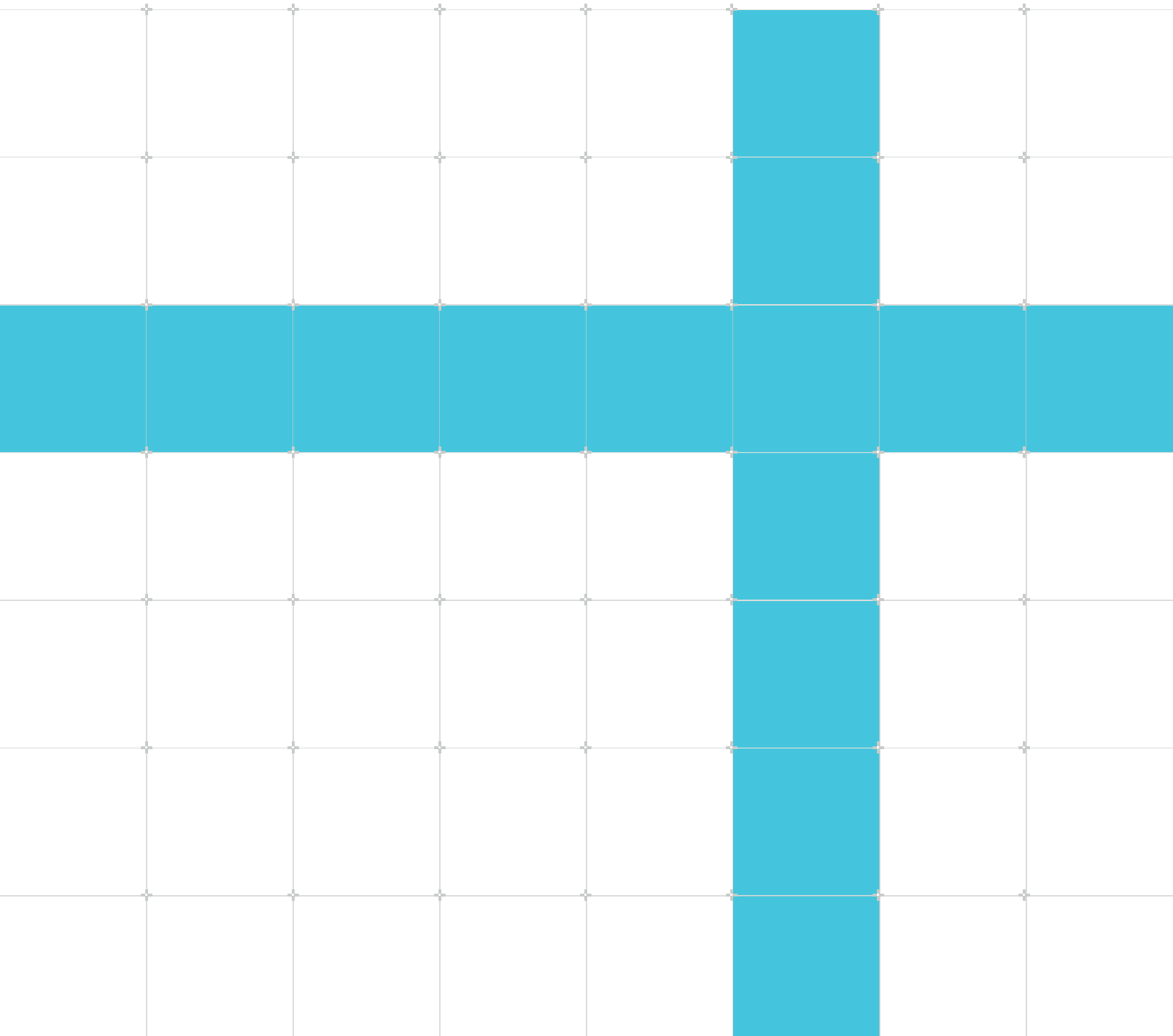
Arm® SBSA Architecture Compliance

Revision: r7p1

User Guide

Issue 05
101547_0701_05_en



Arm® SBSA Architecture Compliance

User Guide

Release Information

Document history

Issue	Date	Confidentiality	Change
A	30 November 2016	Non-Confidential	Alpha release
B	31 March 2017	Non-Confidential	Beta release
C	13 July 2017	Non-Confidential	REL 1.0
D	11 May 2018	Non-Confidential	REL 2.0
0200-01	27 December 2018	Non-Confidential	REL 2.1. The document now follows a new numbering format.
0200-02	26 April 2019	Non-Confidential	REL 2.2
0200-03	18 September 2019	Non-Confidential	REL 2.3
0200-04	20 March 2020	Non-Confidential	REL 2.4
0300-01	30 September 2020	Non-Confidential	REL 3.0
0301-01	27 September 2021	Non-Confidential	REL 3.1
0302-01	26 July 2022	Non-Confidential	REL 3.2
0601-01	28 October 2022	Non-Confidential	REL 6.1
0700-01	15 June 2022	Non-Confidential	REL 7.0 ALPHA release

Issue	Date	Confidentiality	Change
0701-01	16 January 2023	Non-Confidential	REL 7.1 BETA-0 release
0701-02	28 March 2023	Non-Confidential	REL 7.1.1 BETA-1 release
0701-03	29 June 2023	Non-Confidential	REL 7.1.2 EAC release
0701-04	28 September 2023	Non-Confidential	REL 7.1.3 EAC release
0701-05	29 March 2024	Non-Confidential	REL 7.2.0 BETA release

Proprietary Notice

makes no representation with respect to, and has undertaken no analysis to identify or understand the scope and content of, any patents, copyrights, trade secrets, trademarks, or other rights.

TO THE EXTENT NOT PROHIBITED BY LAW, IN NO EVENT WILL ARM BE LIABLE FOR ANY DAMAGES, INCLUDING WITHOUT LIMITATION ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, PUNITIVE, OR CONSEQUENTIAL DAMAGES, HOWEVER CAUSED AND REGARDLESS OF THE THEORY OF LIABILITY, ARISING OUT OF ANY USE OF THIS DOCUMENT, EVEN IF ARM HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Reference by Arm to any third party's products or services within this document is not an express or implied approval or endorsement of the use thereof.

This document consists solely of commercial items. You shall be responsible for ensuring that any permitted use, duplication, or disclosure of this document complies fully with any relevant export laws and regulations to assure that this document or any portion thereof is not exported, directly or indirectly, in violation of such export laws. Use of the word "partner" in reference to Arm's customers is not intended to create or refer to any partnership relationship with any other company. Arm may make changes to this document at any time and without notice.

This document may be translated into other languages for convenience, and you agree that if there is any conflict between the English version of this document and any translation, the terms of the English version of this document shall prevail.

The validity, construction and performance of this notice shall be governed by English Law.

Arm Limited. Company 02557590 registered in England.

110 Fulbourn Road, Cambridge, England CB1 9NJ.

PRE-1121-V1.0

Confidentiality Status

This document is Non-Confidential. The right to use, copy and disclose this document may be subject to license restrictions in accordance with the terms of the agreement entered into by Arm and the party that Arm delivered this document to.

Unrestricted Access is an Arm internal classification.

Product Status

The information in this document is for a Beta product, that is a product under development.

Feedback on content

Information about how to give feedback on the content.

If you have comments on content then send an e-mail to support-systemready-acs@arm.com. Give:

- The title Arm® SBSA Architecture Compliance User Guide.
- The number 101547_0701_05_en.
- If applicable, the page number(s) to which your comments refer.
- A concise explanation of your comments.

Arm also welcomes general suggestions for additions and improvements.

Arm tests the PDF only in Adobe Acrobat and Acrobat Reader, and cannot guarantee the quality of the represented document when used with any other PDF reader.

Inclusive language commitment

Arm values inclusive communities. Arm recognizes that we and our industry have used language that can be offensive. Arm strives to lead the industry and create change.

This document includes language that can be offensive. We will replace this language in a future issue of this document.

To report offensive language in this document, email terms@arm.com.

Contents

1. Introduction

1.1 Conventions

The following subsections describe conventions used in Arm documents.

Glossary

The Arm® Glossary is a list of terms used in Arm documentation, together with definitions for those terms. The Arm Glossary does not contain terms that are industry standard unless the Arm meaning differs from the generally accepted meaning.

See the Arm Glossary for more information: developer.arm.com/glossary.

Convention	Use
italic	Citations.
bold	Terms in descriptive lists, where appropriate.
`monospace`	Text that you can enter at the keyboard, such as commands, file and program names, and source code.
`monospace underline`	A permitted abbreviation for a command or option. You can enter the underlined text instead of the full command or option name.
`<and>`	Encloses replaceable terms for assembler syntax where they appear in code or code fragments. For example: `MRC p15, 0, <Rd>, <CRn>, <CRm>, <Opcode_2>`
SMALL CAPITALS	Terms that have specific technical meanings as defined in the *Arm® Glossary*. For example, **IMPLEMENTATION DEFINED**, **IMPLEMENTATION SPECIFIC**, **UNKNOWN**, and **UNPREDICTABLE**.

We recommend the following. If you do not follow these recommendations your system might not work.

Your system requires the following. If you do not follow these requirements your system will not work.

You are at risk of causing permanent damage to your system or your equipment, or of harming yourself.

This information is important and needs your attention.

This information might help you perform a task in an easier, better, or faster way.

This information reminds you of something important relating to the current content.

1.2 Useful resources

This document contains information that is specific to this product. See the following resources for other useful information.

Access to Arm documents depends on their confidentiality:

- Non-Confidential documents are available at developer.arm.com/documentation. Each document link in the following tables goes to the online version of the document.
- Confidential documents are available to licensees only through the product package.

Arm product resources	Document ID	Confidentiality
Arm® Server Base System Architecture 7.1	DEN0029H	Non-Confidential
GICv3 and GICv4 Software Overview	DAI0492	Non-Confidential

Arm architecture and specifications	Document ID	Confidentiality
Arm® Architecture Reference Manual for A-profile architecture	DDI0487I.a	Non-Confidential
Arm® Generic Interrupt Controller Architecture Specification for GIC architecture version 3.0 and version 4.0	IHI0069H	Non-Confidential

Arm tests its PDFs only in Adobe Acrobat and Acrobat Reader. Arm cannot guarantee the quality of its documents when used with any other PDF reader.

Adobe PDF reader products can be downloaded at http://www.adobe.com.

1.3 Other information

See the Arm® website for other relevant information.

- Arm® Developer.
- Arm® Documentation.
- Technical Support.
- Arm® Glossary.

2. Overview of the SBSA tests

This chapter provides an overview of the SBSA tests and the test IDs.

2.1 Abbreviations

The following table lists the abbreviations used in this document.

Table 2-1: Abbreviations and expansions

Abbreviation	Expansion
ACPI	Advanced Configuration and Power Interface
ACS	Architecture Compliance Suite
AEST	Arm Error Source Table
BDF	Bus, Device, and Function
CATU	CoreSight Address Translation Unit
ETE	Embedded Trace Extension
ELx	Exception Level x (where x can be 0 to 3)
ETR	Embedded Trace Router
GIC	Generic Interrupt Controller
GCD	Grand Central Dispatch
HMAT	Heterogeneous Memory Attribute Table
HVC	HyperVisor Call
IOMMU	Input-Output Memory Management Unit
ITS	Interrupt Translation Service
LPI	Locality-specific Peripheral Interrupt
MPAM	Memory System Resource Partitioning and Monitoring
MSI	Message-Signaled Interrupt
MTE	Memory Tagging Extension
NUMA	Non-Uniform Memory Access
PAL	Platform Abstraction Layer
PCIe	Peripheral Component Interconnect express
PCCT	Platform Communications Channel Table
APMT	Performance Monitoring Unit Table
PE	Processing Element
PMU	Performance Monitor Unit
PPTT	Processor Properties Topology Table
PSCI	Power State Coordination Interface
RAS	Reliability, Availability, and Serviceability
RAS2	Reliability, Availability, and Serviceability 2

Abbreviation	Expansion
RCiEP	Root Complex integrated End Point
SATA	Serial Advanced Technology Attachment
SBSA	Server Base System Architecture
SMC	Secure Monitor Call
SMMU	System Memory Management Unit
SRAT	System Resource Affinity Table
STS	Statistical Test Suite
SoC	System on Chip
UEFI	Unified Extensible Firmware Interface
UART	Universal Asynchronous Receiver and Transmitter
VAL	Validation Abstraction Layer

2.2 Overview of tests

The following table describes the general divisions of Server Base System Architecture (SBSA) tests between Unified Extensible Firmware Interface (UEFI) shell application, Linux application, and Bare-metal.

Table 2-2: Test environment and modules

Test environment	Modules
UEFI Shell	PE, GIC, Timers, Watchdog, Wakeup, PCIe, NIST, Peripherals, SMMU, PMU, MPAM, RAS, Memory, and ETE
Linux command line	PCIe, SMMU, PMU
Bare-metal	Exerciser

2.3 Test IDs

Each test ID is generated as an addition of module ID and unit test ID. For a given module, unit test ID begins from 1.

The following table lists the module names and their IDs.

Table 2-3: Module names and module IDs

Module name	Module ID
PE	0
Memory	100
GIC	200
SMMU	300
Timer	400
Power and Wakeup	500

Module name	Module ID
Peripheral	600
Watchdog	700
PCIe	800
Exerciser	900
MPAM	1000
PMU	1100
RAS	1200
NIST	1300
ETE	1400

3. UEFI shell application

This chapter provides information on executing tests from the UEFI Shell application and its PAL API implementation.

3.1 UEFI application arguments

Run the UEFI Shell application with the following set of arguments:

```
uefi shell> sbsa.efi [-v <n>] [-l <n>] [-only] [-skip <x,y,z, ..>] [-f <file name>]
 [-nist] [-mmio] [-p2p] [-cache] [-t <x, y, z>] [-m <x,y,z>] [-timeout <wakeup test
 timeout multiple>] [-fr]
```

The following table provides descriptions to the arguments.

Table 3-1: Descriptions of UEFI application arguments

Argument	Description
`-v`	Print level **1** INFO and above. **2** DEBUG and above. **3** TEST and above. **4** WARN and ERROR. **5** ERROR.
`-l`	Level of compliance to be tested for (0-7). The default value is 4.
`-only`	Runs tests of a selected level. This option needs to be passed along with `-l` (level) option.
`-skip`	Overrides the suite to skip the execution of a particular test(s) and/or module(s). For example, 301 skips test case with ID = 301. 500 skips all tests in module with ID = 500. For more information on module IDs, see 2.3 Test IDs on page 11.
`-f`	File name to which the output log is written.
`-nist`	Runs the SBSA ACS with NIST STS.
`-mmio`	Enables all the mmio read/write prints. **Note:** • To enable pal_mmio_read or write prints, use with `-v 1`. • Enables prints from specific module by using module id. For example, `-mmio 200`, enables for GIC module, and `-mmio 0`, enables for PE module.
`-p2p`	Enables p2p feature support.
`-cache`	Enables cache support.

Argument	Description
`-t`	To run only multiple selected tests.
`-m`	To run only multiple selected modules. **Note:** `-m` will override `-t` if used on the same module.
`-timeout`	Timeout value for wakeup test.
`-fr`	To run SBSA future requirements tests. **Note:** `-l` will override `-fr` if given together.


Note

The UEFI session becomes unusable after the SBSA tests are run and the test results are printed on the UEFI console.

Example 1

```
shell> sbsa.efi -v 2 -l 3 -skip 100,36 -f acs.txt
```

The set of parameters shown in the code block:

- Prints messages with verbosity of 2 and above.
- Tests for compliance against SBSA level 3.
- Skips execution of all tests belonging to Memory module and test number 36.
- Stores the log messages to the file `acs.txt`.

Example 2

```
shell > sbsa.efi -m 0,200 -skip 2
```

The set of parameters shown in the code block:

- Runs only the PE and GIC modules.
- Skips the PE test 02.

3.2 UEFI implementation of PAL APIs

This section provides information on infrastructure APIs and module-specific APIs.

Infrastructure APIs

The following table describes the Platform Abstraction Layer (PAL) APIs and UEFI interfaces.

Table 3-2: PAL APIs and UEFI interfaces

PAL API	UEFI interfaces
pal_print	AsciiPrint
mem_alloc	gBS->AllocatePool
mem_free	gBS->FreePool
mem_alloc_shared	gBS->AllocatePool
mem_free_shared	gBS->FreePool
mem_get_shared_addr	None
mem_alloc_cachebale	gBS->AllocatePages
mem_free_cacheable	gBS->FreePages
time_delay_ms	gBS->Stall
mem_alloc_pages	gBS->AllocatePages
mem_free_pages	gBS->FreePages
mmio_read	None
mmio_write	None
aligned_alloc	gBS->AllocatePool
mem_free_aligned	gBS->FreePool

Module-specific APIs

The following table represents the mapping of PAL API to Advanced Configuration and Power Interface (ACPI), if the system firmware presents platform configuration through ACPI tables.

Table 3-3: PAL APIs, UEFI interfaces, and ACPI tables consumed

PAL API	UEFI interfaces consumed	ACPI table consumed
pe_create_info_table	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	MADT Table
pe_execute_payload	-	-
pe_install_esr	• gEfiCpuArchProtocolGuid • Cpu->RegisterInterruptHandler	-
gic_create_info_table	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	MADT table
gic_install_isr	• gHardwareInterruptProtocolGuid • RegisterInterruptSource • EnableInterruptSource	-
timer_create_info_table	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	GTDT table
wd_create_info_table	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	GTDT table

PAL API	UEFI interfaces consumed	ACPI table consumed
`pcie_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	MCFG table
`pcie_get_mcfg_ecam`	• gST->ConfigurationTable • CompareGuid, IndustryStandard/Acpi.h • IndustryStandard/MemoryMappedConfigurationSpaceAccessTable.h	MCFG table
`iovirt_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	IORT table
`peripheral_create_info_table`	• gEfiPciIoProtocolGuid • Pci->GetLocation • Pci->Pci.Read	-
`memory_create_info_table`	gBS->GetMemoryMap	-
`cache_create_info_table`	• IndustryStandard/Acpi.h • gST->ConfigurationTable • CompareGuid	PPTT table
`hmat_create_info_table`	• IndustryStandard/Acpi.h • gST->ConfigurationTable • CompareGuid	HMAT table
`ras_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/ArmErrorSourceTable.h	AEST table
`mpam_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	MPAM table
`pmu_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	APMT table
`ras2_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	RAS2 and PCCT table
`srat_create_info_table`	• gST->ConfigurationTable • CompareGuid • IndustryStandard/Acpi.h	SRAT table

4. Linux application

This chapter provides information on executing tests from the Linux application.

4.1 Linux application arguments

Run the Linux application with the following set of arguments:

```
shell> sbsa [-v <n>] [-l <n>] [--skip <x,y,z>]
```

Table 4-1: Description of Linux application arguments

Argument	Description
`-v`	Print level **1** INFO and above **2** DEBUG and above **3** TEST and above **4** WARN and ERROR **5** ERROR
`-l`	Level of compliance to be tested for. (0 to 7)
`--skip`	Overrides the suite to skip the execution of a particular tests (Upto 3). For example, 53 skips test case with ID 53.

Example

```
shell> sbsa -v 3 -l 3 --skip 57
```

This set of parameters tests for compliance against SBSA level 3 with print verbosity set to 3, and skips test number 57.

Loading the kernel module

Before the SBSA ACS Linux application is run, load the SBSA ACS kernel module using the `insmod` command.

```
shell> insmod sbsa_acs.ko
```

4.2 Environment setup

This section details the target and runtime environment setup.

4.2.1 Test requirements

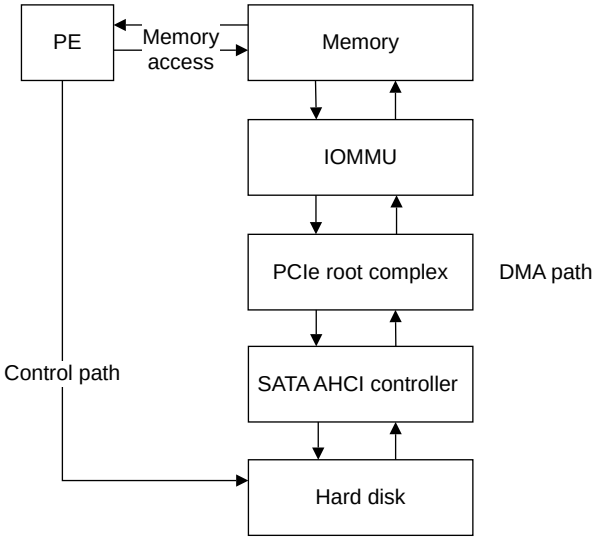
The set of tests assumes that at least one Serial Advanced Technology Attachment (SATA) controller is behind a PCIe root complex. The SATA controller may or may not be behind an Input-Output Memory Management Unit (IOMMU).

Before running these tests, at least one SATA hard disk must be connected to the SATA controller. The test performs read and write operations to the SATA hard disk. Therefore, the data on the HDD is overwritten. The SATA drive must not be the boot device for the OS.

4.2.2 Runtime environment

The following figure describes the hardware functional blocks.

Figure 4-1: Hardware functional blocks



The PCIe-DMA tests initiate data transfers from a DMA requester. By default, the test searches for a SATA controller which is part of the PCIe subsystem.

1. The test programs the known data from the PE to main memory.
2. The test programs the DMA requester to transfer this known data to its end-point device.
3. The test programs the DMA requester to transfer the data back to a different location in the main memory.
4. The test compares the data at both the locations.

If the SATA controller is not placed before an IOMMU, then during this data transfer, the address that is used by the SATA controller is retrieved and compared with the DMA address that is seen by the PE.

If the DMA requester is placed before an IOMMU, then the address that is used by the SATA AHCI controller is compared with the address that is seen by the IOMMU. Both these addresses must match.

To enable the export of the addresses that are seen by the SATA AHCI controller and IOMMU, the kernel drivers for these two modules must be patched.

5. PMU Linux application

This chapter describes how to run the PMU Linux application.

5.1 Running the PMU application

The following steps describe how to run the PMU application.

Steps to run the application

1. Export the path from which the Python modules are present.
   ```
   export PYTHONPATH=/lib/python3.10/site-packages/
   ```
2. Navigate to the directory where the scripts are present.
   ```
   cd /bin/pmuval
   ```
3. Run script.
   ```
   python sbsa_acs_pmu.py -a
   ```

   Option `-a` to run on all PEs.

Appendix A Revisions

This appendix describes the technical changes between released issues of this book.

A.1 Revisions

The following tables describe the changes between different issues of this document.

Table A-1: Issue 0200-01

Change	Location
Information about exerciser is added.	See, 2.3 Test IDs on page 11.
A new parameter `[--e]` is added to Linux application arguments.	See, 4.1 Linux application arguments on page 17.

Table A-2: Differences between Issue 0200-01 and Issue 0200-02

Change	Location
Bare-metal test environment is added to the table.	See, 2.2 Overview of tests on page 11.
A note about additional porting for the exerciser is added.	See, 4.1 Linux application arguments on page 17.

Table A-3: Differences between Issue 0200-02 and Issue 0200-03

Change	Location
No technical changes.	-

Table A-4: Differences between Issue 0200-03 and Issue 0200-04

Change	Location
• Arguments for NIST and PCIe tests are added. • A note about UEFI session is added.	See, 3.1 UEFI application arguments on page 13.
NIST module ID is updated.	See, 2.3 Test IDs on page 11.
Linux application arguments are updated.	See, 4.1 Linux application arguments on page 17.

Table A-5: Differences between Issue 0200-04 and Issue 0300-01

Change	Location
Additional level of compliance to be tested is added.	See table in 3.1 UEFI application arguments on page 13 and 4.1 Linux application arguments on page 17.

Table A-6: Differences between Issue 0300-01 and Issue 0301-01

Change	Location
Removed Secure module.	See, 2.3 Test IDs on page 11.
Updated the link to linux-acs.	See, 4.2 Environment setup on page 17.
Updated the build steps and environment setup.	See, 4.2 Environment setup on page 17.

Table A-7: Differences between Issue 0301-01 and Issue 0302-01

Change	Location
Arguments for p2p and cache are added.	See, 3.1 UEFI application arguments on page 13.

Table A-8: Differences between Issue 0302-01 and Issue 0601-01

Change	Location
Added an abbreviation for HVC.	See, 2.1 Abbreviations on page 10.
Removed Exerciser module from the Linux command line.	See, 2.2 Overview of tests on page 11.
Added new argument options for test id, module id, and timeout with more examples.	See, 3.1 UEFI application arguments on page 13.
Section on Build steps and environment setup is moved to the README file.	-

Table A-9: Differences between Issue 0601-01 and Issue 0700-01

Change	Location
Added information on PMU Linux application	See, 5. PMU Linux application on page 20.
Added new terms in Abbreviations and new APIs in UEFI implementation of PAL APIs.	See, 2.1 Abbreviations on page 10, 3.2 UEFI implementation of PAL APIs on page 14.
Added details for PMU, MPAM, and RAS; removed Exerciser module.	See, 2.2 Overview of tests on page 11.
Updated the arguments and description for UEFI application.	See, 3.1 UEFI application arguments on page 13.
Added new module names and IDs.	See, 2.3 Test IDs on page 11.
Added new PAL APIs.	See, 3.2 UEFI implementation of PAL APIs on page 14.
Updated the commands and versions.	See, 4.2 Environment setup on page 17.

Table A-10: Differences between Issue 0700-01 and Issue 0701-01

Change	Location
Added details for Memory module.	See, 2.2 Overview of tests on page 11.
Updated the arguments and description for UEFI application.	See, 3.1 UEFI application arguments on page 13.
Added a new module Memory.	See, 2.3 Test IDs on page 11.
Added RAS and SRAT APIs.	See, 3.2 UEFI implementation of PAL APIs on page 14.
Added new terms in Abbreviations.	See, 2.1 Abbreviations on page 10.
Updated the steps to run the PMU application.	See, 5.1 Running the PMU application on page 20.

Table A-11: Differences between Issue 0701-01 and Issue 0701-02

Change	Location
Changed the order of modules executed in the Table 2-3: Test environment and modules.	See, 2.2 Overview of tests on page 11
Updated the UEFI application arguments.	See, 3.1 UEFI application arguments on page 13
Added new PAL APIs in Table 3-2: PAL APIs and UEFI interfaces.	See, 3.2 UEFI implementation of PAL APIs on page 14

Table A-12: Differences between Issue 0701-02 and Issue 0701-03

Change	Location
Updated the arguments and descriptions for UEFI Shell application and examples.	See, 3.1 UEFI application arguments on page 13

Change	Location
Updated the Linux application arguments.	See, 4.1 Linux application arguments on page 17

Table A-13: Differences between Issue 0701-03 and Issue 0701-04

Change	Location
No technical changes	-

Table A-14: Differences between Issue 0701-04 and Issue 0701-05

Change	Location
Updated the arguments and descriptions for UEFI Shell application and examples.	See, 3.1 UEFI application arguments on page 13
Added ETE module name	See, 2.2 Overview of tests on page 11
Added ETE module name and ID.	See,2.3 Test IDs on page 11.