



# Architecture Compliance Test Scenario IR

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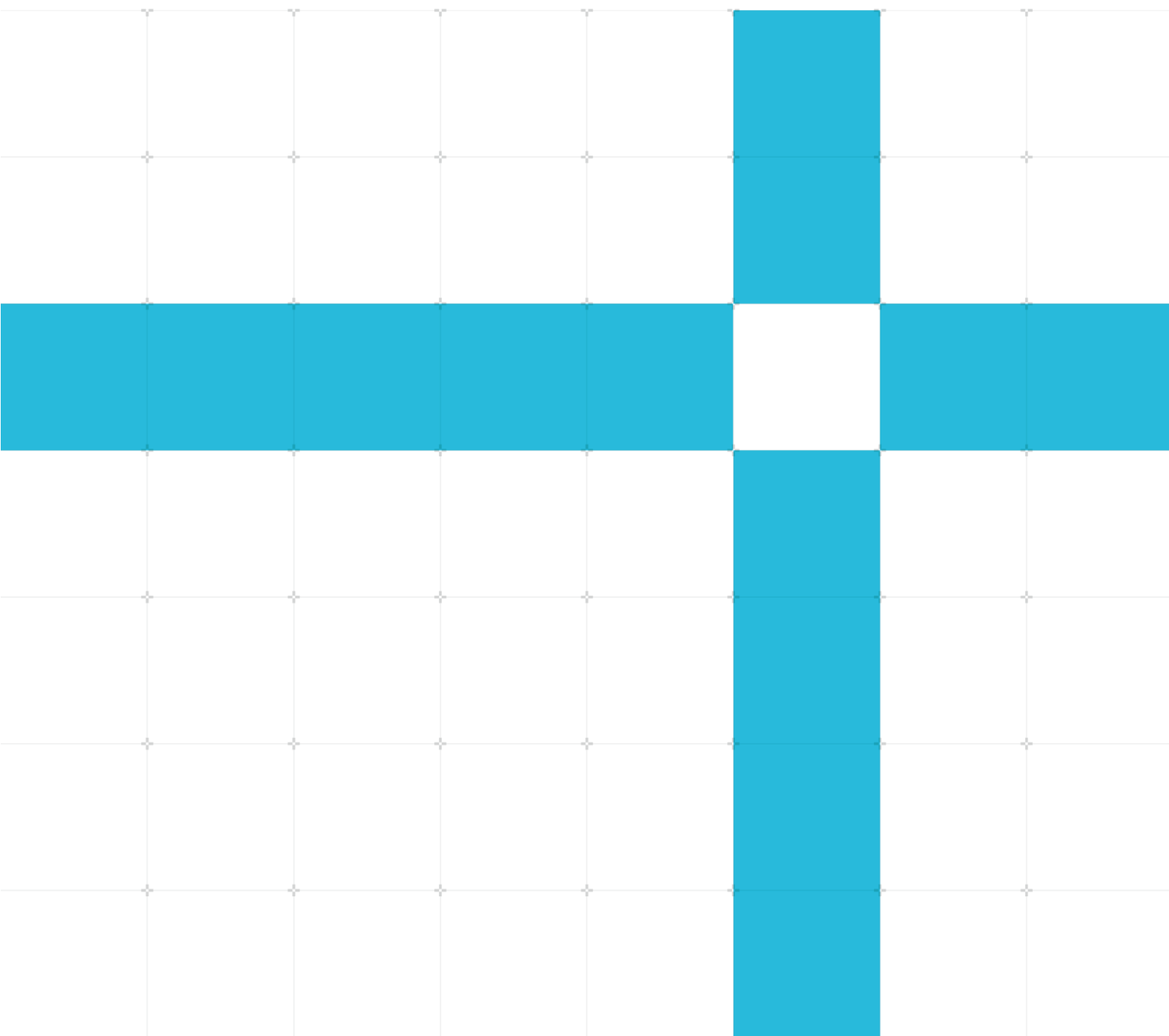
## Arm Base System Architecture

Non-Confidential

Issue 04

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# Arm BSA

## Arm Base System Architecture Scenario

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### Release information

#### Document history

| Issue | Date         | Confidentiality  | Change            |
|-------|--------------|------------------|-------------------|
| 01    | 12 May 2021  | Non-Confidential | Alpha release 0.5 |
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# 1 Introduction

## 1.1 Product revision status

The *rm**pn* identifier indicates the revision status of the product described in this book, for example, *r1p2*, where:

*rm*            Identifies the major revision of the product, for example, *r1*.

*pn*            Identifies the minor revision or modification status of the product, for example, *p2*.

## 1.2 Intended audience

This document is for engineers who are verifying an implementation of Arm® Base System Architecture 1.0.

## 1.3 Conventions

The following subsections describe conventions used in Arm documents.

### 1.3.1 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: <https://developer.arm.com/glossary>.

## 1.3.2 Typographical Conventions

| Convention                 | Use   |
|----------------------------|---|
| <i>italic</i>              | Introduces citations.   |
| <b>bold</b>                | Highlights interface elements, such as menu names. Denotes signal names. Also used for terms in descriptive lists, where appropriate.   |
| monospace                  | Denotes text that you can enter at the keyboard, such as commands, file and program names, and source code.   |
| monospace <b>bold</b>      | Denotes language keywords when used outside example code.   |
| monospace <u>underline</u> | Denotes 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.<br>For example:<br><pre>MRC p15, 0, &lt;Rd&gt;, &lt;CRn&gt;, &lt;CRm&gt;, &lt;Opcode_2&gt;</pre>     |
| SMALL CAPITALS             | Used in body text for a few terms that have specific technical meanings, that are defined in the Arm® Glossary. For example, IMPLEMENTATION, IMPLEMENTATION SPECIFIC, UNKNOWN, and UNPREDICTABLE. |

## 1.4 Useful resources

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

- Arm Non-Confidential documents are available on [developer.arm.com/documentation](https://developer.arm.com/documentation). Each document link in the tables below provides direct access to the online version of the document.
- Arm Confidential documents are available to licensees only through the product package.

| Arm products                      | Document ID | Confidentiality  |
|-----------------------------------|-------------|------------------|
| Arm® Base System Architecture 1.0 | DEN0094A    | Non-Confidential |
| Arm® Base Boot Requirements 1.0   | DEN0107A    | Non-Confidential |

| Arm architecture and specifications                                  | Document ID | Confidentiality  |
|--|-------------|------------------|
| <b>Arm® Architecture Reference Manual for A-profile architecture</b> | DDI0487F    | Non-Confidential |

| Non-Arm resources  | Document ID | Organization |
|--|-------------|--------------|
| PCI Express Base Specification Revision 5.0, Version 1.0 | NA          | PCI-SIG      |
| PCI-To-PCI Bridge Architecture Specification 1.2         | NA          | PCI-SIG      |



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- The product revision or version.
- An explanation with as much information as you can provide. Include symptoms and diagnostic procedures if appropriate.

### 1.5.2 Feedback on content

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- The title Arm Base System Architecture Scenario.
- The number PJDOC-2042731200-6896.
- 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.



## 2 Base System Architecture

Base System Architecture (BSA) specifies a hardware system architecture, based on Arm 64-bit architecture, that system software such as operating systems, hypervisors, and firmware can rely on. The document addresses PE features and key aspects of system architecture. The primary goal of the document is to ensure sufficient standard system architecture to enable a suitably built single OS image to run on all the hardware compliant with the specifications.

Arm does not mandate compliance with this specification. However, Arm anticipates that OEMs, ODMs, cloud service providers, and software providers require compliance to maximize Out-of-Box software compatibility and reliability.

### 2.1 BSA ACS

BSA ACS provides tests for validating a platform compliance with BSA specifications. The tests are divided into a hierarchy of subcategories depending on the runtime environment and the component submodules that are required for achieving the verification. The top level of a hierarchy is consistent with the target hardware subsystem which is validated by a test. A test may check for different parameters of the hardware subsystem.

The tests are classified as:

- PE
- Memory Map
- GIC
- SMMU
- Clock and Timer
- Wakeup Semantics
- Power State Semantics
- Watchdog
- Peripherals
- PCIe

## 2.2 PE

| Test number | Rule ID | Scenario  | Algorithm   |
|-------------|---------|---|---|
| 1           | B_PE_01 | All PEs are architecturally symmetric except for the permitted exceptions listed in Section A of BSA specification.   | CPU System register read.<br>Read all the processor ID registers from all PEs and then compare values with the main PE.   |
| 2           | B_PE_02 | The number of PEs must not exceed: <ul style="list-style-type: none"> <li>8, when the interrupt controller is compliant to GICv2.</li> <li>2<sup>28</sup> when the interrupt controller is compliant to GICv3 or higher.</li> </ul> | Read from ACPI MADT table.  |
| 3           | B_PE_03 | PEs must implement the Advanced SIMD and FEAT_FP extensions.  | CPU System register read: ID_AA64PFR0_EL1 must indicate support bits [23:20].   |
| 4           | B_PE_04 | PEs must support 4KB translation granules at stage 1.   | ID_AA64MMFR0_EL1 must indicate support for 4KB and 64KB granules for all cores.   |
| 5           | B_PE_05 | All the PEs are coherent and in the same Inner Shareable domain.  | 1. ID_MMFR0_EL1.InnerShr must indicate hardware coherency support for InnerShr across all cores.<br>2. ShreLvl must be 0001 across all cores (later it is mandated for Armv8).<br>3. Functional verification is optional. |
| 6           | B_PE_06 | Export restrictions allow PEs to implement cryptography extension support for FEAT_AES, FEAT_SHA1 and FEAT_SHA256.  | CPU System register read:<br>Bits [4:15] of ID_AA64ISAR0_EL1 must be supported.   |
| 7           | B_PE_07 | PEs must implement little-endian support.   | CPU System register read:<br>SCTLR.EE should be supported.  |
| 8           | B_PE_08 | PEs must implement EL1 and ELO in the AArch64 Execution state.  | ID_AA64PFR0_EL1.ELO and ID_AA64PFR0_EL1.EL1 should be supported.  |
| 9           | B_PE_09 | PEs must implement the FEAT_PMU extension, and the base system must expose a minimum of four programmable PMU counters to the operating system.   | If ID_AA64DFR0_EL1.PMUVer is supported, then PMCR_ELO.N should be greater than 3.   |
| 10          | B_PE_10 | The PMU overflow signal from each PE must be wired to a unique PPI interrupt with no intervening logic.   | If ID_AA64DFR0_EL1.PMUVer is supported, install ISR and verify PMU overflow interrupt by programming System register.   |
| 11          | B_PE_11 | Each PE must implement a minimum of six breakpoints, two of which should match virtual address, contextID or VMID.  | 1. Read ID_AA64DFR0_EL1 and check number of breakpoints.<br>2. Read DBGBCR<n>_EL1 & check type of breakpoint.   |
| 12          | B_PE_12 | Each PE implements a minimum of four synchronous watchpoints.   | ID_AA64DFR0_EL1.WRPs must be greater than 2.  |

| Test number | Rule ID | Scenario   | Algorithm  |
|-------------|---------|--|--|
| 13          | B_PE_13 | PEs must implement the FEAT_CRC32 instructions.  | ID_AA64ISAR0_EL1.CRC32 should be supported.  |
|             | B_PE_14 | Implementation of SVE or SVE2 is optional. If implemented, Arm strongly recommends that the performance of well-optimized SVE or SVE2 code is no worse than code which uses the equivalent NEON instructions.  | Not implemented<br><br>Requires the performance comparison between SVE/SVE2 and NEON code which is not feasible.                                   |
| 14          | B_PE_15 | If FEAT_PAuth (Pointer Authentication), mandatory from Armv8.3, is implemented. Arm recommends that the standard algorithm defined by the Arm architecture is implemented for address and generic authentication. <ul style="list-style-type: none"> <li>If an alternative algorithm is used, it must be at least as cryptographically strong as the Arm recommended algorithm.</li> </ul> | If pointer signing is implemented, check ID_AA64ISAR1_EL1[11:4] for address authentication and ID_AA64ISAR1_EL1[31:24] for generic authentication. |
| 51          | B_PE_18 | PEs must implement Non-secure EL2 in AArch64.  | ID_AA64PFR0_EL1.EL2 must be supported.   |
| 52          | B_PE_19 | PEs must support 4KB translation granules at stage 2.  | ID_AA64MMFR0_EL1.TGran4_2 must be supported.   |
| 53          | B_PE_20 | The translation granules supported at stage 2 should match those supported at stage 1.   | Check AA64MMFR0_EL1 register.  |
| 54          | B_PE_21 | The base system must expose a minimum of two programmable PMU counters to a hypervisor.  | Check whether minimum two programmable PMU counters are exposed.   |
| 55          | B_PE_22 | Two of the implemented breakpoints in each PE must be able to match on VMID. See the B_PE_11.  | Read DBGBCR<n>_EL1 & check the type of breakpoint.   |
| 76          | B_PE_23 | PEs must implement EL3 in the AArch64 Execution state.   | ID_AA64PFR0_EL1.EL3 must be supported.   |
| 76          | B_PE_24 | PEs must implement Secure state.   | ID_AA64PFR0_EL1.EL3 must be supported.   |

## 2.3 Memory Map

| Test number | Rule ID  | Scenario   | Algorithm  |
|-------------|----------|--|--|
| 102         | B_MEM_01 | All memory accesses, whether they access memory space which is populated, must respond within finite time, to avoid the possibility of system deadlock.  | <ol style="list-style-type: none"> <li>1. Initialize the exception handlers.</li> <li>2. Get the address range from the system table or memory map.</li> <li>3. Try to access the memory.</li> <li>4. Exception may or may not occur, but the test should continue to proceed.</li> <li>5. Once all memory range is accessed, the test is considered as pass.</li> </ol> |
| -           | B_MEM_02 | The memory access is to an unpopulated part of the addressable memory space. Accesses must be terminated in a manner that is presented to the PE as either a precise Data Abort, or as a system error interrupt, or an SPI, or LPI interrupt to be delivered to the GIC. | Not implemented in the current release.  |
| 104         | B_MEM_03 | All Non-secure on-chip DMA requestors in a base system that are expected to be under the control of the operating system or hypervisor, must be capable of addressing all the Non-secure address space.  | <ol style="list-style-type: none"> <li>1. Check if the PCIe device is capable of 64-bit DMA.</li> <li>2. If not, check if it is present behind an SMMU</li> </ol>  |
| -           | B_MEM_04 | If the Requester goes through an SMMU, then the Requester must be capable of addressing all the Non-secure address space when the SMMU is turned off.  | Covered by Test 104  |
| 103         | B_MEM_05 | All PEs must be able to access all the Non-secure address space.   | <ol style="list-style-type: none"> <li>1. For the current PE, read ID_AA64MMFR0_EL1[3:0] to get max number of bits that PE can access.</li> <li>2. Check if the maximum accessible memory is accessible by PE</li> </ol>   |

| Test number | Rule ID  | Scenario  | Algorithm   |
|-------------|----------|---|---|
| -           | B_MEM_06 | Non-secure off-chip devices that cannot address all the Non-secure address space directly, must be placed behind the stage 1. SMMU that is compatible with the Arm SMMUv2 or SMMUv3 specification, that has an output address size large enough to address all the Non-secure address space. (See Section 3.7). | Covered by Test 104   |
| -           | B_MEM_07 | Where it is possible for the progress of a memory transaction to depend on a second memory access, the system must avoid deadlock if the memory access gets ordered behind the original transaction.  | Not implemented.<br><br>The sequence to generate deadlock is not repeatable in an environment such as UEFI shell. |
| -           | B_MEM_08 | The system must provide some memory that is mapped in the Secure address space.   | Not implemented.<br><br>Do not have access to Secure memory map from UEFI shell.                                  |

## 2.4 GIC

| Test number | Rule ID  | Scenario  | Algorithm   |
|-------------|----------|---|---|
| 201         | B_GIC_01 | A base system must present operating systems and hypervisors with the interfaces defined by one of the following: <ul style="list-style-type: none"> <li>Generic Interrupt Controller (GIC) v2 interrupt controller.</li> <li>GICv2 interrupt controller with GICv2m extension.</li> <li>GICv3 interrupt controller.</li> </ul> | Check the version from the platform information. If it is not present here, then read GICD_PIDR2. |
| 202         | B_GIC_02 | Limitations and valid configurations are allowed in a base system.  | Check that PCIe support should not be present if GICv2.   |
| 203         | B_GIC_03 | If the system includes PCI Express and GICv3 interrupt controller is supported, then the GICv3 interrupt controller must implement ITS and LPI.   | Check for the GIC version and the PCIe presence in the system, and check for ITS/LPI if present.  |
| 204         | B_GIC_04 | If a GICv3 interrupt controller is supported, then the interrupt controller must support two Security states.   | Read Security states from GICD_CTLR.DS bit.   |

| Test number | Rule ID     | Scenario   | Algorithm   |
|-------------|-------------|--|---|
| 205         | B_GIC_05    | The system may implement at least 8 Non-secure SGIs assigned to interrupt IDs 0-7.     | <ol style="list-style-type: none"> <li>1. Check whether the distributor forwards Non-secure Group 1 interrupts.</li> <li>2. If NS Group 1 interrupts are forwarded, try to enable SGI INTID 0-15 by writing to the distributor or redistributor enable register.</li> <li>3. Check which interrupt IDs are enabled afterwards. Secure interrupts return 0, and Non-secure interrupts return 1.</li> </ol>   |
| 206         | B_PPI_01    | Check PPI assignments for operating system.  | <ol style="list-style-type: none"> <li>1. Detect the interrupt IDs.</li> <li>2. Install ISRs for those IDs.</li> <li>3. Trigger the conditions to assert the interrupts.</li> <li>4. Check whether the interrupt has been received.</li> </ol>  |
| 226         | B_PPI_02    | Check PPI assignments for hypervisor.  | <ol style="list-style-type: none"> <li>1. Detect the interrupt IDs.</li> <li>2. Install ISRs for those IDs.</li> <li>3. Trigger the conditions to assert the interrupts.</li> <li>4. Check whether the interrupt has been received.</li> </ol>  |
| -           | B_PPI_03    | Check PPI assignments for platform security.   | <p>Not implemented.</p> <p>BSA ACS is executed from Non-secure mode and cannot access Secure PPI interrupts.</p>  |
| 251         | Section I.6 | Check SPIs which are assigned to MSIs are edge-triggered.                              | <ol style="list-style-type: none"> <li>1. Get the number of MSI frames.</li> <li>2. Loop through number of SPIs for that frame</li> <li>3. Check by reading the value of GICD_ICFGRn register for SPI.</li> </ol>   |
| 252         | Section I.9 | Check GICv2m MSI Frame Register Configuration.   | <ol style="list-style-type: none"> <li>1. Get the number of MSI frames.</li> <li>2. Loop through number of SPIs for that frame.</li> <li>3. Check MSI_TYPER is RO.</li> <li>4. Check for SPI_ID is 32-1020.</li> <li>5. Check MSI_IIDR is RO.</li> </ol>  |
| 253         | Section I.6 | Check GICv2m MSI to SPI generation functional test.                                    | <ol style="list-style-type: none"> <li>1. Get the number of MSI frames.</li> <li>2. For each frame get an SPI_ID.</li> <li>3. Install a Handler.</li> <li>4. Trigger an SPI using MSI_SETSPI_NS register.</li> <li>5. Check if interrupt is triggered.</li> </ol>   |
| 254         | Section I.5 | SPIs that are allocated to MSIs must only be controllable by the GICv2m MSI registers. | <ol style="list-style-type: none"> <li>1. Get the number of MSI frames.</li> <li>2. For each frame get an SPI_ID.</li> <li>3. Install a Handler.</li> <li>4. Generate SPI using GICD_ISPENDR register.</li> <li>5. No Interrupt should be generated.</li> <li>6. Trigger an SPI using the MSI_SETSPI_NS register.</li> <li>7. Check the Interrupt is triggered as SPIs should be controlled by the MSI frame register instead of other GICD Registers.</li> </ol> |

## 2.5 SMMU

| Test number | Rule ID   | Scenario  | Algorithm   |
|-------------|-----------|---|---|
| 301         | B_SMMU_01 | All the System MMUs presented to an operating system or hypervisor must be compliant with the same architecture version.  | For all SMMU controllers in the system, check if they are based on v2 or v3 architecture.   |
| 302         | B_SMMU_02 | The SMMU must support the translation granule sizes that are supported by the PEs.  | <ol style="list-style-type: none"> <li>1. Read out the granule size support for the PE (AA64MMFR0_EL1.TGran<sub>x</sub>).</li> <li>2. Verify if this is congruent to the granule sizes supported by the SMMU.</li> </ol>  |
| 305         | B_SMMU_06 | This means that, if PEs implement FEAT_LPA (ID_AA64MMFR0_EL1.PARange = 0b0110), then the SMMU must support a 52-bit output size (SMMU_IDR5.OAS = 0b0110).   | <ol style="list-style-type: none"> <li>1. Read out: ID_AA64MMFR0_EL1.PARange.</li> <li>2. If enabled, check whether SMMU_IDR5.OAS equals "0b0110".</li> </ol>   |
| -           | B_SMMU_07 | Devices that operate across non-contiguously allocated memory, require stage 1 System MMU functionality.  | <p>Not implemented.</p> <p>This requires the availability of device-specific drivers and device-specific knowledge. This is not available in UEFI shell application.</p>  |
| 306         | B_SMMU_08 | <p>If Secure-EL2 is not implemented, stage 1 System MMU functionality that is made visible to an operating system must present the interface of a System MMU compatible with one of the following:</p> <ul style="list-style-type: none"> <li>• The SMMUv2 specification, where each context bank must present a unique physical interrupt to the GIC</li> <li>• The Arm SMMUv3 specification or higher, where the integration of the System MMUs is compliant with the requirements in Section D.</li> </ul> | <ol style="list-style-type: none"> <li>1. Read out: ID_AA64PFR0_EL1.SEL2.</li> <li>2. If enabled, and SMMU handles stage 1 policing, check if SMMU_AIDR.ArchMajorRev ≥ 3 and SMMU_AIDR.ArchMinorRev ≥ 2.</li> <li>3. Else, check if SMMU Major revision is at least 2.</li> </ol> |

| Test number | Rule ID   | Scenario   | Algorithm  |
|-------------|-----------|--|--|
| -           | B_SMMU_12 | All addresses output from a device to an SMMU must lie in a continuous space with no holes. All address in said space will be treated equally by the SMMU. There should be no areas within the address space that receive exceptional treatment, like bypassing the SMMU.          | Not implemented.<br><br>We require device drivers to generate DMA and a configurable memory map to access the whole address space. Not feasible to generate these transactions from UEFI shell.  |
| 351         | B_SMMU_16 | If the device is assigned and passed through an operating system under the hypervisor, then the memory transactions of the device must subject to stage 2 translation, allocation of memory attributes, and application of permission checks, under the control of the hypervisor. | Depending on the architecture revision of the SMMU, check if SMMU_IDR0.S2TS (v2) or SMMU_IDR0.S2P (v3) is enabled.   |
| -           | B_SMMU_17 | From a hardware perspective, this means that a base system supporting a protection hypervisor requires all Non-secure DMA capable devices that will be assigned to a Non-secure VM for direct control to be policed by stage 2 System MMU functionality.                           | Covered by Test 351.   |
| 352         | B_SMMU_18 | If Secure-EL2 is not implemented, stage 2 System MMU functionality must be provided by a System MMU compatible with the Arm SMMUv2 specification or Arm SMMUv3 specification.  | 1. Read out: ID_AA64PFR0_EL1.SEL2.<br><br>2. If enabled, and SMMU handles stage 2 policing, check whether SMMU_AIDR.ArchMajorRev $\geq$ 3 and SMMU_AIDR.ArchMinorRev $\geq$ 2.<br><br>3. Else, check if SMMU major revision is at least 2. |
| 353         | B_SMMU_19 | When stage 2 System MMU functionality is provided by a System MMU compatible with the Arm SMMUv2 specification: <ul style="list-style-type: none"> <li>Each context bank must present a unique physical interrupt to the GIC.</li> </ul>   | 1. Create a list of all physical interrupts per context bank with their corresponding IDs.<br><br>2. For each interrupt present in the list, check whether the assigned ID appears elsewhere in the list.                                  |
| -           | B_SMMU_24 | If Secure-EL2 is implemented, all Secure DMA capable devices that can be assigned to a Secure VM must be policed by stage 2 Secure SMMU functionality.   | Not implemented.<br><br>It is not feasible to check if Secure-EL2 is implemented and get Secure devices configuration from ACS framework in UEFI shell.  |



| Test number | Rule ID   | Scenario   | Algorithm   |
|-------------|-----------|--|---|
| -           | B_SMMU_25 | <p>If Secure-EL2 is implemented, stage 2 Secure MMU functionality must be provided by a system MMU compatible with the Arm SMMUv3.2, or higher, architecture revision where:</p> <ul style="list-style-type: none"> <li>• The integration of the system MMUs is compliant with the rules in Section D.</li> <li>• SMMU implementations must provide level 1 or level 2 support for page table resizing.</li> </ul> | <p>Not implemented.</p> <p>It is not feasible to check if Secure-EL2 is implemented from ACS framework in UEFI shell.</p> |

## 2.6 Clock and Timer

| Test number | Rule ID   | Scenario  | Algorithm   |
|-------------|-----------|---|---|
| 401         | B_TIME_01 | The base system must include the system counter of the generic Timer.   | If the test can access the timer, the test is passed  |
| 401         | B_TIME_02 | The system counter of the generic Timer must run at a minimum frequency of 10MHz.   | <ol style="list-style-type: none"> <li>1. Read the CNTFREQ register.</li> <li>2. If the read value is greater than 10MHz, test passed.</li> <li>3. Else, test failed.</li> </ol>                              |
| -           | B_TIME_03 | The counter must not roll over inside a 10-year period.   | <p>Not implemented.</p> <p>RW access to CNTControlBase is allowed only through EL3. The BSA ACS is run on Non-secure mode. Cannot change the register value from the tests.</p>                               |
| -           | B_TIME_04 | The architecture of the counter mandates that the counter must be at least 56 bits, and at most 64 bits. From Armv8.4, for systems that implement counter scaling, the minimum becomes 64 bits. | <p>Not implemented.</p> <p>RW access to CNTControlBase is allowed only through EL3. The BSA ACS is run on non-secure mode. Cannot change the register value from the tests.</p>                               |
| -           | B_TIME_05 | This count must be available to the PE timers when they are active, which is when the PEs are in power state where the PE timer must be on.   | Covered by wakeup and power tests.  |
| 402         | B_TIME_06 | Unless all the local PE timers are always on, the base system must implement a system wakeup timer that can be used when PE timers are powered down.  | <ol style="list-style-type: none"> <li>1. If any platform timer is available, the test passes.</li> <li>2. Else if all PE timers are always on, the test passes.</li> <li>3. Else, the test fails.</li> </ol> |

| Test number | Rule ID   | Scenario  | Algorithm  |
|-------------|-----------|---|--|
| 403         | B_TIME_07 | The system wakeup timer must in the form of the memory-mapped timer.  | <ol style="list-style-type: none"> <li>1. Check timer is secured or not.</li> <li>2. For NS timer, check CNTLBASE is accessible or not.</li> <li>3. If CNTLBase is accessible, then timer is in the form of memory mapped timer.</li> </ol>  |
| 404         | B_TIME_08 | On timer expiry, the system wakeup timer must generate an interrupt that must be wired to the GIC as an SPI or LPI. Also, the system wakeup timer can be used to wake up PEs. | <ol style="list-style-type: none"> <li>1. Generate the timer interrupt.</li> <li>2. Check if the interrupt is reaching GIC.</li> <li>3. Check the system-specific interrupt controller with interrupt id.</li> </ol>   |
| 405         | B_TIME_09 | The platform either implements hardware always-on PE timers or uses the platform firmware to save and restore the PE timers in a performance-scalable fashion.                | <ol style="list-style-type: none"> <li>1. Program PE timer with a large value X</li> <li>2. Program system timer with a small value Y.</li> <li>3. Put PE in to power down mode with PSCI call CPU_SUSPEND.</li> <li>4. PE should wake up due to sys timer interrupt.</li> <li>5. Read PE timer current count value, should be less than <math>((X - Y) + 1\% \text{ of } Y)</math> &amp; count should not be zero.</li> </ol> |
| -           | B_TIME_10 | If the system includes a system wakeup timer, this memory-mapped timer must be mapped on to Non-secure address space.   | Covered by Test 403.   |

## 2.7 Wakeup Semantics

Tests 501-505 are checking the BSA Table 8: Power state semantics.

Wakeup semantics rules RB\_WAK\_01 to RB\_WAK\_06 are derived from the above table.

| Test number | Rule ID  | Scenario   | Algorithm   |
|-------------|----------|--|---|
| 501-505     | B_WAK_01 | A PE must wake in response to a wakeup interrupt, independent of the state of its PSTATE interrupt mask bits, which are the A, I, and F bits, and of the wakeup interrupt priority.  | <ol style="list-style-type: none"> <li>1. Suspend PE.</li> <li>2. Get intid of wakeup interrupt.</li> <li>3. Generate interrupt.</li> <li>4. PE should wakeup irrespective of the mask bits.</li> <li>5. Fail if does not wakeup.</li> </ol>                                |
| -           | B_WAK_02 | If the system supports a low-power state where the GIC is powered down, then there must be an IMPLEMENTATION DEFINED way to program the power controller to wake a PE on expiry of the system wakeup timer or the generic watchdog. In this scenario, the system wakeup timer or generic watchdog is still required to send its interrupt. | Not implemented in the current release.   |
| 501-505     | B_WAK_03 | Whenever a PE is woken from sleep or off state the OS or hypervisor must be presented with an interrupt so that the PE software can determine the device that requested the wakeup.  | <ol style="list-style-type: none"> <li>1. Install interrupt handlers.</li> <li>2. Suspend PE.</li> <li>3. Wake PE by providing interrupt.</li> <li>4. Check if OS raises an interrupt once PE is woken.</li> <li>5. Find which device has caused this interrupt.</li> </ol> |
| 501-505     | B_WAK_04 | The interrupt must be pending in GIC at the point that control is handed back to the OS or hypervisor from the system-specific software performing the state restore.  | <ol style="list-style-type: none"> <li>1. Generate interrupt.</li> <li>2. Install interrupt handlers.</li> <li>3. In ISR read the interrupt pending bit (it must be '1')</li> <li>4. Clear interrupt and ISR.</li> </ol>  |
| 501-505     | B_WAK_05 | This interrupt must behave like any other, where a device sends an interrupt to the GIC, and the GIC sends the interrupt to the OS or hypervisor. The OS or hypervisor must not communicate with a system-specific interrupt controller.   | <ol style="list-style-type: none"> <li>1. Generate the interrupt.</li> <li>2. Check if the interrupt is reaching GIC.</li> <li>3. Check the system-specific interrupt controller with interrupt id.</li> </ol>  |
| -           | B_WAK_06 | If the wakeup event is an edge, then the system must ensure that this edge is not lost. The system must ensure that the edge wakes the system and is then delivered to the GIC without losing the edge.  | Covered by Test 501-505   |

## 2.8 Power State Semantics

Tests 501-505 are checking the BSA specification Table 8: Power state semantics.

Power semantics rules RB\_WAK\_07 to RB\_WAK\_11 is derived from the above table.

| Test number | Rule ID  | Scenario  | Algorithm                      |
|-------------|----------|---|--------------------------------|
| -           | B_WAK_07 | OS or hypervisor, or both, can be the reason for wakeup events and to know which timers are available to wake up the PE. All PEs must be in a state that is consistent with one of the semantics.   | Covered by Test 501-505.       |
| -           | B_WAK_08 | System MMUs and GICv3 make use of tables in memory in the power states where GIC is on. For this type of state, system memory must be available and responds to requests without requiring intervention from software running on the PEs. | Covered in SMMU and GIC tests. |
| 501-505     | B_WAK_10 | Schematic check.  | Covered by Test 501-505.       |
| -           | B_WAK_11 | Component check.  | Covered by Test 501-505.       |

## 2.9 Watchdog

| Test number | Rule ID | Scenario  | Algorithm   |
|-------------|---------|---|---|
| 701         | B_WD_01 | The generic watchdog must be implemented as specified in Section C of BSA specification 1.0.  | Read and verify watchdog refresh and control registers  |
| -           | B_WD_02 | The watchdog must have both its register frames mapped on to Non-secure address space. This watchdog is referred to as the Non-secure watchdog.             | Covered by test 701.  |
| 702         | B_WD_03 | Watchdog Signal 0 is routed as an SPI or an LPI to the GIC and it is expected that this is configured as a Non-secure EL2 interrupt, targeting a single PE. | <ol style="list-style-type: none"> <li>1. Generate the watchdog interrupt.</li> <li>2. Check if the interrupt is reaching GIC.</li> <li>3. Check the system-specific interrupt controller with interrupt id.</li> </ol> |

| Test number | Rule ID | Scenario   | Algorithm   |
|-------------|---------|--|---|
| -           | B_WD_04 | Watchdog Signal 1 must be routed to the platform.                                | Not implemented.<br><br>WS1 signal is routed to a higher privilege entity to perform IMPDEF behavior. |
| -           | B_WD_05 | The action taken on the raising of watchdog signal 1 is IMPLEMENTATION SPECIFIC. | Not implemented.<br><br>WS1 signal performs platform-specific action. This is IMPDEF behavior.        |

## 2.10 Peripherals

| Test number | Rule ID  | Scenario  | Algorithm   |
|-------------|----------|---|---|
| 601         | B_PER_01 | If the system has a USB2.0 host controller peripheral, it must conform to EHCI v1.1 or later.   | All the available UART in the Device Tree are parsed and their type is obtained using compatible string, if the type does not match EHCI/XCHI test is failed. |
| 601         | B_PER_02 | If the system has a USB3.0 host controller peripheral it must conform to XHCI v1.0 or later.  | All available UART in the Device Tree are parsed and their type is obtained using compatible string, if the type does not match EHCI/XCHI test is failed.     |
| 602         | B_PER_03 | If the system has a SATA host controller peripheral, it must conform to AHCI v1.3 or later.   | All available SATA in the Device Tree is parsed and their type is obtained using compatible string, if the type does not match AHCI test is failed.           |
| -           | B_PER_04 | Peripheral subsystems which do not conform to rules B_PER_01, B_PER_02 or B_PER_03 are permitted if those peripherals are not required to boot and install an OS. | Manual verification required by user.   |

| Test number | Rule ID  | Scenario  | Algorithm  |
|-------------|----------|---|--|
| 603         | B_PER_05 | <p>By the system development and bring up, the base system must include a UART. The UART must be one of:</p> <ul style="list-style-type: none"> <li>The Generic UART as specified in Section B.</li> </ul> <p>A fully 16550 compatible UART [9].</p>        | <p>For generic UART algorithm steps are</p> <ol style="list-style-type: none"> <li>1. Install handlers to catch unexpected exceptions.</li> <li>2. Get the base address for each UART present.</li> <li>3. Validate the read-only registers UARTFR, UARTRIS, UARTRIS, UARTDR if they conform to BSA specification.</li> </ol> <p>For 16550 uart algorithm steps are</p> <ol style="list-style-type: none"> <li>1. Get 16550 UART details from system hardware table (ACPI/DT)</li> <li>2. Check if the I/O base address is present.</li> <li>3. Check the baud rate from the hardware table.</li> <li>4. Check the baud rate in the UART register. Obtained the divisor by enabling the divisor latch access and reading the divisor latch byte1 and byte2. Divisor = system clock speed / (16 * baud rate)</li> <li>5. Check the read/write property of Line Control Register</li> <li>6. Check the read/write property of Interrupt Enable Register</li> <li>7. Check if UART is present using loopback test mode</li> </ol> |
| 604, 606    | B_PER_06 | The UART interrupt output is connected to the GIC as an SPI or an LPI.  | <ol style="list-style-type: none"> <li>1. Get the interrupt ID of the UART peripheral.</li> <li>2. Install the ISR for the interrupt ID.</li> <li>3. Generate an UART transaction.</li> <li>4. Check if the interrupt is received in the ISR.</li> </ol>   |
| -           | B_PER_07 | UART must be mapped on to Non-secure address space. This is called the Non-secure UART.   | Covered by Test-604  |
| -           | B_PER_08 | If the system has a PCI Express root complex, then it must comply with the rules in Section E.  | Covered by PCIe tests  |
| 605         | B_PER_09 | <p>The memory attributes of DMA traffic must be one of the following:</p> <ul style="list-style-type: none"> <li>Inner Write-Back, outer Write-Back, Inner Shareable.</li> <li>Inner Non-cacheable, outer Non-cacheable.</li> <li>A device type.</li> </ul> | <ol style="list-style-type: none"> <li>1. Get the DMA controllers present in the system.</li> <li>2. Allocate a memory for a DMA transaction.</li> <li>3. Read the memory attributes of the allocated memory.</li> <li>4. If DMA supports coherent memory, then the attributes of the allocated memory should be inner/outer writeback, Inner Shareable.</li> <li>5. If the DMA does not support coherent memory, then the attributes of the allocated memory should be inner/outer writeback Inner Shareable, inner and outer Non-cacheable transaction, or device type.</li> </ol>   |

| Test number | Rule ID  | Scenario  | Algorithm                               |
|-------------|----------|---|---|
| -           | B_PER_10 | I/O coherent DMA traffic must have the attribute - Inner Write-Back, Outer Write-Back, Inner Shareable.   | Covered by Test 605.                    |
| -           | B_PER_11 | If a TCG TPM-based security model is supported, the base system must provide a TPM implementation that is compliant to TPM library specification, Family 2.0.             | Not implemented in the current release. |
| -           | B_PER_12 | To ensure standard software support, a device claiming to follow the PCI Express specification must follow all the rules in PCIe specification which are software-visible | Covered by PCIe tests                   |

## 2.11 PCIe

| Test number | Rule ID   | Scenario  | Algorithm  |
|-------------|-----------|---|--|
| 801         | PCI_IN_01 | Systems must map memory space to PCI Express Configuration Space, using the PCI Express Enhanced Configuration Access Mechanism (ECAM).   | Read out the number of detected ECAM regions.  |
| 802         | PCI_IN_02 | Once boot firmware hands control over to the operating system, application processor accesses to ECAM regions must work with no additional programming. The accesses must not require any OS visible programming. | For each ECAM region, access the PCI header space and extended PCIe configuration space.   |
| -           | PCI_IN_03 | The Configuration Space of all the devices, Root Ports, Root Complex Integrated Endpoints, and switches behind a PHB must be in a single ECAM region.   | Part of device print info<br><br>Manual verification required by user by analyzing prints in the logs.   |
| 803         | PCI_IN_04 | The configuration space of all the Endpoints and Switches in a Root port's hierarchy must be in the same ECAM space as the root port.   | For all PCIe devices and switches in the system:<br><br>1. Find the Root Port it is under.<br><br>2. Check if the RP and the device are in the same ECAM region. |

| Test number | Rule ID   | Scenario   | Algorithm  |
|-------------|-----------|--|--|
| -           | PCI_IN_05 | <p>Root Port must appear as a PCI-PCI bridge to software (See Section 7.1). This implies that a Root Port:</p> <ul style="list-style-type: none"> <li>*must have all registers that are part of the type 1 header, as specified in PCIe specification (See Section 7.5.1.3).</li> <li>* must have all the capabilities required by PCIe specification for a Root Port. This includes the PCI Express capability structure (See Section 7.5.3).</li> <li>* registers must follow the access attributes (RW/RO, and so on) specified in the PCIe specification.</li> </ul> | <p>Register checks.</p> <p>Covered by Test 820-835</p> |
| -           | PCI_IN_06 | <p>PHB, with Root Port, must recognize transactions that are coming in from application PEs as PCIe configuration transactions if the transaction address is within the ECAM range mapped to the Root Port, or the hierarchy that originates at that Root Port.</p> <p>This must be done by mapping the address of the incoming memory transaction to the PCIe Configuration address space, as described in Table 22 (See Section 7.2.2).</p>  | Covered by PCIe Table creation                         |
| -           | PCI_IN_07 | <p>PHB in conjunction with Root Port must return all 1s as read response data for Configuration read requests to nonexistent functions and devices on the root bus, that is the primary bus of the Root Port. No error must be reported to software by the Root Port unless explicitly enabled to do so.</p>   | Covered by PCIe Table creation                         |



| Test number | Rule ID   | Scenario  | Algorithm   |
|-------------|-----------|---|---|
| -           | PCI_IN_08 | PHB, in conjunction with Root Port, must return all 1s as read response data for Configuration read requests that get an unsupported request response from downstream Endpoints or switches. No error must be reported to software by the Root Port unless explicitly enabled to do so.   | Not implemented in current release.   |
| -           | PCI_IN_09 | PHB in conjunction with Root Port must return all 1s as read response data for configuration read requests that arrive at the Root Port when the Root port link is in DL_Down state (See Section 2.9.1). Note that this includes the case when the link is in L3 and the downstream device is in D3cold. No error must be reported to software by the Root Port unless explicitly enabled to do so. | Not implemented.<br><br>Controlling Link state and device state through test sequence is not feasible without device-specific drivers   |
| 909         | PCI_IN_10 | PHB in conjunction with Root Port must send out Configuration transactions that are intended for the subordinate bus range of the Root Port as Type 1 Configuration transactions to downstream devices and switches. Subordinate bus range is between secondary bus number, exclusive, and the subordinate bus number, inclusive.   | Increment the root port with exerciser endpoint connected subordinate bus by 1. Generate transaction by reading endpoint vendor id register. The endpoint must receive type 1 transactions.<br><br>In case RP has right sibling, set its secondary and subordinate bus number to invalid bus number so that transaction is not forwarded to it. Bus number restored at the end of test. |
| 910         | PCI_IN_11 | PHB in conjunction with Root Port must send out Configuration transactions that are intended for the secondary bus of the Root Port as Type 0 Configuration transactions to devices and switches downstream (See Section 3.2.2.3.1).  | Initiate transaction for exerciser endpoint which is connected to root port by reading its vendor id. Exerciser must get transaction as type 0.   |
| -           | PCI_IN_12 | PHB in conjunction with Root Port must recognize and consume Configuration transactions intended for the Root Port Configuration space and, read or write the appropriate Root Port Configuration register (See Section 3.2.2.3.1).   | Covered as part of PCIe table creation and PCIe tests.  |

| Test number | Rule ID   | Scenario  | Algorithm   |
|-------------|-----------|---|---|
| 804         | PCI_IN_13 | PHB in conjunction with Root Port must recognize transactions received on the primary side of the Root Port PCI-PCI bridge, targeting prefetchable or non-prefetchable memory spaces of devices and switches that are on the secondary side of the bridge:  | For all Root-Ports in the system:<br><br>1. Detect the Non-Prefetchable address range.<br><br>2. Read / write memory from / to this memory range. |
| --          | PCI_IN_14 | PHB in conjunction with Root Port must return all 1s data to the requestor PE as the response for a configuration read if the following are true:<br><br><ul style="list-style-type: none"> <li>• CRS software visibility is disabled or not present.</li> <li>• CRS response was received for the request the first time it was issued by the Root Complex. The Root Complex then tried to make the request return valid data by re-issuing the request an IMPLEMENTATION DEFINED number of times, but CRS was the response received for all such re-issues.</li> </ul>  | Not implemented.<br><br>Generating CRS requests as part of test sequence is not possible on Silicon tests.  |
| --          | PCI_IN_15 | PHB in conjunction with Root Port must return all 1s data to the requestor PE as the response for a configuration read if all the following are true:<br><br><ul style="list-style-type: none"> <li>• CRS software visibility is enabled</li> <li>• The Configuration read is not targeting the Vendor ID register</li> <li>• CRS response was received for the request the first time it was issued by the Root Complex. The Root Complex then tried to make the request return valid data by re-issuing the request an IMPLEMENTATION DEFINED number of times, but CRS was the response received for all such re-issues.</li> </ul> | Not implemented.<br><br>Generating CRS requests as part of test sequence is not possible on silicon tests.  |

| Test number | Rule ID   | Scenario   | Algorithm   |
|-------------|-----------|--|---|
| 808         | PCI_IN_16 | <p>PHB in conjunction with the Root Port must return all 1s data to the requestor PE as the response for a configuration read if the following are true:</p> <ul style="list-style-type: none"> <li>• Target bus number of the request is not within the secondary bus to subordinate bus range of any of the Root Ports.</li> <li>• Target Bus, Device, and Function (BDF) of the request does not match BDF of any on-chip functions.</li> <li>• Target BDF of the request does not match the BDF of any of the Root Ports.</li> </ul> | <ol style="list-style-type: none"> <li>1. Get the maximum bus value from the PCIe info table.</li> <li>2. Get highest BDF of the segment.</li> <li>3. Get least high of max bus number.</li> <li>4. Form BDF using the segment, bus, device, and function numbers.</li> <li>5. Read should return all 1s.</li> </ol>  |
| 836         | PCI_IN_17 | The Root port must comply with the following (as per section 6.13).  | <p>Partially covered</p> <p>If ARI forwarding is disabled and target device number of the request &gt; 0, then the access is terminated and all 1s data is returned to the requestor PE.</p>  |
| 811         | PCI_IN_18 | The Root Port must comply with the byte enable rules that are specified in the PCIe specification (See Section 2.2.5) and must support 1 byte, 2 byte and 4-byte Configuration read and write requests.  | <p>For every Root Port in the system,</p> <ol style="list-style-type: none"> <li>1. Read the command register of the RP with 8-bit (1 byte), 16-bit (2 byte), 32-bit (4 byte) and compare.</li> <li>2. Verify the Read and write behavior for each of 8-bit (1 byte), 16-bit (2 byte) and 32-bit (4 byte).</li> </ol> |
| -           | PCI_IN_19 | All registers present in the Root Port PCIe configuration space must follow the rules as defined in section 7.2 of the PCIe specification.   | Covered by other PCIe test.   |
| 809         | PCI_IN_20 | <p>Any vendor-specific data in the PCIe configuration space must be presented by one of the following capabilities, as defined in the PCIe specification:</p> <ul style="list-style-type: none"> <li>• Vendor-Specific Capability.</li> <li>• Vendor Specific Extended Capability (VSEC).</li> <li>• Designated Vendor Specific Extended Capability (DVSEC).</li> </ul>  | For all the Root Ports in the system, search through the base and extended PCIe configuration spaces for non-PCIe compliant capabilities.   |

| Test number | Rule ID   | Scenario   | Algorithm  |
|-------------|-----------|--|--|
| 861         | PCI_MM_01 | All systems must support mapping PCI Express memory space as device memory.  | Map the BARs to normal memory attribute and check unaligned access and device memory attribute and check transaction   |
| -           | PCI_MM_02 | All systems must support mapping PCI Express memory space as Non-cacheable memory.   | Covered by Test 861  |
| -           | PCI_MM_03 | When PCI Express memory space is mapped as normal memory, the system must support unaligned accesses to that region.   | Covered by Test 861  |
| 866         | PCI_MM_04 | <p>Systems compliant to this specification must support 32-bit programming of NP BARs on such endpoints. This can be achieved in two ways:</p> <p>Method 1: PE physical address space can be reserved below 4GB, while maintaining a one-to-one mapping between PE physical address space and NP memory address space.</p> <p>Method 2: It is also possible to use a fixed offset translation scheme that creates a fixed offset in direction between PE physical address space, and PCI memory. This allows a window in PE physical address space that is above 4G to be mirrored in PCI memory space below 4G. This requires support in the PHB. Furthermore, firmware must program the PHB with the fixed offset, and to supply this information to the OS.</p> | <p>For the host bridge in the system, check the pre-fetchable type, if 0 then read the memory type.</p> <p>Scan all the bridge devices and check the memory type</p>   |
| 862         | PCI_MM_05 | For accesses from a PCIe endpoint to the host memory system, the address sent by PCI Express devices must be presented to the memory system or SMMU unmodified.  | <p>For all DMA Requesters populated in the information table, which are behind an SMMU, verify there are no additional translations before address is given to SMMU.</p> <p>Check if IOMMU operations are properly integrated for this device by making the standard OS DMA API call and verifying the DMA address is part of the IOVA translation table</p> |

| Test number | Rule ID   | Scenario   | Algorithm   |
|-------------|-----------|--|---|
| -           | PCI_MM_06 | For accesses from a PCIe endpoint to the host memory system, in a system where the PCI Express does not use an SMMU, the PCI Express devices have the same view of physical memory as the PEs.   | Covered by Test 862   |
| -           | PCI_MM_07 | For accesses from a PCIe endpoint to the host memory system, in a system with an SMMU for PCI Express there are no transformations to addresses being sent by PCI Express devices before they are presented as an input address to the SMMU. | Covered by Test 862   |
| 863         | PCI_MSI_1 | Support for Message Signaled Interrupts (MSI/MSI-X) is required for PCI Express devices.   | Check if PCI device is PCI Express capable and MSI is supported   |
| 904         | PCI_MSI_2 | The intended use model is that each unique MSI(-X) must trigger an interrupt with a unique ID and the MSI(-X) must target GIC registers requiring no hardware-specific software to service the interrupt.                                    | For all exerciser in the system,<br><br>1. Disable all SMMU and check if MSI-X capability is supported. If not supported skip, else create MSI mapping and configure the MSI table.<br><br>2. Install ISR and trigger the interrupt.<br><br>3. Check completion of ISR. Clear the interrupt and the MSI mappings. |
| 806         | PCI_LI_01 | PCI Express legacy Interrupt messages must be converted to an SPI.   | For all PCIe devices in the system:<br><br>1. Detect whether the legacy IRQ map exists.<br><br>2. If it exists, check whether the interrupt falls in SPI range.   |
| 906, 865    | PCI_LI_02 | A unique SPI ID must be allocated to each of the legacy interrupt lines of a PHB. It is permissible to share SPIIDs across PCI host bridges.   | 1. Allocate memory for interrupt mappings.<br>2. Get the exerciser BDF.<br>3. Register an interrupt handler to verify legacy interrupt functionality.<br>4. Trigger the legacy interrupt.<br>5. Check the completion of interrupt service routine.<br>6. Return the interrupt.                                    |

| Test number | Rule ID   | Scenario   | Algorithm   |
|-------------|-----------|--|---|
| 806         | PCI_LI_03 | Each legacy interrupt SPI must be programmed as level-sensitive in the appropriate GIC_ICFGR.  | For all PCIe devices in the system:<br><br>1. Detect whether the legacy IRQ map exists.<br><br>2. If it exists, read GICD_ICFGR to check whether the interrupts in this map are level or edge sensitive.  |
| --          | PCI_LI_04 | Implementation defined REGISTERS MUST NOT BE USED TO DELIVER THESE MESSAGES, ONLY REGISTERS DEFINED IN THE PCI EXPRESS SPECIFICATION AND THE ARM GIC SPECIFICATION.                        | OS boot covers this.  |
| --          | PCI_SM_01 | Hardware support for function or virtual function assignment to a VM or user-space driver is optional, but if necessary, use a System MMU compliant with the Arm System MMU specification. | OS boot will cover this.  |
| --          | PCI_SM_02 | Functions intended for VM assignment, or assignment to a user-space driver must implement function level reset.  | Covered by Test 835   |
| 907         | PCI_IC_01 | PCI Express transactions not marked as No_snoop accessing memory that the PE translation tables attribute as cacheable and shared are I/O Coherent with the PEs.                           | For all exercisers in the system,<br><br>1. Find the SMMU node and disable it globally so that the transaction passes through SMMU without address modification.<br><br>2. Get a WB, Outer Shareable DDR Buffer.<br><br>3. Program exerciser hierarchy to start sending/receiving TLPs with No Snoop attribute header.<br><br>4. Initialize main memory region marked as WB, Outer Shareable by the PE page tables. CPU write and read to this region with new data and ensure that the new data is cached in the CPU caches. Read and write the same data locations from the Exerciser with NS=0. The exerciser and CPU should get the latest data (hardware enforced cache coherency expected). |
| 864         | PCI_IC_02 | The PCI Express root complex is in the same Inner Shareable domain as the PEs.   | The memory attribute of the PCIe Root complex is Inner Shareable.   |

| Test number | Rule ID   | Scenario  | Algorithm   |
|-------------|-----------|---|---|
| -           | PCI_IC_03 | This means that if a PCI Express device is accessing cached memory, then the transactions from the PCI Express devices snoop the PE caches.   | Covered by Test 907   |
| 908         | PCI_IC_04 | PCI Express also allows PCI Express devices to mark transactions as No_snoop. The memory accessed by such transactions must have coherency managed by software.   | For all exercisers in the system,<br><br>1. Find the SMMU node and disable it globally so that the transaction passes through SMMU without address modification.<br><br>2. Get a WB, Outer Shareable DDR buffer.<br><br>3. Program exerciser hierarchy to start sending or receiving TLPs with no snoop attribute header.<br><br>4. Perform DMA transactions.   |
| 903         | PCI_IC_05 | If there is no SMMU or an SMMU that is not policing transactions from the root complex, the system must be able to distinguish between addresses that are targeted at memory and devices. Transactions that are targeted at devices must be treated as device type accesses. They must be ordered, must not merge, and must not allocate in caches. | 1. Read and write on config space mapped to device memory. Map config space to Arm device memory in MMU page tables. Perform transactions on incremental aligned address and on the same address.<br><br>2. Read and write on BAR space mapped to device memory. Map MMIO space to Arm device memory in MMU page tables. Perform transactions on incremental aligned address and on the same address. |
| -           | PCI_IC_06 | Transactions that are targeted at memory and that are marked No_snoop must be presented to the memory system as non-cached. Transactions that are targeted at memory and not marked as No_snoop must be presented as cached, shared.  | Covered by Test 907   |
| -           | PCI_IC_07 | If a memory page is marked as non-cached in the PE translation tables, all PCI Express transactions accessing that memory must be marked as No_snoop. Failure to do so can result in loss of coherency.   | Covered by Test 907   |
| -           | PCI_IC_08 | IO Coherency Table.   | Covered by Test 907   |

| Test number | Rule ID   | Scenario  | Algorithm  |
|-------------|-----------|---|--|
| -           | PCI_IC_09 | In the case where the system has a System MMU translating and attributing the transactions from the Root Complex, the PCI Express transactions must keep the memory attributes assigned by the System MMU. If the System MMU-assigned attribute is cacheable, then it is IMPLEMENTATION DEFINED if No_snoop transactions replace the attribute with non-cached. | Not implemented.<br><br>This rule has IMPDEF behavior  |
| -           | PCI_IO_01 | If an implementation supports legacy I/O, it is supported using a one-to-one mapping between legacy I/O space and a window in the host physical address space. However, such schemes must not require a kernel driver to be set up, any necessary initialization must be performed before OS boot.  | Not implemented.<br><br>This rule requires an EP with Legacy IO support and device driver.   |
| -           | PCI_IEP_1 | Anything claiming to follow the PCI Express specification must follow all the specification that is software-visible to ensure standard, quality software support.  | iEP rules are out of scope for current release.  |
|             | PCI_PP_01 | It is system-specific whether peer-to-peer traffic through the system is supported.   | Not implemented.<br><br>This is IMPDEF rule.   |
| 914         | PCI_PP_02 | Systems must not deadlock if PCI Express devices attempt peer-to-peer transactions – even if the system does not support peer-to-peer traffic. This rule is needed to uphold the principle that a virtual machine and its assigned devices should not deadlock the system for other virtual machines or the hypervisor.   | 1. Check if the platform does not support peer-to-peer transaction<br><br>2. Initiate a peer-to-peer transaction by generating a DMA from one exerciser to another<br><br>3. The transaction should not result in a deadlock and the ACS must continue execution |



| Test number | Rule ID   | Scenario   | Algorithm  |
|-------------|-----------|--|--|
| 819         | PCI_PP_03 | In a system where the PCIe hierarchy allows peer-to-peer transactions, the root ports in an Arm-based SoC must implement PCIe access control service (ACS) features.   | <p>It is IMPLEMENTATION DEFINED whether a given platform supports peer-to-peer traffic. If the platform supports this, check in the ACS PCIe capability whether:</p> <ol style="list-style-type: none"> <li>1. Source validation is supported.</li> <li>2. Translation blocking is supported.</li> <li>3. P2P request redirect is supported.</li> <li>4. P2P completion redirect is supported.</li> <li>5. Upstream forwarding is supported.</li> </ol>  |
| 901, 902    | PCI_PP_04 | <p>For Root ports this means that the following must be supported:</p> <ol style="list-style-type: none"> <li>1. ACS Source Validation. (V)</li> <li>2. ACS Translation Blocking. (B)</li> <li>3. ACS P2P Request Redirect (R).</li> <li>4. ACS P2P Completion Redirect (C).</li> <li>5. ACS Upstream Forwarding (U).</li> <li>6. The root port must support redirected request validation by querying an Arm architecture compliant SMMU to get the final target physical address and access permission information.</li> <li>7. The root port must support ACS violation error detection, logging, and reporting. Logging and reporting must be through the usage of AER mechanism.</li> </ol> | <p>It is IMPLEMENTATION DEFINED whether a given platform supports peer-to-peer traffic. If the platform supports this, For an exerciser in the system.</p> <ol style="list-style-type: none"> <li>1. Get RP of the exerciser.</li> <li>2. If ACS supported, enable Source Validation &amp; Transaction Blocking.</li> <li>3. Find another exerciser on other root port, break from the test if no such exerciser is found.</li> <li>4. If both RPs support ACS, then check for ACS functionality.</li> </ol> |

| Test number | Rule ID   | Scenario   | Algorithm  |
|-------------|-----------|--|--|
| 817, 818    | PCI_PP_05 | <p>If the Root port supports peer-to-peer traffic with other root ports, then it must support the following:</p> <ul style="list-style-type: none"> <li>• Validation of the peer-to-peer transactions before sending it to the destination root port using the same mechanism as ACS redirected request validation. Any ACS violation error generated because of the request validation should be reported using the standard ACS violation error detection, logging and reporting mechanism specified in PCIe specification.</li> <li>• If the root port supports Address Translation services and peer-to-peer traffic with other root ports, then it must support ACS direct translated P2P (T).</li> </ul> | <p>It is IMPLEMENTATION DEFINED whether a given platform supports peer-to-peer traffic. If the platform supports this, then check:</p> <ol style="list-style-type: none"> <li>1. If ACS is supported, direct translated P2P is supported.</li> <li>2. AER is supported</li> </ol>  |
| 905         | PCI_PAS_1 | <p>If the system supports PCIe PASID, then at least 16 bits of PASID must be supported. This support must be full system support, from the root complex through to the SMMUv3 and any end points for which PASID support is required.</p>  | <p>For all exercisers in the system behind an SMMU:</p> <ol style="list-style-type: none"> <li>1. Create a mapping of 1 IOVA region to 2 PA regions, via SMMU (Each of the two mappings is identified by a distinct PASID).</li> <li>2. Check whether there is support for at least 16-bit PASIDs.</li> <li>3. Configure the exerciser DMA engine to access the IOVA region base.</li> <li>4. Configure the exerciser to perform a DMA accesses with PASID1 in its transactions (Accesses must target PA region 1).</li> <li>5. Configure the exerciser to perform DMA accesses with PASID2 in its transactions (Accesses must target PA region 2).</li> </ol> |
| -           | PCI_PTM_1 | <p>Any system that implements PCIe Precision Time Measurement (PTM) must use the Arm architecture defined System Counter as PTM Requester time source at the PTM root(s).</p>  | Not Implemented in current release   |

**NOTE:** DeviceID and ITS rules are out of scope for this release for platforms using Device tree.

# Appendix A Revisions

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

**Table A-1 Issue 01**

| Change        | Location |
|---------------|----------|
| First release | -        |

**Table A-2 Issue 02**

| Change                        | Location                  |
|-------------------------------|---------------------------|
| Increased PCIe rules coverage | <a href="#">2.11 PCIe</a> |

**Table A-3 Issue 03**

| Change  | Location                         |
|---|----------------------------------|
| Added B_PER_01, B_PER_02, B_PER_03 rule IDs in Peripheral section | <a href="#">2.10 Peripherals</a> |
| Added PCI_IN_08, PCI_PP_02, RE_ORD_4 rule IDs in PCIe section.    | <a href="#">2.11 PCIe</a>        |

**Table A-4 Issue 04**

| Change  | Location                       |
|---|--------------------------------|
| Deleted B_PE_16, B_PE_17, B_SEC_01, B_SEC_02, B_SEC_03, B_SEC_04, B_SEC_05 rule IDs in PE section.  | <a href="#">2.2 PE</a>         |
| Deleted B_MEM_09 rule IDs in Memory Map section.  | <a href="#">2.3 Memory Map</a> |
| Deleted B_SMMU_03, B_SMMU_04, B_SMMU_05, B_SMMU_09, B_SMMU_11, B_SMMU_13, B_SMMU_14, B_SMMU_20, B_SMMU_21, B_SMMU_22, B_SMMU_23 rule IDs in SMMU section. | <a href="#">2.5 SMMU</a>       |
| Deleted RCiEP rule IDs in PCIe section.   | <a href="#">2.11 PCIe</a>      |