CONFIG\_STATUS Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:0	In	REPORTED_TCB	The TCB version string to report in guest attestation reports.
08h	31:1	-	-	Reserved. Must be zero.
	0	In	MASK_CHIP_ID	Indicates that the CHIP_ID field in the attestation report will always be zero.
0Ch – 3Fh		-	-	Reserved. Must be zero.

### 8.4.2 Actions

The firmware checks that the REPORTED\_TCB parameter is less than or equal to the installed TCB version. If not, the firmware returns INVALID\_PARAM.

The firmware sets the system wide ReportedTcb value to REPORTED\_TCB.

The firmware sets the system wide MaskChipId to MASK\_CHIP\_ID.

### 8.4.3 Status Codes

**Table 41. Status Codes for SNP\_CONFIG\_STATUS**

Status	Condition
SUCCESS	Successful completion.
INVALID_PARAM	The desired reported TCB string is invalid
INVALID_PLATFORM_STATE	The platform is not in the INIT state

## **8.5 SNP\_INIT**

This command validates the platform configuration of the SNP and initializes the firmware. This command is a specialization of the SNP\_INIT\_EX command.

### **8.5.1 Parameters**

None.

### **8.5.2 Actions**

This command behaves as if SNP\_INIT\_EX was called with INIT\_RMP set to 1 and all other parameters set to zero.

### **8.5.3 Status Codes**

See SNP\_INIT\_EX.



## 8.6 SNP\_INIT\_EX

This command validates the platform configuration of the SNP and initializes the firmware.

### 8.6.1 Parameters

#### Layout of the CMDBUF\_SNP\_INIT\_EX Structure

Byte Offset	Bits	In/Out	Name	Description
00h	31:1	-	-	Reserved. Must be zero.
	0	In	INIT_RMP	Indicates that the RMP should be initialized.
04h – 39h		-	-	Reserved. Must be zero.

### 8.6.2 Actions

Before invoking SNP\_INIT\_EX with INIT\_RMP set to 1, software must ensure that no CPUs contain dirty cache lines for the memory containing the RMP.

The firmware checks that the platform is in the UNINIT state. The firmware also checks that SEV-legacy firmware is not already initialized. If either check fails, the firmware returns INVALID\_PLATFORM\_STATE.

If INIT\_RMP is 0, then the firmware determines if SNP can be initialized securely without initializing the RMP table. The firmware requires initialization if the RMP is not yet initialized. The firmware may also require initialization for other reasons, such as if the RMP was incompatibly initialized by a previous version of the firmware. If the firmware determines the RMP requires initialization, the firmware returns RMP\_INIT\_REQUIRED.

If INIT\_RMP is 1, then the firmware ensures the following system requirements are met:

- SYSCFG[MemoryEncryptionModEn] must be set to 1 across all cores (SEV must be enabled)
- SYSCFG[SecureNestedPagingEn] must be set to 1 across all cores
- SYSCFG[VMPLEn] must be set to 1 across all cores.
- VM\_HSAVE\_PA (MSR C001\_0117) must be set to 0h across all cores

If any of the above checks fail, the firmware returns INVALID\_CONFIG.

If INIT\_RMP is 1, then the firmware also ensures that the following requirements for the RMP have been met:

- RMP\_BASE and RMP\_END must be set identically across all cores
- RMP\_BASE must be 1 MB aligned

- $RMP\_END - RMP\_BASE + 1$  must be a multiple of 1 MB
- RMP is large enough to protect itself

If any of the above checks fail, the firmware returns `INVALID_ADDRESS`.

If `INIT_RMP` is 1, then the firmware alters the RMP such that pages of the RMP are in the Firmware state and all other pages covered by the RMP are in the Hypervisor state, The firmware also initializes any microarchitectural data structures within the RMP. Immediately after completing RMP initialization, the firmware forces a TLB flush across all cores on all sockets.

The firmware marks all encryption capable ASIDs as unusable for encrypted virtualization.

The firmware sets the platform state to `INIT`.

### 8.6.3 Status Codes

**Table 42. Status Codes for `SNP_INIT`**

Status	Condition
<code>SUCCESS</code>	Successful completion.
<code>INVALID_CONFIG</code>	The system is not in a valid configuration that can support SNP.
<code>INVALID_PLATFORM_STATE</code>	The platform is not in the <code>UNINIT</code> state.
<code>INVALID_ADDRESS</code>	<code>RMP_BASE</code> or <code>RMP_END</code> are not valid addresses
<code>RMP_INIT_REQUIRED</code>	Initialization of the RMP is required.

## 8.7 SNP\_GCTX\_CREATE

This command donates a page from the hypervisor to the firmware to be used to store the guest context.

### 8.7.1 Parameters

**Table 43. Layout of the CMDBUF\_SNP\_GCTX\_CREATE Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of a page donated to the firmware by the hypervisor to contain the guest context.
	11:0	-	-	Reserved. Must be zero.

### 8.7.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the donated context page is in the Firmware state. If not, the firmware returns `INVALID_PAGE_STATE`. The firmware checks that the donated page is marked as a 4 KB page in the RMP. If not, the firmware returns `INVALID_PAGE_SIZE`.

The firmware transitions the page to the Context state and initializes the guest context according to Table 44. All other fields within the guest context remain indeterminate until they are initialized through the launch process or through the import process.

**Table 44. Guest Context Initialized by the SNP\_GCTX\_CREATE Command**

Field	Value
ASID	Set to 0h indicating that no ASID has been associated with this guest.
State	<code>GSTATE_INIT</code> .
VEK	Generated using a CSRNG.
OeklvCount	0h

### 8.7.3 Status Codes

**Table 45. Status Codes for SNP\_GCTX\_CREATE**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_ADDRESS	The address is invalid for use by the firmware.
INVALID_PARAM	MBZ fields are not zero.
INVALID_PAGE_STATE	The page is not in the Firmware state.
INVALID_PAGE_SIZE	The page is not a 4 KB page.

## 8.8 SNP\_ACTIVATE

This command installs the guest's VEK into the memory controller in the key slot associated with a given ASID.

### 8.8.1 Parameters

**Table 46. Layout of the CMDBUF\_SNP\_ACTIVATE Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of a page donated to the firmware by the hypervisor to contain the guest context.
	11:0	-	-	Reserved. Must be zero.
08h	31:0	In	ASID	ASID to bind to the guest.

### 8.8.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page at `GCTX_PADDR` is in the Context state. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` state or in the `GSTATE_RUNNING` state. If not, the firmware returns `INVALID_GUEST_STATE`.

The firmware checks that `ASID` is an encryption capable ASID and must be within the range `1h` to `(MIN_SEV_ASID-1)`, inclusive. The `MIN_SEV_ASID` value is discovered by `CPUID Fn8000_001F[EDX]`. If not, the firmware returns `INVALID_ASID`. If the ASID is already assigned to another guest, the firmware returns `ASID_OWNED`. If the guest is already activated, the firmware returns `ACTIVE`.

The firmware checks that a `DF_FLUSH` is not required. If a `DF_FLUSH` is required, the firmware returns `DFFLUSH_REQUIRED`. Note that all ASIDs are marked to require a `DF_FLUSH` at reset.

The firmware checks that there are no pages assigned to the ASID in the RMP. If not, the firmware returns `INVALID_CONFIG`.

The firmware installs the guest's VEK into the memory controllers in the key slot associated with the given ASID.

### 8.8.3 Status Codes

**Table 47. Status Codes for SNP\_ACTIVATE**

Status	Condition
SUCCESS	Successful completion.
INVALID_CONFIG	ASID has pages assigned to it already.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_GUEST_STATE	The guest is not in the LAUNCH state.
INVALID_ADDRESS	The address is invalid for use by the firmware.
INVALID_PARAM	MBZ fields are not zero.
INVALID_GUEST	The guest is invalid.
INVALID_ASID	The provided ASID is not an encryption capable ASID.
ASID_OWNED	The ASID is already owned by another guest.
ACTIVE	The guest is already activated.
DFFLUSH_REQUIRED	DF_FLUSH was not invoked before this command.

## 8.9 SNP\_ACTIVATE\_EX

This command installs the guest's VEK into the memory controller in the key slot associated with a given ASID on select core complexes. Only hardware threads in the selected core complex may execute the guest. When an ASID is later re-used, WBINVD need be done only on core complexes associated with the guest.

### 8.9.1 Parameters

**Table 48. Layout of the CMDBUF\_SNP\_ACTIVATE\_EX Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	31:0	In	EX_LEN	Length of command buffer. 20h for this version.
04h	31:0	-	-	Reserved.
08h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of a page donated to the firmware by the hypervisor to contain the guest context.
	11:0	-	-	Reserved. Must be zero.
10h	31:0	In	ASID	The ASID in which the guest should be bound.
14h	31:0	In	NUMIDs	Number of APIC IDs in the ID_PADDR list.
18h	63:0	In	ID_PADDR	Bits 63:0 of the sPA of a list of 32-bit APIC IDs.

### 8.9.2 Actions

The firmware checks that the platform is in the INIT state. If not, the firmware returns INVALID\_PLATFORM\_STATE.

The firmware checks that GCTX\_PADDR is a valid sPA. If not, the firmware returns INVALID\_ADDRESS. The firmware then checks that the page at GCTX\_PADDR is in the Context state. If not, the firmware returns INVALID\_GUEST.

The firmware checks that the guest is in the GSTATE\_LAUNCH state or in the GSTATE\_RUNNING state. If not, the firmware returns INVALID\_GUEST\_STATE.

The firmware checks that ASID is an encryption capable ASID. If not, the firmware returns INVALID\_ASID. If the ASID is already assigned to another guest, the firmware returns ASID\_OWNED. If the guest is already activated but on a different ASID, the firmware returns ACTIVE.

The firmware checks that a DF\_FLUSH is not required. If so, the firmware returns DFFLUSH\_REQUIRED. Note that all ASIDs are marked to require a DF\_FLUSH at reset.

If the guest is not yet activated, the firmware checks that there are no pages assigned to the ASID in the RMP. If not, the firmware returns INVALID\_CONFIG.

The firmware installs the guest's VEK into the memory controllers for the given APIC IDs into the key slot associated with the given ASID. This command can be called multiple times in order to expand the set of CCXs on which the guest may execute.

### 8.9.3 Status Codes

**Table 49. Status Codes for SNP\_ACTIVATE\_EX**

Status	Condition
INVALID_CONFIG	ASID has pages assigned to it already.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_GUEST_STATE	The guest is not in the LAUNCH state.
INVALID_ADDRESS	The address is invalid for use by the firmware.
INVALID_PARAM	MBZ fields are not zero.
INVALID_GUEST	The guest is invalid.
INVALID_ASID	The provided ASID is not an encryption capable ASID.
ASID_OWNED	The ASID is already owned by another guest.
ACTIVE	The guest is already activated.
DFFLUSH_REQUIRED	DF_FLUSH was not invoked before this command.
SUCCESS	Successful completion.



## 8.10 SNP\_DECOMMISSION

This command destroys a guest context. After this command successfully completes, the guest will not long be runnable.

### 8.10.1 Parameters

**Table 50. Layout of the CMDBUF\_SNP\_DECOMMISSION Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest's context page.
	11:0	-	-	Reserved. Must be zero.

### 8.10.2 Actions

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

The firmware checks that the `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the page is a Context page. If not, the firmware returns `INVALID_GUEST`.

The firmware marks the ASID of the guest as not runnable. Then, the firmware records that each CPU core on each of the CCXs that the guest was activated on requires a `WBINVD` followed by a single `DF_FLUSH` command to ensure that all unencrypted data in the caches are invalidated before reusing the ASID. The firmware then transitions the page into a Firmware page.

### 8.10.3 Status Codes

**Table 51. Status Codes for SNP\_DECOMMISSION**

Status	Condition
<code>SUCCESS</code>	Successful completion.
<code>INVALID_PLATFORM_STATE</code>	The platform is not in the INIT state.
<code>INVALID_ADDRESS</code>	The address is not valid or is misaligned.
<code>INVALID_PARAM</code>	MBZ fields are not zero.
<code>INVALID_GUEST</code>	The guest is not valid.

## 8.11 SNP\_DF\_FLUSH

This command flushes SOC data buffers after CPU caches have been invalidated. After a VM is decommissioned or exported, the hypervisor must execute a WBINVD on the cores that the previous guest was active on before invoking the SNP\_DF\_FLUSH command. The combination of WBINVD and SNP\_DF\_FLUSH ensures that all data associated with the previous guest is no longer in any CPU caches.

### 8.11.1 Parameters

None

### 8.11.2 Actions

For each core marked for cache invalidation, the firmware checks that the core has executed a WBINVD instruction. If not, the firmware returns WBINVD\_REQUIRED. The commands that mark cores for cache invalidation include SNP\_DECOMMISSION and the guest request MSG\_EXPORT\_REQ.

The firmware flushes the write buffers of the data fabric and records that a flush has been performed for all decommissioned ASIDs.

### 8.11.3 Status Codes

**Table 52. Status Codes for SNP\_DF\_FLUSH**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The firmware is not in the INIT state.
WBINVD_REQUIRED	At least one core did not execute a WBINVD instruction before calling this command.

## 8.12 SNP\_SHUTDOWN

This command returns the firmware to an uninitialized state.

### 8.12.1 Parameters

None

### 8.12.2 Actions

If the SNP firmware is in the UNINIT state, the firmware returns SUCCESS without taking any further action.

If SEV firmware is not in the UNINIT state, the firmware returns INVALID\_PLATFORM\_STATE.

If the SNP firmware is in the INIT state, the firmware checks for every encryption capable ASID that the ASID is not in use by a guest and a DF\_FLUSH is not required. If a DF\_FLUSH is required, the firmware returns DFFLUSH\_REQUIRED. The firmware then clears the encryption keys out of the memory controller. Finally, the firmware transitions the platform to the UNINIT state and returns SUCCESS.

Note that the firmware will not automatically reclaim any pages marked as immutable in the RMP. The hypervisor should either reclaim the pages using SNP\_PAGE\_RECLAIM or should call SNP\_INIT afterwards to reset the RMP.

### 8.12.3 Status Codes

**Table 53. Status Codes for SNP\_SHUTDOWN**

Status	Condition
INVALID_PLATFORM_STATE	SEV is not in the UNINIT state.
DFFLUSH_REQUIRED	DF_FLUSH was not invoked before this command
SUCCESS	Successful completion.

## 8.13 SNP\_LAUNCH\_START

This command initializes the flow to launch a guest.

### 8.13.1 Parameters

**Table 54. Layout of the CMDBUF\_SNP\_LAUNCH\_START Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:0	In	POLICY	Guest policy. See Table 7 for a description of the guest policy structure.
10h	63:12	In	MA_GCTX_PADDR	Bits 63:12 of the sPA of the guest context of the migration agent. Ignored if MA_EN is 0.
	11:0	In	-	Reserved. Must be zero.
18h	31:2	-	-	Reserved. Must be zero.
	1	In	IMI_EN	Indicates that this launch flow is launching an IMI for the purpose of guest-assisted migration.
	0	In	MA_EN	1 if this guest is associated with a migration agent. Otherwise 0.
1Ch	31:0	-	-	Reserved. Must be zero.
20h	127:0	In	GOSVW	Hypervisor provided value to indicate guest OS visible workarounds. The format is hypervisor defined.

### 8.13.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If `MA_EN` is 1, the firmware checks that `MA_GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that `GCTX_PADDR` is a Context page. If `MA_EN` is 1, the firmware checks that `MA_GCTX_PADDR` is a Context pages. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_INIT` state. If not, the firmware returns `INVALID_GUEST_STATE`.

The firmware checks that the guest's policy is satisfied by checking that the following conditions are met:

- If MA\_EN is 1, POLICY.MIGRATE\_MA must be 1.
- If MA\_EN is 1, then the migration agent must not be migratable—that is, the migration agent itself must not be bound to another migration agent.
- If POLICY.SMT is 0, then SMT must be disabled.
- POLICY.ABI\_MAJOR must be equal the major version of this ABI.
- POLICY.ABI\_MINOR must be less than or equal to the minor version of this ABI.

If any of the above conditions are not met, the firmware returns POLICY\_FAILURE.

The firmware initializes the guest context with the values defined in Table 55.

**Table 55. Guest Context Field Initialization for the Launch Flow**

Field	Value
MsgCount0 MsgCount1 MsgCount2 MsgCount3	0h
Policy	Set to POLICY.
MA	Set to MA_GCTX_PADDR if MA_EN is 1. Set to PADDR_INVALID otherwise.
OEK	Generated using a CSRNG.
VMPCK0 VMPCK1 VMPCK2 VMPCK3	Generated using a CSRNG.
VMRK	Generated using a CSRNG. May be replaced by a VMRK guest message from the associated migration agent. See 7.7.
LD	0h
IMD	0h
IDBlockEn	0
IDBlock	0h
IDKeyDigest	0h
AuthorKeyEn	0
AuthorKeyDigest	0h
ReportID	Generated using a CSRNG.
IMIEn	Set to IMI_EN.
GOSVW	GOSVW field.

The firmware sets the guest state to GSTATE\_LAUNCH.

### 8.13.3 Status Codes

**Table 56. Status Codes for SNP\_LAUNCH\_START**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_ADDRESS	An address was not a valid sPA or properly aligned.
INVALID_PARAM	MBZ fields are not zero.
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest was not in the GSTATE_INIT state.
POLICY_FAILURE	The guest's policy was violated.

## 8.14 SNP\_LAUNCH\_UPDATE

This command inserts pages into the guest physical address space.

### 8.14.1 Parameters

**Table 57. Layout of the CMDBUF\_SNP\_LAUNCH\_UPDATE Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	31:5	-	-	Reserved. Must be zero.
	4	In	IMI_PAGE	Indicates that this page is part of the IMI of the guest.
	3:1	In	PAGE_TYPE	Encoded page type. See Table 58.
	0	In	PAGE_SIZE	Indicates page size. 0 indicates a 4 KB page. 1 indicates a 2 MB page.
0Ch	31:0	-	-	Reserved. Must be zero.
10h	63:12	In	PAGE_PADDR	Bits 63:12 of the sPA of the destination page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.
18h	63:32	-	-	Reserved. Must be zero.
	31:24	In	VMPL3_PERMS	VMPL permission mask for VMPL3. See Table 59 for the definition of the mask.
	23:16	In	VMPL2_PERMS	VMPL permission mask for VMPL2. See Table 59 for the definition of the mask.
	15:8	In	VMPL1_PERMS	VMPL permission mask for VMPL1. See Table 59 for the definition of the mask.
	7:0	-	-	Reserved. Must be zero.

**Table 58. Encodings for the PAGE\_TYPE Field**

Value	Name	Description
00h	-	Reserved.
01h	PAGE_TYPE_NORMAL	A normal data page.
02h	PAGE_TYPE_VMSA	A VMSA page.
03h	PAGE_TYPE_ZERO	A page full of zeroes.
04h	PAGE_TYPE_UNMEASURED	A page that is encrypted but not measured.
05h	PAGE_TYPE_SECRETS	A page for the firmware to store secrets for the guest.

Value	Name	Description
06h	PAGE_TYPE_CPUID	A page for the hypervisor to provide CPUID function values.
All other encodings		Reserved.

**Table 59. VMPL Permission Mask**

Bit	Field	Description
7:4	-	Reserved. Must be zero.
3	Execute-Supervisor	Page is executable by the VMPL in CPL2, CPL1, and CPL0.
2	Execute-User	Page is executable by the VMPL in CPL3.
1	Write	Page is writeable by the VMPL.
0	Read	Page is readable by the VMPL.

### 8.14.2 Actions

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

The firmware checks that `GCTX_PADDR` and `PAGE_PADDR` are valid sPAs. If not, the firmware returns `INVALID_ADDRESS`. The firmware checks that if `PAGE_SIZE` is 1, then `PAGE_PADDR` is 2 MB aligned. If this check fails, the firmware returns `INVALID_ADDRESS`.

The firmware checks that `GCTX_PADDR` is a Context page. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` state. If not, the firmware returns `INVALID_GUEST_STATE`.

The firmware also checks that the page at `PAGE_PADDR` is Pre-Guest page. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the guest is activated—that is, it has an assigned ASID. If not, the firmware returns `INACTIVE`.

The firmware checks that the ASID of the destination page indicated by the RMP matches the ASID of the guest. If not, the firmware returns `INVALID_PAGE_OWNER`.

The firmware checks that the destination page size indicated by the RMP matches the page size indicated by the `PAGE_SIZE` parameter. If not, the firmware returns `INVALID_PAGE_SIZE`.

The firmware checks that if `GCTX.IMIEn` is 1, then `IMI_PAGE` is also 1. If not, then the firmware returns `INVALID_PARAM`.

The firmware checks that if VMPLs are not enabled, then `VMPL1_PERMS`, `VMPL2_PERMS`, and `VMPL3_PERMS` must be zero. If not, the firmware returns `INVALID_PARAM`.



The firmware updates the GCTX.LD and possibly the GCTX.IMD with information describing the contents and location of the pages inserted into the guest. Each update to the digest is of the following form:

$$\text{DIGEST\_NEW} := \text{SHA-384}(\text{PAGE\_INFO})$$

where PAGE\_INFO is the structure defined in Table 60.

**Table 60. Layout of the PAGE\_INFO Structure**

Byte Offset	Bits	Field	Description
0h	383:0	DIGEST_CUR	The value of the current digest (either LD or IMD).
30h	383:0	CONTENTS	The SHA-384 digest of the measured contents of the region, if any. See the following subsections.
60h	15:0	LENGTH	Length of this structure in bytes.
62h	7:0	PAGE_TYPE	The zero-extended PAGE_TYPE field provided by the hypervisor.
63h	7:1	-	0h
	0	IMI_PAGE	Set to the IMI_PAGE flag provided by the hypervisor.
64h	31:24	VMPL3_PERMS	The VMPL3_PERMS field provided by the hypervisor.
	23:16	VMPL2_PERMS	The VMPL2_PERMS field provided by the hypervisor.
	15:8	VMPL1_PERMS	The VMPL1_PERMS field provided by the hypervisor.
	7:0	-	0Fh
68h	63:0	GPA	The 64-bit gPA of the region.

The firmware unconditionally updates GCTX.LD. If IMI\_PAGE is 1, the firmware updates the GCTX.IMD.

The following subsections describe how the PAGE\_TYPE, GPA, and CONTENTS fields are determined.

The following subsections describes the actions the firmware takes on the guest address space depending on the page type, PAGE\_TYPE. If the page size is 2 MB, then the firmware will update the launch digest as if the data were provided in a contiguous sequence of 4 KB pages. The final launch digest is therefore independent of how the hypervisor chooses to size the pages within the nested page tables and in the RMP.

#### 8.14.2.1 PAGE\_TYPE\_NORMAL

The firmware performs the actions in this subsection when PAGE\_TYPE is PAGE\_TYPE\_NORMAL.

For each 4 KB chunk within the page, the firmware constructs a PAGE\_INFO structure with the following data:

- **PAGE\_TYPE:** PAGE\_TYPE\_NORMAL
- **GPA:** The gPA of the 4 KB chunk. The firmware calculates this by adding the offset of the chunk to RMP.GPA of the page.
- **CONTENTS:** The SHA-384 digest of the contents of the 4 KB chunk

The firmware updates GCTX.LD and GCTX.IMD as described above.

The firmware encrypts the page with the VEK in place. The firmware then sets the VMPL permissions for the page and transitions the destination page to Guest-Valid.

#### 8.14.2.2 PAGE\_TYPE\_VMSA

The firmware performs the actions in this subsection when PAGE\_TYPE is PAGE\_TYPE\_VMSA.

The firmware checks that the destination page is 4 KB. If not, the firmware returns INVALID\_PAGE\_SIZE.

The firmware constructs a PAGE\_INFO structure with the following data:

- **PAGE\_TYPE:** PAGE\_TYPE\_VMSA
- **GPA:** The gPA of the 4 KB page. The firmware uses the RMP.GPA of the page.
- **CONTENTS:** The SHA-384 digest of the contents of the 4 KB page

The firmware updates GCTX.LD and GCTX.IMD as described above.

The firmware encrypts the page with the VEK in place. The firmware sets the RMP.VMSA of the page to 1. The firmware sets the VMPL permissions for the page and transitions the page to Guest-Valid.

#### 8.14.2.3 PAGE\_TYPE\_ZERO

The firmware performs the actions in this subsection when PAGE\_TYPE is PAGE\_TYPE\_ZERO.

For each 4 KB chunk within the page, the firmware constructs a PAGE\_INFO structure with the following data:

- **PAGE\_TYPE:** PAGE\_TYPE\_ZERO
- **GPA:** The gPA of the 4 KB chunk. The firmware calculates this by adding the offset of the chunk to RMP.GPA of the page.
- **CONTENTS:** 0h.

The firmware updates GCTX.LD and GCTX.IMD as described above.

The firmware encrypts a page of zeroes with the VEK. The firmware sets the VMPL permissions for the page and transitions the page to Guest-Valid.

#### 8.14.2.4 PAGE\_TYPE\_UNMEASURED

The firmware performs the actions in this subsection when PAGE\_TYPE is PAGE\_TYPE\_UNMEASURED.

For each 4 KB chunk within the page, the firmware constructs a PAGE\_INFO structure with the following data:

- **PAGE\_TYPE:** PAGE\_TYPE\_UNMEASURED
- **GPA:** The gPA of the 4 KB chunk. The firmware calculates this by adding the offset of the chunk to RMP.GPA of the page.
- **CONTENTS:** 0h.

The firmware updates GCTX.LD and GCTX.IMD as described above.

The firmware encrypts the page with the VEK in place. The firmware sets the VMPL permissions for the page and transitions the page to Guest-Valid.

#### 8.14.2.5 PAGE\_TYPE\_SECRETS

The firmware performs the actions in this subsection when PAGE\_TYPE is PAGE\_TYPE\_SECRETS.

The firmware checks that the destination page is 4 KB. If not, the firmware returns INVALID\_PAGE\_SIZE.

The firmware constructs a PAGE\_INFO structure with the following data:

- **PAGE\_TYPE:** PAGE\_TYPE\_SECRETS
- **GPA:** The gPA of the 4 KB page. The firmware uses the RMP.GPA of the page.
- **CONTENTS:** 0h.

The firmware updates GCTX.LD and GCTX.IMD as described above.

The firmware constructs the 4 KB data structure described in Table 56. Reserved fields are set to 0h. The firmware then encrypts the data structure with the guest’s VEK and writes it into the page. The firmware ensures that the data structure content remains confidential to the guest and the firmware.

**Table 61. Secrets Page Format**

Byte Offset	Bits	Name	Description
000h	31:0	VERSION	Version of the secrets page format. The version

Byte Offset	Bits	Name	Description
			described in this specification is 2h.
004h	31:1	-	Reserved.
	0	IMI_EN	Set to the value of GCTX.IMIEn.
008h	31:0	FMS	Family, model, and stepping information as reported in CPUID Fn0000_0001_EAX.
0Ch	31:0	-	Reserved.
10h	127:0	GOSVW	GOSVW guest context field as provided by the hypervisor in SNP_LAUNCH_START.
020h	255:0	VMPCK0	Set to GCTX.VMPCK0.
040h	255:0	VMPCK1	Set to GCTX.VMPCK1.
060h	255:0	VMPCK2	Set to GCTX.VMPCK2.
080h	255:0	VMPCK3	Set to GCTX.VMPCK3.
0A0h – 0FFh		-	Reserved for guest OS usage
100h – 13Fh		-	Reserved.
140h–FFFh		-	Reserved.

The firmware sets the VMPL permissions for the page and transitions the page to Guest-Valid.

#### 8.14.2.6 PAGE\_TYPE\_CPUID

The firmware performs the actions in this subsection when PAGE\_TYPE is PAGE\_TYPE\_CPUID.

The firmware checks that the destination page is 4 KB. If not, the firmware returns INVALID\_PAGE\_SIZE.

The hypervisor should fill the page with CPUID functions structures as described in Table 61. These structures inform the guest of the machine configuration exposed to the guest by the hypervisor. However, a malicious hypervisor could provide a value that puts the guest in an insecure state. Therefore, the firmware checks each CPUID function structure to determine if the provided value is secure.

If firmware encounters a CPUID function that is not in the standard range (Fn0000\_0000 through Fn0000\_FFFF) or the extended range (Fn8000\_0000 through Fn8000\_FFFF), the firmware does not perform any checks on the function output.

If firmware encounters a CPUID function that is in the standard or extended ranges, then the firmware performs a check to ensure that the provided output would not lead to an insecure guest state. If insecure function output is identified, the firmware updates the field with an acceptable value. Note that some functions have multiple acceptable values, and the firmware may choose any one of them. The firmware then returns INVALID\_PARAM. Note that in this failure case, the

page is not encrypted with the VEK, the page measurement is not updated, and the page state remains unaltered.

The policy used by the firmware to assess CPUID function output can be found in [PPR].

The firmware constructs a PAGE\_INFO structure with the following data:

- **PAGE\_TYPE:** PAGE\_TYPE\_CPUID
- **GPA:** The gPA of the 4 KB page. The firmware uses the RMP.GPA of the page.
- **CONTENTS:** 0h.

The firmware updates GCTX.LD and GCTX.IMD as described above.

The page has enough for COUNT\_MAX function structures, but only COUNT function structures are valid. COUNT\_MAX is 64.

The firmware then encrypts the page with the VEK in place.

**Table 62. CPUID Page Format**

Byte Offset	Bits	Name	Description
00h	31:0	COUNT	Number of CPUID functions to validate. Must be less than or equal to COUNT_MAX.
04h	31:0	-	Reserved. Must be zero.
08h	63:0	-	Reserved. Must be zero.
10h–C0Fh		CPUID_FUNCTION[]	COUNT_MAX number of CPUID_FUNCTION records (See 7.1 for the format of this record). Only the first COUNT records are valid.

The firmware sets the VMPL permissions for the page and transitions the page to Guest-Valid.

### 8.14.3 Status Codes

**Table 63. Status Codes for SNP\_LAUNCH\_UPDATE**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_ADDRESS	An address is invalid or incorrectly aligned.
INVALID_PARAM	MBZ fields are not zero.
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest is not in the GSTATE_LAUNCH state.
INACTIVE	The guest has not been activated.
INVALID_PAGE_STATE	A page was not in the correct state.

<b>Status</b>	<b>Condition</b>
INVALID_PAGE_OWNER	The destination page was not owned by the guest.
INVALID_PAGE_SIZE	The destination page was not the correct size.
INVALID_PARAM	IMI_PAGE was incorrectly set.

## 8.15 SNP\_LAUNCH\_FINISH

This command completes the guest launch flow.

### 8.15.1 Parameters

**Table 64. Layout of the CMDBUF\_SNP\_LAUNCH\_FINISH Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:0	In	ID_BLOCK_PADDR	sPA of the ID block. Ignored if ID_BLOCK_EN is 0.
10h	63:0	In	ID_AUTH_PADDR	sPA of the authentication information of the ID block. Ignored if ID_BLOCK_EN is 0.
18h	63:2	-	-	Reserved. Must be zero.
	1	In	AUTH_KEY_EN	Indicates that the author key is present in the ID authentication information structure. Ignored if ID_BLOCK_EN is 0.
	0	In	ID_BLOCK_EN	Indicates that the ID block is present.
20h	255:0	In	HOST_DATA	Opaque host-supplied data to describe the guest. The firmware does not interpret this value.

**Table 65. Structure of the ID Block**

Byte Offset	Bits	Name	Description
0h	383:0	LD	The expected launch digest of the guest.
30h	127:0	FAMILY_ID	Family ID of the guest, provided by the guest owner and uninterpreted by the firmware.
40h	127:0	IMAGE_ID	Image ID of the guest, provided by the guest owner and uninterpreted by the firmware.
50h	31:0	VERSION	Version of the ID block format. Must be 1h for this version of the ABI.
54h	31:0	GUEST_SVN	SVN of the guest.
58h	63:0	POLICY	The policy of the guest.

**Table 66. Structure of the ID Authentication Information Structure**

Byte Offset	Bits	Name	Description
0h	31:0	ID_KEY_ALGO	The algorithm of the ID Key. 1h indicates ECDSA P-384 with SHA-384. All other encodings are reserved.
4h	31:0	AUTH_KEY_ALGO	The algorithm of the Author Key. 1h indicates ECDSA P-384 with SHA-384. All other encodings are reserved. Ignored if AUTH_KEY_EN is 0.
8h–3Fh		-	Reserved. Should be zero.
40h–23Fh		ID_BLOCK_SIG	The signature of all bytes of the the ID block. See Table 67 for the format of the signature.
240h–643h		ID_KEY	The public component of the ID key. See Table 63 for the format of the key.
644h–67Fh		-	Reserved. Should be zero.
680h–87Fh		ID_KEY_SIG	The signature of the ID_KEY. See Table 67 for the format of the signature.
880h–C83h		AUTHOR_KEY	The public component of the Author key. See Table 68 for the format of the key. Ignored if AUTHOR_KEY_EN is 0.
C84h–FFFh		-	Reserved. Should be zero.

**Table 67. Format for an ECDSA P-384 Signature**

Byte Offset	Bits	Name	Description
000h	575:0	R	R component of this signature. Value is zero-extended little-endian encoded.
048h	575:0	S	S component of this signature. Value is zero-extended little-endian encoded.
090h–1FFh		-	Reserved. Must be zero.

**Table 68. Format for an ECDSA P-384 Public Key**

Byte Offset	Bits	Name	Description
000h	31:0	CURVE	Curve ID. 2h indicates P-384. All other encodings are reserved.
004h	575:0	QX	R component of this signature. Value is zero-extended little-endian encoded.
04Ch	575:0	QY	S component of this signature. Value is zero-extended little-endian



Byte Offset	Bits	Name	Description
			encoded.
094h–403h		-	Reserved. Must be zero.

### 8.15.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that `GCTX_PADDR` is a Context page. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` state. The firmware also checks that `GCTX.IMIEN` is 0. If either check fails, the firmware returns `INVALID_GUEST_STATE`.

The firmware checks that the guest is activated—that is, it has an assigned ASID. If not, the firmware returns `INACTIVE`.

The firmware checks that, if `ID_BLOCK_EN` is 1, then `ID_BLOCK_PADDR` and `ID_AUTH_PADDR` are valid sPAs. If not, the firmware returns `INVALID_ADDRESS`.

If `ID_BLOCK_EN` is 1, the firmware checks that the LD field of the ID block is equal to `GCTX.LD`. If not, the firmware returns `BAD_MEASUREMENT`. The firmware then checks that the `POLICY` field of the ID block is equal to `GCTX.Policy`. If not, the firmware returns `POLICY_FAILURE`. The firmware then validates the signature of the ID block using the ID public key. If `AUTH_KEY_EN` is also 1, the firmware validates the signature of the ID key using the Author public key. If either signature fails to validate, the firmware returns `BAD_SIGNATURE`.

The firmware then initializes the guest context fields according to Table 69.

**Table 69. Guest Context Fields Initialized During `SNP_LAUNCH_FINISH`**

Field	Value
HostData	<code>HOST_DATA</code> .
IDBlockEn	<code>ID_BLOCK_EN</code> .
IDBlock	If <code>ID_BLOCK_EN</code> is 1, then set to the ID block. 0 otherwise.
IDKeyDigest	If <code>ID_BLOCK_EN</code> is 1, then set to the SHA-384 digest of the ID public key. 0 otherwise.
AuthorKeyEn	<code>AUTHOR_KEY_EN</code> .
AuthorKeyDigest	If <code>AUTHOR_KEY_EN</code> is 1, then set to the SHA-384 digest of the Author public key. 0 otherwise.

The firmware makes the guest runnable on the ASID it is activated on. The firmware then sets the guest state to `GSTATE_RUNNING`.

### 8.15.3 Status Codes

**Table 70. Status Codes for `SNP_LAUNCH_FINISH`**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_GUEST_STATE	The guest is not in the <code>GSTATE_LAUNCH</code> state or <code>GCTX.IMIEn</code> is not 0.
INVALID_GUEST	The guest is invalid.
INVALID_ADDRESS	An address is invalid or incorrectly aligned.
INVALID_PARAM	MBZ fields are not zero.
INVALID_PAGE_STATE	A page was not in the correct state.
INACTIVE	The guest has not been activated.
BAD_SIGNATURE	Incorrect signature provided.

## 8.16 SNP\_GUEST\_STATUS

This command is used to retrieve information about an SNP guest.

### 8.16.1 Parameters

**Table 71. Layout of the CMDBUF\_SNP\_GUEST\_STATUS Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:0	In	STATUS_PADDR	Bits 63:0 of the sPA of the guest status structure. See Table 72.

### 8.16.2 Actions

The firmware checks that the platform is in the INIT state. If not, the firmware returns INVALID\_PLATFORM\_STATE.

The firmware checks that the GCTX\_PADDR and STATUS\_PADDR are valid sPAs. If either check fails, the firmware returns INVALID\_ADDRESS.

The firmware checks that the guest context page is a Context page. If not, the firmware returns INVALID\_GUEST. The firmware checks that the guest status page is a Firmware or Default page. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware writes the following structure to the beginning of the guest status page.

**Table 72. Layout of the STRUCT\_SNP\_GUEST\_STATUS Structure**

Byte Offset	Bits	Name	Description
00h	63:0	POLICY	Guest policy.
08h	31:0	ASID	Current ASID. If none is assigned, set to 0h.
0Ch	7:0	STATE	Current guest state.
0Dh	7:0	-	Reserved.
0Eh	15:0	-	Reserved.
10h	63:0	-	Reserved.
18h	63:0	-	Reserved.

### 8.16.3 Status Codes

**Table 73. Status Codes for SNP\_GUEST\_STATUS**

<b>Status</b>	<b>Condition</b>
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_ADDRESS	The address is invalid for use by the firmware.
INVALID_PARAM	MBZ fields are not zero.
INVALID_GUEST	The guest context page was invalid.
INVALID_PAGE_STATE	The guest status page was not in the correct state.
INVALID_PAGE_SIZE	The guest status page was not the correct size.

## 8.17 SNP\_PAGE\_MOVE

This command moves the contents of SNP-protected pages within the system physical address space without violating SNP security.

### 8.17.1 Parameters

**Table 74. Layout of the CMDBUF\_SNP\_PAGE\_MOVE Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	31:1	-	-	Reserved. Must be zero.
	0	In	PAGE_SIZE	Indicates page size. 0 indicates a 4 KB page. 1 indicates a 2 MB page.
0Ch	31:0	-	-	Reserved. Must be zero.
10h	63:12	In	SRC_PADDR	Bits 63:12 of the sPA of the source page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.
18h	63:12	In	DST_PADDR	Bits 63:12 of the sPA of the destination page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.

### 8.17.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page at `GCTX_PADDR` is in the Context state. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` or `GSTATE_RUNNING` states. If not, the firmware returns `INVALID_GUEST_STATE`. The firmware then checks that the guest is activated. If not, the firmware returns `INACTIVE`.

The firmware checks that `SRC_PADDR` and `DST_PADDR` are valid sPAs. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the source and destination page sizes indicated by the RMP match the page size indicated by the PAGE\_SIZE parameter. If not, the firmware returns INVALID\_PAGE\_SIZE.

This command operates either on guest pages or on Metadata pages. The following subsections describe each case.

### **8.17.2.1 Guest Pages**

The firmware performs the actions in this section when the source page is a Pre-Swap or Pre-Guest page.

The firmware checks that the destination page is a Pre-Guest page. If either check fails, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the RMP.ASID of both the source and destination pages are equal to the ASID of the guest. If not, the firmware returns INVALID\_PAGE\_OWNER.

The firmware uses the guest's VEK to copy the plaintext of the source page into the plaintext of the destination page.

The firmware sets the RMP.GPA and RMP.VMSA of the destination page to match the RMP.GPA and RMP.VMSA of the source page. If VMPLs are enabled, the firmware also sets the VMPL permissions bits of the destination page to match the VMPL permission bits of the source page.

If the source page is a Pre-Guest page, the firmware transitions the destination page into a Guest-Invalid page. If the source page is a Pre-Swap page, the firmware transitions the destination page into a Guest-Valid page. Finally, the firmware transitions the source page into a Guest-Invalid page.

### **8.17.2.2 Metadata Pages**

The firmware performs the actions in this section when the source page is a Metadata page.

The firmware checks that the destination page is a Firmware page. If either check fails, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the RMP.GPA of the source page is equal to the sPA of the guest context. If not, the firmware returns INVALID\_PAGE\_OWNER.

The firmware copies the contents of the source page into the destination page. The firmware then sets the RMP.GPA of the destination to match the sPA of the guest context page and transitions the destination page into a Metadata page.

Finally, the firmware transitions the source page into a Firmware page.

### 8.17.3 Status Codes

**Table 75. Status Codes for SNP\_PAGE\_MOVE**

<b>Status</b>	<b>Condition</b>
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	MBZ fields are not zero.
INVALID_ADDRESS	An address is invalid for use by the firmware or is misaligned.
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest is not in the correct state.
INACTIVE	The guest is not activated.
INVALID_PAGE_STATE	A page was in the incorrect state.
INVALID_PAGE_OWNER	A page was not owned by the guest.
INVALID_PAGE_SIZE	A page was not the correct size.

## 8.18 SNP\_PAGE\_MD\_INIT

This command constructs a new Metadata page that can be used to store metadata entries.

### 8.18.1 Parameters

**Table 76. Layout of the CMDBUF\_SNP\_PAGE\_MD\_INIT Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:12	In	PAGE_PADDR	Bits 63:12 of the sPA of the page to turn into a metadata page.
	11:0	-	-	Reserved. Must be zero.

### 8.18.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page at `GCTX_PADDR` is in the Context state. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` or `GSTATE_RUNNING` states. If not, the firmware returns `INVALID_GUEST_STATE`.

The firmware checks that `PAGE_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page pointed at by `PAGE_PADDR` is a Firmware page. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware zeroes the page then transitions the page into a Metadata page and setting its `RMP.GPA` to `GCTX_PADDR`.

### 8.18.3 Status Codes

**Table 77. Status Codes for SNP\_PAGE\_MD\_INIT**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	MBZ fields are not zero.
INVALID_ADDRESS	An address is invalid for use by the firmware or is misaligned.



<b>Status</b>	<b>Condition</b>
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest is not in the correct state.
INVALID_PAGE_STATE	A page was in the incorrect state.

## 8.19 SNP\_PAGE\_SWAP\_OUT

This command swaps an SNP-protected page out so that the hypervisor can relieve memory pressure or migrate the guest.

### 8.19.1 Parameters

**Table 78. Layout of the CMDBUF\_SNP\_PAGE\_SWAP\_OUT Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the Guest Context page.
	11:0	In	-	Reserved. Must be zero.
08h	63:12	In	SRC_PADDR	Bits 63:12 of the sPA of the source page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.
10h	63:12	In	DST_PADDR	Bits 63:12 of the sPA of the destination page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.
18h	63:0	In	MDATA_PADDR	Bits 63:0 of the sPA of a metadata entry. See 2.1 for the format of a metadata entry. Ignored if ROOT_MDATA_EN is 1.
20h	63:0	In	SOFTWARE_DATA	Software available data supplied by the hypervisor.
28h	63:5	-	-	Reserved. Must be zero.
	4	In	ROOT_MDATA_EN	Indicates that the metadata entry will be stored in the guest context and not in MDATA_PADDR.
	3	-	-	Reserved. Must be zero.
	2:1	In	PAGE_TYPE	Indicates the page type of the source page. 0h indicates a Data page. 1h indicates a Metadata page. 2h indicates a VMSA page. Other encodings are reserved.
	0	In	PAGE_SIZE	Indicates page size. 0 indicates a 4 KB page. 1 indicates a 2 MB page.

## 8.19.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page at `GCTX_PADDR` is in the Context state. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` or `GSTATE_RUNNING` states. If not, the firmware returns `INVALID_GUEST_STATE`. The firmware then checks that the guest is activated. If not, the firmware returns `INACTIVE`.

The firmware checks that `SRC_PADDR`, `DST_PADDR` are valid sPAs. If `ROOT_MDATA_EN` is 0, the firmware also checks that `MDATA_PADDR` is a valid sPA, is aligned to the size of an MDATA structure (64 B) and does not overlap the source or destination pages. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the source page size indicated by the RMP matches the page size indicated by the `PAGE_SIZE` parameter. If the destination page is not a Default page, the firmware checks that the destination page size also matches the `PAGE_SIZE` parameter. If either check fails, the firmware returns `INVALID_PAGE_SIZE`.

If `ROOT_MDATA_EN` is 0, then the firmware checks that the page containing `MDATA_PADDR` is a Metadata page. If not, the firmware returns `INVALID_PAGE_STATE`. Then the firmware checks that the RMP.GPA of the page containing `MDATA_ENTRY` matches `GCTX_PADDR`. If not, the firmware returns `INVALID_PAGE_OWNER`.

This command operates on data pages, metadata pages, or VMSA pages. The firmware performs the actions in one of the following subsections depending on the value of `PAGE_TYPE`.

### 8.19.2.1 Data Pages

The actions in this section are performed only when `PAGE_TYPE` is 0h.

The firmware checks that the source page is a Pre-Swap or a Pre-Guest page. The firmware then checks that the destination page is a Firmware or Default page. If either check fails, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the RMP.ASID of the source page matches the ASID of the guest. If not, the firmware returns `INVALID_PAGE_OWNER`.

The firmware uses the guest's VEK to decrypt the contents of the source page and uses the guest's OEK to wrap the contents with `Aead_Wrap()` (see Chapter 9) without AAD. The firmware checks that incrementing the `OekIvCount` would not cause an overflow. If overflow would occur, the firmware returns `AEAD_OFLOW`. Otherwise, the firmware increments the `OekIvCount` and uses

that new value as the IV. The firmware then writes the produced ciphertext into the destination page.

The firmware then constructs a MDATA structure as described in Table 79. If ROOT\_MDATA\_EN is 0, the firmware writes the MDATA entry at MDATA\_PADDR. If ROOT\_MDATA\_EN is 1, the firmware writes the MDATA entry into GCTX.RootMDEntry.

**Table 79. Metadata Entry (MDATA) for Data Pages**

MDATA Field	Value
SOFTWARE_DATA	SOFTWARE_DATA.
IV	Constructed from OekIvCount.
AUTH_TAG	Authentication tag generated by Aead_Wrap().
PAGE_SIZE	RMP.Page_Size of the source page.
VALID	1
METADATA	0
VMSA	0
GPA	gPA of the source page.
PAGE_VALIDATED	RMP.Validated of the source page.
VMPL0	RMP.VMPL0 of the source page if VMPLs are enabled. 0h otherwise.
VMPL1	RMP.VMPL1 of the source page if VMPLs are enabled. 0h otherwise.
VMPL2	RMP.VMPL2 of the source page if VMPLs are enabled. 0h otherwise.
VMPL3	RMP.VMPL3 of the source page if VMPLs are enabled. 0h otherwise.

The firmware then transitions the source page into a Pre-Guest page state.

### 8.19.2.2 Metadata Page

The actions in this section are performed only when PAGE\_TYPE is 1h.

The firmware checks that the source page is a Metadata page. The firmware then checks that the destination page is a Firmware or Default page. If either check fails, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the RMP.GPA of the source page matches GCTX\_PADDR. If not, the firmware returns INVALID\_PAGE\_OWNER.

The firmware uses the guest's OEK to wrap the contents of the source page with Aead\_Wrap() without AAD. The firmware checks that incrementing the OekIvCount would not cause an overflow. If overflow would occur, the firmware returns AEAD\_OFLOW. Otherwise, the firmware increments the OekIvCount and uses that new value as the IV. The firmware then writes the produced ciphertext into the destination page.

The firmware then constructs a MDATA structure as described in Table 80. If ROOT\_MDATA\_EN is 0h, the firmware writes the MDATA entry at MDATA\_PADDR. If ROOT\_MDATA\_EN is 1h, the firmware writes the MDATA entry into GCTX.RootMDEntry.

**Table 80. Metadata Entry (MDATA) for Metadata Pages**

MDATA Field	Value
SOFTWARE_DATA	SOFTWARE_DATA.
IV	Constructed from OekIvCount.
AUTH_TAG	Authentication tag generated by Aead_Wrap().
PAGE_SIZE	RMP.Page_Size of the source page.
VALID	1
METADATA	1
VMSA	0
GPA	PADDR_INVALID.
PAGE_VALIDATED	0
VMPL0	0h
VMPL1	0h
VMPL2	0h
VMPL3	0h

The firmware then transitions the source page into a Firmware page state.

### 8.19.2.3 VMSA Pages

The actions in this section are performed only when PAGE\_TYPE is 2h.

The firmware checks that the source page is a Pre-Swap or Pre-Guest page. The firmware then checks that the destination page is a Firmware or Default page. If either check fails, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the RMP.ASID of the source page matches the ASID of the guest. If not, the firmware returns INVALID\_PAGE\_OWNER.

The firmware uses the guest's OEK to wrap the contents of the source page with Aead\_Wrap() without AAD. The firmware checks that incrementing the OekIvCount would not cause an overflow. If overflow would occur, the firmware returns AEAD\_OFLOW. Otherwise, the firmware increments the OekIvCount and uses that new value as the IV. The firmware then writes the produced ciphertext into the destination page.

The firmware then constructs a MDATA structure as described in Table 81. If ROOT\_MDATA\_EN is 0, the firmware writes the MDATA entry at MDATA\_PADDR. If ROOT\_MDATA\_EN is 1, the firmware writes the MDATA entry into GCTX.RootMDEntry.

**Table 81. Metadata Entry (MDATA) for Data Pages**

MDATA Field	Value
SOFTWARE_DATA	SOFTWARE_DATA.
IV	Constructed from OeklvCount.
AUTH_TAG	Authentication tag generated by Aead_Wrap().
PAGE_SIZE	RMP.Page_Size of the source page.
VALID	1
METADATA	0
VMSA	1
GPA	gPA of the source page.
PAGE_VALIDATED	RMP.Validated of the source page.
VMPL0	RMP.VMPL0 of the source page if VMPLs are enabled. 0h otherwise.
VMPL1	RMP.VMPL1 of the source page if VMPLs are enabled. 0h otherwise.
VMPL2	RMP.VMPL2 of the source page if VMPLs are enabled. 0h otherwise.
VMPL3	RMP.VMPL3 of the source page if VMPLs are enabled. 0h otherwise.

The firmware then transitions the source page into a Pre-Guest page state.

### 8.19.3 Status Codes

**Table 82. Status Codes for SNP\_PAGE\_SWAP\_OUT**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	MBZ fields are not zero.
INVALID_ADDRESS	An address is invalid for use by the firmware or is misaligned.
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest is not in the correct state.
INACTIVE	The guest is not activated.
INVALID_MDATA_ENTRY	The metadata entry is not correct.
INVALID_PAGE_STATE	A page was in the incorrect state.
INVALID_PAGE_OWNER	A page was not owned by the guest.
INVALID_PAGE_SIZE	A page was not the correct size.
AEAD_OFLOW	An overflow in the IV counter was detected

## 8.20 SNP\_PAGE\_SWAP\_IN

This command swaps an SNP-protected page back in.

### 8.20.1 Parameters

**Table 83. Layout of the CMDBUF\_SNP\_PAGE\_SWAP\_IN Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:12	In	SRC_PADDR	Bits 63:12 of the sPA of the source page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.
10h	63:12	In	DST_PADDR	Bits 63:12 of the sPA of the destination page. The page size is determined by PAGE_SIZE.
	11:0	-	-	Reserved. Must be zero.
18h	63:0	In	MDATA_PADDR	Bits 63:0 of the sPA of a metadata entry. See 2.1 for the format of a metadata entry. Ignored if ROOT_MDATA_EN is 1.
20h	63:0	-	-	Reserved. Must be zero.
28h	63:5	-	-	Reserved. Must be zero.
	4	In	ROOT_MDATA_EN	Indicates that the metadata entry will be retrieved in the guest context and not in MDATA_PADDR.
	3	In	SWAP_IN_PLACE	If set, then SRC_PADDR and DST_PADDR are equal and the page will be swapped in place.
	2:1	In	PAGE_TYPE	Indicates the page type of the source page. 0h indicates a data page. 1h indicates a metadata page. 2h indicates a VMSA page. Other encodings are reserved.
	0	In	PAGE_SIZE	Indicates page size. 0 indicates a 4 KB page. 1 indicates a 2 MB page.

### 8.20.2 Actions

The firmware checks that the platform is in the INIT state. If not, the firmware returns INVALID\_PLATFORM\_STATE.

The firmware checks that GCTX\_PADDR is a valid sPA. If not, the firmware returns INVALID\_ADDRESS. The firmware then checks that the page at GCTX\_PADDR is in the Context state. If not, the firmware returns INVALID\_GUEST.

The firmware checks that the guest is in the `GSTATE_LAUNCH` or `GSTATE_RUNNING` states. If not, the firmware returns `INVALID_GUEST_STATE`. The firmware then checks that the guest is activated. If not, the firmware returns `INACTIVE`.

The firmware checks that `SRC_PADDR`, `DST_PADDR` are valid sPAs. If `ROOT_MDATA_EN` is 0, the firmware also checks that `MDATA_PADDR` is a valid sPA and is aligned to the size of an MDATA structure (64B) and does not overlap the source and destination pages. If not, the firmware returns `INVALID_ADDRESS`.

If `ROOT_MDATA_EN` is 0, then the firmware checks that the page containing `MDATA_PADDR` is a Metadata page. If not, the firmware returns `INVALID_PAGE_STATE`. Then the firmware checks that the `RMP.GPA` of the page containing `MDATA_ENTRY` matches `GCTX_PADDR`. If not, the firmware returns `INVALID_PAGE_OWNER`.

The metadata entry used for this command is selected according to `ROOT_MDATA_EN`. If `ROOT_MDATA_EN` is set, the firmware uses the metadata entry in `GCTX.RootMDEntry`. If `ROOT_MDATA_EN` is clear, the firmware uses the metadata entry at `MDATA_PADDR`.

The firmware checks that the destination page size indicated by the `RMP` matches the page size indicated by the `PAGE_SIZE` parameter. If the source page is not a Default page, the firmware checks that the destination page size also matches the `PAGE_SIZE` parameter. The firmware then checks that the `PAGE_SIZE` field of the metadata entry matches the `PAGE_SIZE` parameter. If either check fails, the firmware returns `INVALID_PAGE_SIZE`.

The metadata entry determines the page type according to Table 84.

**Table 84. Determining the Page Type Based on the Metadata Entry**

Page Type	METADATA	VMSA
<code>PAGE_TYPE_DATA</code>	0	0
<code>PAGE_TYPE_MDATA</code>	1	0
<code>PAGE_TYPE_VMSA</code>	0	1

The firmware checks that the page type indicated by the metadata entry matches `PAGE_TYPE`. The firmware then checks that the `VALID` bit in the metadata entry is set. If either check fails, the firmware returns `INVALID_MDATA_ENTRY`.

This command operates on data pages, metadata pages, or VMSA pages. The firmware performs the actions in one of the following subsections depending on the value of `PAGE_TYPE`.

### 8.20.2.1 Data Pages

The actions in this section are performed only when `PAGE_TYPE` is `PAGE_TYPE_DATA`.

If `SWAP_IN_PLACE` is 0, the firmware checks that the destination page is a Pre-Guest page. If not, the firmware returns `INVALID_PAGE_STATE`.



If SWAP\_IN\_PLACE is 1, the firmware checks that the SRC\_PADDR equals DST\_PADDR. If not, the firmware returns INVALID\_ADDRESS. The firmware then checks that the page is in the Pre-Guest state. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that the RMP.ASID of the destination page matches the ASID of the guest. If not, the firmware returns INVALID\_PAGE\_OWNER.

The firmware uses the IV field in the metadata entry and the guest's OEK to unwrap the contents of the source page with Aead\_Unwrap() with no AAD. The firmware checks that the produced authentication tag is equal to AUTH\_TAG in the metadata entry. If not, the firmware returns BAD\_MEASUREMENT.

The firmware clears the VALID flag in the metadata entry.

The firmware writes the plaintext produced by Aead\_Unwrap() into the destination page and updates the RMP of the destination page as follows:

- Sets the RMP.GPA to GPA in the metadata entry
- Sets the RMP.VMSA to 0
- If VMPLs are enabled, sets the VMPL permission masks in the RMP entry to the VMPL permission masks in the metadata entry

If PAGE\_VALIDATED in the metadata entry is 1, the firmware transitions the destination page into a Pre-Swap page.

### **8.20.2.2 Metadata Pages**

The actions in this section are performed only when PAGE\_TYPE is PAGE\_TYPE\_MDATA.

The firmware checks that SWAP\_IN\_PLACE is 0. If not, the firmware returns INVALID\_PARAM.

The firmware checks that the destination page is a Firmware page. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware uses the IV field in the metadata entry and the guest's OEK to unwrap the contents of the source page with Aead\_Unwrap() with no AAD. The firmware checks that the produced authentication tag is equal to AUTH\_TAG in the metadata entry. If not, the firmware returns BAD\_MEASUREMENT.

The firmware clears the VALID flag in the metadata entry.

The firmware writes the plaintext produced by Aead\_Unwrap() into the destination page.

The firmware then transitions the destination page into a Metadata page by setting the RMP.GPA of the destination page to the GCTX\_PADDR of the guest.

### 8.20.2.3 VMSA Pages

The actions in this section are performed only when `PAGE_TYPE` is `PAGE_TYPE_VMSA`.

The firmware checks that `SWAP_IN_PLACE` is 0. If not, the firmware returns `INVALID_PARAM`.

The firmware checks that `PAGE_SIZE` indicates a 4 KB page size. If not, the firmware returns `INVALID_PAGE_SIZE`.

The firmware checks that the destination page is a Pre-Guest page. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the `RMP.ASID` of the destination page matches the `ASID` of the guest. If not, the firmware returns `INVALID_PAGE_OWNER`.

The firmware uses the `IV` field in the metadata entry and the guest's `OEK` to unwrap the contents of the source page with `Aead_Unwrap()` with no `AAD`. The firmware checks that the produced authentication tag is equal to `AUTH_TAG` in the metadata entry. If not, the firmware returns `BAD_MEASUREMENT`.

The firmware clears the `VALID` flag in the metadata entry.

The firmware writes the plaintext produced by `Aead_Unwrap()` into the destination page and updates the `RMP` of the destination page as follows:

- Sets the `RMP.GPA` to `GPA` field in the metadata entry
- Sets the `RMP.VMSA` to 1
- If `VMPLs` are enabled, sets the `VMPL` permission masks in the `RMP` entry to the `VMPL` permission masks in the metadata entry

If `PAGE_VALIDATED` in the metadata entry is 1h, the firmware transitions the destination page into a Pre-Swap page.

### 8.20.3 Status Codes

**Table 85. Status Codes for `SNP_PAGE_SWAP_IN`**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	MBZ fields are not zero.
INVALID_ADDRESS	An address is invalid for use by the firmware or is misaligned.
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest is not in the correct state.

<b>Status</b>	<b>Condition</b>
INACTIVE	The guest is not activated.
INVALID_MDATA_ENTRY	The metadata entry is not correct.
BAD_MEASUREMENT	The page does not match the metadata entry's authentication tag.
INVALID_PAGE_STATE	A page was in the incorrect state.
INVALID_PAGE_OWNER	A page was not owned by the guest.
INVALID_PAGE_SIZE	A page was not the correct size.

## 8.21 SNP\_PAGE\_RECLAIM

This command reclaims Metadata, Firmware, Pre-Guest, and Pre-Swap pages.

### 8.21.1 Parameters

**Table 86. Layout of the CMDBUF\_SNP\_PAGE\_PAGE\_RECLAIM Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	PAGE_PADDR	Bits 63:12 of the sPAs of the page. The page size is determined by PAGE_SIZE.
	11:1	-	-	Reserved. Must be zero.
	0	In	PAGE_SIZE	Indicates page size. 0 indicates a 4 KB page. 1 indicates a 2 MB page.

### 8.21.2 Actions

The firmware checks that the platform is in the INIT state. If not, the firmware returns INVALID\_PLATFORM\_STATE.

The firmware checks that PAGE\_PADDR is a valid sPA. If not, the firmware returns INVALID\_ADDRESS.

The firmware checks that RMP.Immutable equals 1. If not, the firmware returns SUCCESS without taking any further actions. The firmware then checks that the page is either a Metadata, Firmware, Pre-Guest, or Pre-Swap page. If not, the firmware returns INVALID\_PAGE\_STATE.

The firmware checks that PAGE\_SIZE equals the RMP.PageSize of the page. If not, the firmware returns INVALID\_PAGE\_SIZE. The firmware then checks that if the page size is 2 MB, then the PAGE\_PADDR is 2 MB aligned. If not, the firmware returns INVALID\_ADDRESS.

The firmware transitions the provided page according to Table 87.

**Table 87. State Transitions Triggered by the SNP\_PAGE\_RECLAIM Command**

Original State	New State
Metadata	Reclaim.
Firmware	Reclaim.
Pre-Guest	Guest-Invalid.
Pre-Swap	Guest-Valid.

### 8.21.3 Status Codes

**Table 88. Status Codes for SNP\_PAGE\_RO\_RESTORE**

<b>Status</b>	<b>Condition</b>
SUCCESS	Successful completion.
INVALID_ADDRESS	The address is invalid for use by the firmware or is misaligned.
INVALID_PARAM	MBZ fields are not zero.
INVALID_PAGE_STATE	The page is not in the correct state.
INVALID_PAGE_SIZE	The page is not the correct size.

## 8.22 SNP\_PAGE\_UNSMASH

This command combines 512 pages of 4 KB in size into a single 2 MB page in the RMP.

### 8.22.1 Parameters

**Table 89. Layout of the CMDBUF\_SNP\_PAGE\_UNSMASH Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	PAGE_PADDR	Bits 63:12 of the sPAs of the page.
	11:0	-	-	Reserved. Must be zero.

### 8.22.2 Actions

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

The firmware checks that `PAGE_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that each 4 KB page in the 2 MB region starting at `PAGE_PADDR` meet the following requirements.

1. Each page has `RMP.PageSize` that indicates a 4 KB page.
2. Each page has `RMP.Immutable` equal to 1.
3. Each page has `RMP.VMSA` equal to 0.
4. All pages are in the same state.
5. If VMPLs are enabled, then all pages have identical VMPL permissions.
6. All pages have `RMP.ASID` set identically and must not be zero.

If any of the above checks fail, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the range of guest physical pages are 2 MB total in size, 2 MB aligned, and consecutive. The firmware also checks that `PAGE_PADDR` is 2 MB aligned. If either check fails, the firmware returns `INVALID_PAGE_STATE`.

The firmware then turns the 4 KB pages into one 2 MB page. The resulting page is in the same state as its constituent pages.

### 8.22.3 Status Codes

**Table 90. Status Codes for SNP\_PAGE\_UNSMASH**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	MBZ fields are not zero.
INVALID_ADDRESS	An address is invalid for use by the firmware or is misaligned.
INVALID_PAGE_STATE	A page was in the incorrect state.

## 8.23 SNP\_GUEST\_REQUEST

This command sends a guest message to the firmware and returns the firmware response. See Chapter 7 for details.

### 8.23.1 Parameters

**Table 91. Layout of the CMDBUF\_SNP\_GUEST\_REQUEST Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:0	In	REQUEST_PADDR	Bits 63:0 of the sPA of the request message. See Chapter 7 for details.
10h	63:0	In	RESPONSE_PADDR	Bits 63:0 of the sPA of the response message See Chapter 7 for details.

**Table 92. Message Header Format**

Byte Offset	Bits	Name	Description
00h	255:0	AUTHTAG	Message authentication tag. If the authentication tag for the designated algorithm is shorter than 32 B, the first bytes of AUTHTAG are used and the remaining bytes must be zero. The authentication tag authenticates the bytes from 20h to the end of the encrypted payload.
20h	127:64	-	Reserved. Must be zero.
	63:0	MSG_SEQNO	The sequence number for this message. Used to construct the IV.
30h	7:0	ALGO	The AEAD used to encrypt this message. See Table 93.
31h	7:0	HDR_VERSION	The version of the message header. Set to 1h for this specification.
32h	15:0	HDR_SIZE	The size of the message header in bytes.
34h	7:0	MSG_TYPE	The type of the payload. See Table 94.
35h	7:0	MSG_VERSION	The version of the payload.
36h	15:0	MSG_SIZE	The size of the payload in bytes.
38h	31:0	-	Reserved. Must be zero.



Byte Offset	Bits	Name	Description
3Ch	7:0	MSG_VMPCK	The ID of the VMPCK used to protect this message.
3Dh	7:0	-	Reserved. Must be zero.
3Eh	15:0	-	Reserved. Must be zero.
40h-5Fh		-	Reserved. Must be zero.
60h		PAYLOAD	Encrypted payload.

**Table 93. AEAD Algorithm Encodings**

Value	Algorithm
0	Invalid
1	AES-256-GCM
All other encodings reserved.	

**Table 94. Message Type Encodings**

Value	Message Type	Message Version
0	Invalid	-
1	MSG_CPUID_REQ	1
2	MSG_CPUID_RSP	1
3	MSG_KEY_REQ	1
4	MSG_KEY_RSP	1
5	MSG_REPORT_REQ	1
6	MSG_REPORT_RSP	1
7	MSG_EXPORT_REQ	1
8	MSG_EXPORT_RSP	1
9	MSG_IMPORT_REQ	1
10	MSG_IMPORT_RSP	1
11	MSG_ABSORB_REQ	1
12	MSG_ABSORB_RSP	1
13	MSG_VMRK_REQ	1
14	MSG_VMRK_RSP	1
15	MSG_ABSORB_NOMA_REQ	1
16	MSG_ABSORB_NOMA_RESP	1
All other encodings reserved.		-

## 8.23.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware then checks that the page at `GCTX_PADDR` is in the Context state. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_RUNNING` states. If not, the firmware returns `INVALID_GUEST_STATE`.

The firmware checks that `REQUEST_PADDR` and `RESPONSE_PADDR` are valid sPAs. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the request and response page sizes indicated by the RMP are 4KB. If not, the firmware returns `INVALID_PAGE_SIZE`.

The firmware checks that the response page is a Firmware page. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware constructs the incoming 96 bit IV. The firmware sets bits `IV[63:0]` to the `MSG_SEQNO` and bits `IV[95:64]` to 0h.

The firmware unwraps the message by setting the parameters of `Aead_Unwrap()` to the following:

- C: PAYLOAD
- A: Bytes 30h to 5Fh of the request message
- IV: Constructed IV.
- K: The guest's VMPCCK identified by `MSG_VMPCCK`
- T: AUTHTAG

The firmware checks that the `Aead_Unwrap()` did not indicate inauthenticity. If the `Aead_Unwrap()` function did report inauthenticity, the firmware returns `BAD_MEASUREMENT`.

The firmware checks that the guest's message count of the VMPCCK used to unwrap this message will not overflow by processing this message. If this check fails, the firmware returns `AEAD_OFLOW`.

The firmware checks that `MSG_SEQNO` is one greater than the guest's message count for the VMPCCK used to unwrap this message. If not, the firmware returns `AEAD_OFLOW`.

The firmware checks that `HDR_VERSION` is supported by this ABI version and that the `HDR_SIZE` matches the expected size for the given header version. When `HDR_VERSION` is 1h, then `HDR_SIZE` must be 60h. The firmware also checks that `MSG_VERSION` is supported by this ABI. If any of these checks fail, the firmware returns `INVALID_PARAM`.

The firmware checks that `MSG_TYPE` is a valid message type. The firmware then checks that `MSG_SIZE` is large enough to hold the indicated message type at the indicated message version. If not, the firmware returns `INVALID_PARAM`.

The firmware creates a message in response to the guest's message. The firmware sets `MSG_SEQNO` of the response message to one greater than the `MSG_SEQNO` of the request message. The firmware then constructs a new IV and wraps the message by setting the parameters of `Aead_Wrap()` to the following:

- P: PAYLOAD plaintext
- A: Bytes 30h to 5Fh of the request message
- IV: Bits 95:0 of the IV
- K: The guest's VMPCCK identified by `VMPCCK_ID`

The firmware constructs the IV by setting `IV[63:0]` to `MSG_SEQNO` and setting `IV[95:64]` to 0h.

The firmware writes the resulting authentication tag into `AUTHTAG` and writes the ciphertext into `PAYLOAD`.

The firmware then increments the guest's message count for the VMPCCK count by two to account for both the request message and the firmware's response message.

### 8.23.3 Status Codes

**Table 95. Status Codes for `SNP_GUEST_REQUEST`**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_PARAM	MBZ fields are not zero.
INVALID_ADDRESS	An address is invalid for use by the firmware or is misaligned.
INVALID_GUEST	The guest is invalid.
INVALID_GUEST_STATE	The guest is not in the correct state.
INACTIVE	The guest is not activated.
INVALID_PAGE_STATE	A page was in the incorrect state.
INVALID_PAGE_SIZE	A page was not the correct size.
AEAD_OFLOW	The message sequence number was incorrect or the guest's message count would overflow.
BAD_MEASUREMENT	The message failed to authenticate.

## 8.24 SNP\_DBG\_DECRYPT

This command enables developers to read encrypted memory in debug enabled VMs.

### 8.24.1 Parameters

**Table 96. Layout of the CMDBUF\_SNP\_DBG\_DECRYPT Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:12	In	SRC_PADDR	Bits 63:12 of the sPA of the source 4 KB region to decrypt.
	11:0	-	-	Reserved. Must be zero.
10h	63:12	In	DST_PADDR	Bits 63:12 of the sPA of the destination page to store the decrypted data.
	11:0	-	-	Reserved. Must be zero.

### 8.24.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware checks that `GCTX_PADDR` is a Context page. If not, the firmware returns `INVALID_GUEST`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` or `GSTATE_RUNNING` guest state. If not, the firmware returns `INVALID_GUEST_STATE`. The firmware then checks that the guest is activated. If not, the firmware returns `INACTIVE`.

The firmware checks that the guest's policy allows debugging. If not, the firmware returns `POLICY_FAILURE`.

The firmware checks that `SRC_PADDR` and `DST_PADDR` are valid sPAs. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the page containing the 4 KB region to decrypt is a Pre-Guest, Pre-Swap, Guest-Invalid, or Guest-Valid page. The firmware also checks that the destination page is a Firmware page. If either check fails, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the source page containing the 4 KB region is owned by the indicated guest. If not, the firmware returns `INVALID_PAGE_OWNER`.

Note that this command always operates on 4 KB regions despite the page size indicated by the RMP entries. If the underlying page is a 2 MB page, the firmware uses the RMP entry for the 2 MB page for the RMP checks.

The firmware decrypts the contents of the 4 KB region at `SRC_PADDR` with the guest's VEK and writes the plaintext to `DST_PADDR`.

### 8.24.3 Status Codes

**Table 97. Status Codes for `SNP_DBG_DECRYPT`**

Status	Condition
<code>SUCCESS</code>	Successful completion.
<code>INVALID_PLATFORM_STATE</code>	The platform is not in the INIT state.
<code>INVALID_GUEST</code>	The guest is not valid.
<code>INACTIVE</code>	The guest is not active.
<code>INVALID_GUEST_STATE</code>	The guest is not in the RUNNING or LAUNCH states.
<code>POLICY_FAILURE</code>	The guest policy disallows debugging.
<code>INVALID_ADDRESS</code>	An address is invalid or misaligned.
<code>INVALID_PARAM</code>	MBZ fields are not zero.
<code>INVALID_PAGE_STATE</code>	A page is not in the correct state.
<code>INVALID_PAGE_OWNER</code>	A page is not owned by the guest.

## 8.25 SNP\_DBG\_ENCRYPT

This command enables developers to write to encrypted memory in debug enabled VMs

### 8.25.1 Parameters

**Table 98. Layout of the CMDBUF\_SNP\_DBG\_ENCRYPT Structure**

Byte Offset	Bits	In/Out	Name	Description
00h	63:12	In	GCTX_PADDR	Bits 63:12 of the sPA of the guest context page.
	11:0	-	-	Reserved. Must be zero.
08h	63:12	In	SRC_PADDR	Bits 63:12 of the sPA of the 4 KB region to be encrypted.
	11:0	-	-	Reserved. Must be zero.
10h	63:12	In	DST_PADDR	Bits 63:12 of the sPA of the 4 KB region page to store the encrypted data.
	11:0	-	-	Reserved. Must be zero.

### 8.25.2 Actions

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

The firmware checks that `GCTX_PADDR` is a valid sPA. If not, the firmware returns `INVALID_ADDRESS`. The firmware checks that `GCTX_PADDR` is a Context page. If not, the firmware returns `INVALID_GUEST`. The firmware then checks that the guest is activated. If not, the firmware returns `INACTIVE`.

The firmware checks that the guest is in the `GSTATE_LAUNCH` or `GSTATE_RUNNING` guest state. If not, the firmware returns `INVALID_GUEST_STATE`.

The firmware checks that the guest's policy allows debugging. If not, the firmware returns `POLICY_FAILURE`.

The firmware checks that `SRC_PADDR` and `DST_PADDR` are valid sPAs. If not, the firmware returns `INVALID_ADDRESS`.

The firmware checks that the destination 4 KB region is a Pre-Swap or a Pre-Guest page. If not, the firmware returns `INVALID_PAGE_STATE`.

The firmware checks that the destination page containing the 4 KB region is owned by the indicated guest. If not, the firmware returns `INVALID_PAGE_OWNER`.

Note that this command always operates on 4 KB regions despite the page size indicated by the RMP entries. If the underlying page is a 2 MB page, the firmware uses the RMP entry for the 2 MB page for the RMP checks.

The firmware encrypts the contents of the source 4 KB region at SRC\_PADDR with the guest's VEK and writes the ciphertext to DST\_PADDR.

### 8.25.3 Status Codes

**Table 99. Status Codes for SNP\_DBG\_ENCRYPT**

Status	Condition
SUCCESS	Successful completion.
INVALID_PLATFORM_STATE	The platform is not in the INIT state.
INVALID_GUEST	The guest is invalid.
INACTIVATE	The guest is not activated.
INVALID_GUEST_STATE	The guest is not in the RUNNING or LAUNCH states.
POLICY_FAILURE	The guest policy disallows debugging.
INVALID_ADDRESS	An address is invalid or misaligned.
INVALID_PARAM	MBZ fields are not zero.
INVALID_PAGE_STATE	A page is not in the correct state.
INVALID_PAGE_OWNER	A page is not owned by the guest.

## Chapter 9      APPENDIX: Common Algorithms

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### 9.1      Aead\_Wrap()

**Inputs:**

- P: Zero or more bytes to be encrypted and authenticated
- A: Zero or more bytes to be authenticated
- IV: Initialization vector (at most 96 bits)
- K: Key used to encrypt and authenticate the plaintext and AAD (256 bits)

**Outputs:**

- C: The encrypted plaintext
- T: Authentication tag (128 bits)

**Algorithm:**

1. If  $\text{len}(\text{IV}) < 96$ , then let  $\text{IV}' = 096 - \text{len}(\text{IV}) \parallel \text{IV}$ . Otherwise,  $\text{IV}' = \text{IV}$
2. Let  $(\text{C}, \text{T}) = \text{GCM-AEK}(\text{IV}', \text{P}, \text{A})$
3. Return  $(\text{C}, \text{T})$



## 9.2 Aead\_Unwrap()

### Inputs:

- C: Zero or more bytes to be decrypted and authenticated
- A: Zero or more bytes to be authenticated
- IV: Initialization vector (at most 96 bits)
- K: Key used to encrypt and authenticate the plaintext and AAD (256 bits)
- T: Authentication tag (128 bits)

### Outputs:

- P: The decrypted plaintext or indication of inauthenticity

### Algorithm:

1. If  $\text{len}(\text{IV}) < 96$ , then let  $\text{IV}' = 0^{96-\text{len}(\text{IV})} \parallel \text{IV}$ . Otherwise,  $\text{IV}' = \text{IV}$
2. Let  $P = \text{GCM-ADK}(\text{IV}', C, A, T)$
3. Return P