



Architecture Compliance Test Scenario IR

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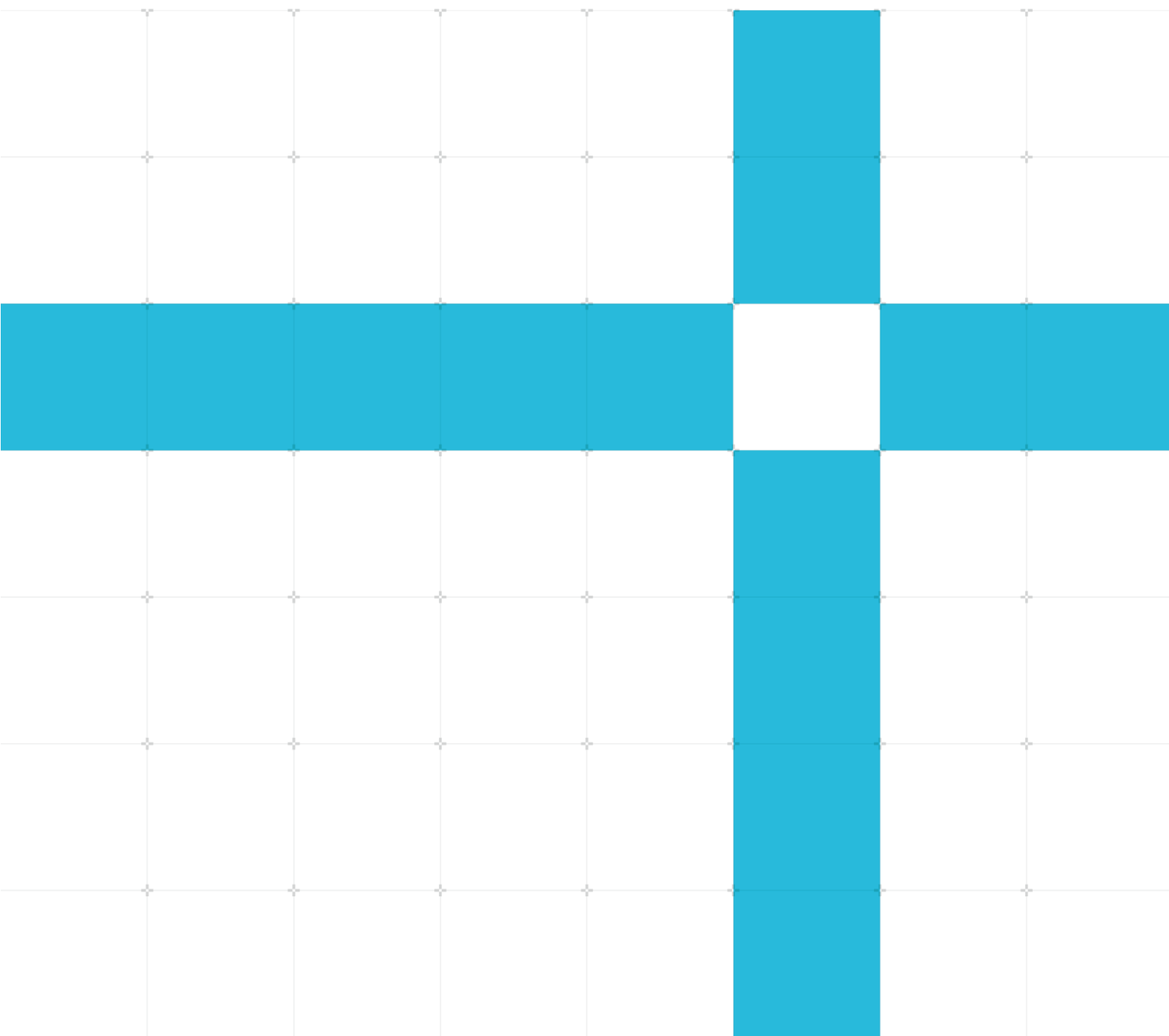
Arm Base System Architecture

Non-Confidential

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Issue 01

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Arm BSA

Arm Base System Architecture Scenario

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Release information

Document history

Issue	Date	Confidentiality	Change
01	25 March 2021	Non-Confidential	Alpha release

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Product Status

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

Progressive terminology commitment

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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.
bold	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 bold	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. For example: <code>MRC p15, 0, <Rd>, <CRn>, <CRm>, <Opcode_2></code>
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 DEFINED, IMPLEMENTATION SPECIFIC, UNKNOWN, and UNPREDICTABLE.

1.4 Additional Reading

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

Table 1-1 Arm publications

Document name	Document ID	Licensee only
Arm® Base System Architecture 1.0	DEN0094A	No
Arm® Base Boot Requirements 1.0	DEN0107A	No
Arm® Architecture Reference Manual Armv8, for Armv8-A Architecture	ARM DDI 0487F	No

Table 1-2 Other publications

Document ID	Document name
None	PCI Express Base Specification Revision 5.0, Version 1.0

1.5 Feedback

Arm welcomes feedback on this product and its documentation.

1.5.1 Feedback on this product

If you have any comments or suggestions about this product, contact your supplier and give:

- The product name.
- 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

If you have comments on content, send an email to support-systemready-accs@arm.com and give:

- 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 like 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 to this specification. However, Arm anticipates that OEMs, ODMs, cloud service providers, and software providers will 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
- Exerciser

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 1.0 [3].	CPU System register read. 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"> Eight, when the interrupt controller is compliant to GICv2. 2^{28} when the interrupt controller is compliant to GICv3 or higher. 	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 PEs are coherent and in the same Inner Shareable domain.	ID_MMFR0_EL1.InnerShr must indicate hardware coherency support for InnerShr across all cores, ShreLvl must be 0001 across all cores (later is mandated for Armv8). Functional verification is optional.
6	B_PE_06	Where export restrictions allow, PEs must implement cryptography extension support for FEAT_AES, FEAT_SHA1 and FEAT_SHA256.	CPU System register read: Bits [4:15] of ID_AA64ISAR0_EL1 must be supported
7	B_PE_07	PEs must implement little-endian support.	CPU System register read: SCTLR.EE should be supported.
8	B_PE_08	PEs must implement EL1 and EL0 in the AArch64 Execution state.	ID_AA64PFR0_EL1.EL0 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 must match virtual address, contextID or VMID.	1. Read ID_AA64DFR0_EL1 and check number of break points. 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.
13	B_PE_13	PEs must implement the FEAT_CRC32 instructions.	ID_AA64ISAR0_EL1.CRC32 should be supported.

Test Number	Rule ID	Scenario	Algorithm
-	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 Feasible
14	B_PE_15	<p>If FEAT_PAuth (Pointer Authentication), mandatory from Armv8.3, is implemented, Arm recommends that the standard algorithm defined by the Arm architecture [2] is implemented for address and generic authentication.</p> <ul style="list-style-type: none"> If an alternative algorithm is used it must be at least as cryptographically strong as the Arm recommended algorithm. 	If pointer signing is implemented, check ID_AA64ISAR1_EL1[11:4] for address authentication and ID_AA64ISAR1_EL1[31:24] for generic authentication.
-	B_PE_16	<p>If FEAT_MTE (Memory Tagging Extension), is implemented,</p> <ul style="list-style-type: none"> The implementation can be full including instructions and checks, or just provide support for the instructions. All general-purpose volatile host DRAM that can be used by an operating system for applications must support memory tagging. Dedicated memories for accelerators, or remote memory, or non-volatile memory do not need to support it. Firmware tables will indicate the memory ranges to the OS. 	Not implemented in current release.
15	B_PE_17	If PEs implement the Scalable Vector Extension (SVE) and the Statistical Profiling Extension (SPE), the PEs must implement FEAT_SPEv1p1.	If ID_AA64PFR0_EL1.SVE is implemented, then ID_AA64DFR0_EL1.PMSVer must be supported.
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 must 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 B_PE_11.	Read DBGBCR<n>_EL1 & check 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.
16	B_SEC_01	PEs must implement the restrictions on speculation that are introduced in the Arm v8.5 extensions to the Arm architecture [2] and SCXTNUM_ELx registers as indicated by ID_AA64PFR0_EL1.CSV2==b0010 and ID_AA64PFR0_EL1.CSV3==b0001. See FEAT_CSV2 and FEAT_CSV3 in [2].	ID_AA64PFR0_EL1.CSV2 and ID_AA64PFR0_EL1.CSV3 must be supported.

Test Number	Rule ID	Scenario	Algorithm
17	B_SEC_02	PEs implement the PSTATE/CPSR SSBS (Speculative Store Bypass Safe) bit and the instructions to manipulate it. See FEAT_SSBS in [2]. This is identified by ID_AA64PFR1_EL1.SSBS==b0010	ID_AA64PFR1_EL1.SSBS must be supported.
18	B_SEC_03	PEs implement the CSDB, SSBB and PSSBB barriers	ID_AA64PFR1_EL1.SSBS must be supported.
19	B_SEC_04	PEs implement the FEAT_SB. This is indicated by ID_AA64ISAR1_EL1.SB== b0001	ID_AA64ISAR1_EL1.SB must be supported.
20	B_SEC_05	PEs implement the CFP RCTX, DVP RCTX, CPP RCTX instructions to restrict use of information gathered through control flow, data value prediction, or cache prefetch prediction, from affecting speculative execution. See FEAT_SPECRES in [2]. Support for the instructions is indicated by ID_AA64ISAR1_EL1.SPECRES==b0001.	ID_AA64ISAR1_EL1.SPECRES must be supported.

2.3 Memory Map

Test Number	Rule ID	Scenario	Algorithm
102	RB_MEM_01	All memory accesses, whether they access memory space that is populated or not, must respond within finite time, to avoid the possibility of system deadlock.	<ol style="list-style-type: none"> 1. Initialize the exception handlers. 2. Get the address range from the system table/memory map. 3. Try to access the memory. 4. Exception may or may not occur, but the test should continue to proceed. 5. Once all memory range are accessed, the test is considered as pass.
101	RB_MEM_02	Where a 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.	This test depends on UEFI DxeServicesTable, which is not supported on U-boot.
104	RB_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"> 1. Check if the PCIe device is capable of 64-bit DMA. 2. If not, check if it is present behind an SMMU.
104	RB_MEM_04	If the Requester goes through a SMMU then the Requester must be capable of addressing all the Non-secure address space when the SMMU is turned off.	<ol style="list-style-type: none"> 1. Check if the PCIe device is capable of 64-bit DMA. 2. If not, check if it is present behind an SMMU.
103	RB_MEM_05	All PEs must be able to access all the Non-secure address space.	<ol style="list-style-type: none"> 1. For the current PE, read ID_AA64MMFRO_EL1[3:0] to get max number of bits that PE can access. 2. Check if the maximum accessible memory is accessible by PE.
104	RB_MEM_06	Non-secure off-chip devices that cannot directly address all the Non-secure address space must be placed behind a stage 1 SMMU that is compatible with the Arm SMMUv2 or SMMUv3 specification, that has an output address size large enough to address all of the Non-secure address space. (See Section 3.7 [3]).	<ol style="list-style-type: none"> 1. Check if the PCIe device is capable of 64-bit DMA. 2. If not, check if it is present behind an SMMU.

Test Number	Rule ID	Scenario	Algorithm
-	RB_MEM_07	Where it is possible for the forward 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 feasible.
-	RB_MEM_08	The system must provide some memory that is mapped in the Secure address space.	Not feasible. This is a Secure platform test.
-	RB_MEM_09	This Secure memory must not be aliased in the Non-secure address space.	Not feasible. This is a Secure platform test.

2.4 GIC

Test Number	Rule ID	Scenario	Algorithm
201	B_GIC_01	A base system must present OSs and hypervisors with the interfaces defined by the one of the following: <ul style="list-style-type: none"> Generic Interrupt Controller (GIC) v2 interrupt controller. GICv2 interrupt controller with GICv2m extension. GICv3 interrupt controller. 	Check for the version from the Platform information and check. And if not present in Platform information, 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 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 implemented from GICD_CTLR.DS bit.
205	B_GIC_05	The system may implement at least eight Non-secure SGIs, assigned to interrupt IDs 0-7.	<ol style="list-style-type: none"> 1. Check whether the distributor forwards Non-Secure Group 1 interrupts. 2. If NS Group 1 interrupts are forwarded, try to enable SGI INTID 0 to 15 by writing to the distributor / redistributor enable register. 3. Check which interrupt IDs are enabled afterwards; Secure interrupts will return 0, and Non-secure interrupts will return 1.
206	B_PPI_01	Check PPI Assignments for Operating System.	<ol style="list-style-type: none"> 1. Detect the interrupt IDs . 2. Install ISRs for those IDs. 3. Trigger the conditions to assert the interrupts. 4. Check whether the interrupt has been received.

Test Number	Rule ID	Scenario	Algorithm
251	B_PPI_02	Check PPI Assignments for Hypervisor.	<ol style="list-style-type: none"> 1. Detect the interrupt IDs. 2. Install ISRs for those IDs. 3. Trigger the conditions to assert the interrupts. 4. Check whether the interrupt has been received.
-	B_PPI_03	Check PPI Assignments for Platform Security.	Not feasible. This is a Secure platform test.
281	Section I	Check SPI's which are assigned to MSIs are Edge-Triggered.	<ol style="list-style-type: none"> 1. Get the number of MSI Frames. 2. Loop through number of SPIs for that frame. 3. Check by reading the value of GICD_ICFGRn register for SPI.
282	Section I	Check GICv2m MSI Frame Register Configuration.	<ol style="list-style-type: none"> 1. Get the number of MSI Frames. 2. Loop through number of SPIs for that frame. 3. Check MSI_TYPER is RO. 4. Check for SPI_ID is 32-1020. 5. Check MSI_IIDR is RO.
283	Section I	Check GICv2m MSI to SPI generation functional test.	<ol style="list-style-type: none"> 1. Get the number of MSI Frames. 2. For each Frame get an SPI_ID. 3. Install a Handler. 4. Trigger an SPI using MSI_SETSPI_NS register. 5. Check Interrupt is triggered.
284	Section I	SPIs that are allocated to MSIs must only be controllable by the GICv2m MSI registers.	<ol style="list-style-type: none"> 1. Get the number of MSI Frames. 2. For each Frame get an SPI_ID. 3. Install a Handler. 4. Generate SPI using GICD_ISPENDR register. 5. No Interrupt should be generated. 6. Trigger an SPI using the MSI_SETSPI_NS register. 7. Check the Interrupt is triggered as SPIs should be controlled by the MSI frame register instead of other GICD Registers.

2.5 SMMU

Test Number	Rule ID	Scenario	Algorithm
301	B_SMMU_01	All the System MMUs presented to an OS or hypervisor must be compliant with the same architecture version.	For all SMMU controllers in the system, check if they are all based on either the v2 or v3 architecture.

Test Number	Rule ID	Scenario	Algorithm
302	B_SMMU_02	The SMMU must support the translation granule sizes that are supported by the PEs.	<ol style="list-style-type: none"> 1. Read out the granule size support for the PE (AA64MMFR0_EL1.TGran_x). 2. Verify whether this is congruent to the granule sizes supported by the SMMU.
303	B_SMMU_03	If PEs implement FEAT_LVA (ID_AA64MMFR2_EL1.VARange = 0b0001), the SMMU must support extended virtual addresses (SMMU_IDR5.VAX = 0b01).	<ol style="list-style-type: none"> 1. Read out: ID_AA64MMFR2_EL1.VARange 2. If enabled, check whether SMMU_IDR5.VAX is set.
304	B_SMMU_04	If PEs use Armv8.4 and can issue TLB range invalidation instructions, the SMMU must support range invalidation.	<ol style="list-style-type: none"> 1. Read out: ID_AA64ISAR0_EL1.TLB 2. If enabled, check whether SMMU_IDR3.RIL is set.
-	B_SMMU_05	All DVM receivers visible to Normal world software in a system must receive all DVM messages initiated by a DVM Requester. This would require that the DVM capabilities of the SMMU and the interconnect are the same or a superset of the initiator (typically PE).	Covered by Test 304.
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"> 1. Read out: ID_AA64MMFR0_EL1.PARange. 2. If enabled, check whether SMMU_IDR5.OAS equals "0b0110".
-	B_SMMU_07	Devices that operate across non-contiguously allocated memory require stage 1 System MMU functionality.	Not feasible to check whether a device operates across non-contiguously allocated memory.
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"> • The SMMUv2 specification, where each context bank must present a unique physical interrupt to the GIC • The Arm SMMUv3 specification or higher, where the integration of the System MMUs is compliant with the requirements in Section D [3] 	<ol style="list-style-type: none"> 1. Read out: ID_AA64PFR0_EL1.SEL2 2. If enabled, and SMMU handles stage 1 policing, check whether SMMU_AIDR.ArchMajorRev ≥ 3 and SMMU_AIDR.ArchMinorRev ≥ 2. <p>Else, check whether SMMU Major revision is at least 2.</p>

Test Number	Rule ID	Scenario	Algorithm
-	B_SMMU_09	<p>If Secure-EL2 is implemented, stage 1 System MMU functionality that is made visible to an operating system must present the interface of a System MMU compatible with the Arm SMMUv3.2, or higher, architecture revision where:</p> <ul style="list-style-type: none"> • The integration of the System MMUs is compliant with the rules in SMMUv3 integration, Section D [3]. • SMMU implementations must provide level 1 or level 2 support for page table resizing. Arm recommends the SMMU implements level 2. If the SMMU implementation provides level 2, then Arm recommends that the PE also provides level 2. 	Covered by Test 306.
309	B_SMMU_11	MPAM architecture requires that all Requesters that can access an MPAM controlled resource must support passing MPAM ID information. Therefore, a SMMUv3.2, or higher, implementation must support the MPAM extension if the requests it serves access MPAM controlled resources.	<ol style="list-style-type: none"> 1. Check if there are any MPAM controlled memory resources (Read out: ID_AA64PFR0_EL1.MPAM). 2. If the architecture revision of the SMMU is at least v3.2, check for MPAM support on the SMMU side (SMMU_IDR3.MPAM == '1' and SMMU_MPAMIDR.PARTID_MAX != 0).
-	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 tested since this test requires DMA support.
307	B_SMMU_13	If PE supports 16-bit ASID, The SMMU must implement support for 16-bit ASID.	<ol style="list-style-type: none"> 1. Read out: ID_AA64MMFR0_EL1.ASIDBits. 2. If enabled, and SMMU handles stage 1 policing, check whether SMMU_IDR0.ASID16 is set.
308	B_SMMU_14	The SMMU will support little-endian for translation table walks, and at a minimum must match the endianness support of the PEs.	<ol style="list-style-type: none"> 1. Read out: SCTLR_EL1.EE 2. If enabled, check whether SMMU_IDR0.TTENDIAN is congruent with this value.
351	B_SMMU_16	If a device is assigned and passed through to an operating system under a hypervisor, then the memory transactions of the device must be 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 whether SMMU_IDR0.S2TS (v2) or SMMU_IDR0.S2P (v3) is enabled.

Test Number	Rule ID	Scenario	Algorithm
-	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.	Not implemented
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.	<ol style="list-style-type: none"> 1. Read out: ID_AA64PFR0_EL1.SEL2 2. If enabled, and SMMU handles stage 2 policing, check whether SMMU_AIDR.ArchMajorRev ≥ 3 and SMMU_AIDR.ArchMinorRev ≥ 2 <p>Else, check whether SMMU Major revision is at least 2.</p>
353	B_SMMU_19	<p>When stage 2 System MMU functionality is provided by a System MMU compatible with the Arm SMMUv2 specification:</p> <ul style="list-style-type: none"> • Each context bank must present a unique physical interrupt to the GIC. 	<ol style="list-style-type: none"> 1. Create a list of all physical interrupts per context bank with their corresponding IDs. 2. For each interrupt present in the list, check whether the assigned ID appears elsewhere in the list.
-	B_SMMU_20	<p>If Secure EL2 is implemented, stage 2 System MMU functionality that is made visible to a hypervisor must present the interface of a System MMU compatible with the Arm SMMUv3.2, or higher, architecture revision where:</p> <ul style="list-style-type: none"> • The integration of the System MMUs is compliant with the rules in SMMUv3 integration, Section D [3]. • SMMU implementations must provide level 1 or level 2 support for page table resizing. Arm recommends that the SMMU implements level 2. If the SMMU implementation provides level 2, then Arm recommends that the PE also provides level 2. 	Covered by Test 352.
354	B_SMMU_21	<p>When stage 2 System MMU functionality is provided by a System MMU compatible with the Arm SMMUv3 spec:</p> <ul style="list-style-type: none"> • The integration of the System MMUs is compliant with the specification in Section D [3]. 	Check whether SMMU_IDR0.COHAAC is set.

Test Number	Rule ID	Scenario	Algorithm
-	B_SMMU_22	MPAM architecture requires that all Requesters that can access an MPAM controlled resource, must support passing MPAM ID information. Therefore, a SMMUv3.2, or higher, implementation must support the MPAM extension if the requests the SMMU serves access MPAM controlled resources.	Covered by Test 309.
355	B_SMMU_23	If PE supports 16-bit VMID, The SMMU must implement support for 16-bit VMID.	1. Read out: ID_AA64MMFR1_EL1.VMID 2. If enabled, check whether SMMU_IDR0.VMID16 is set.
-	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 feasible. This is a Secure platform test.
-	B_SMMU_25	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: <ul style="list-style-type: none"> The integration of the System MMUs is compliant with the rules in Section D [3]. SMMU implementations must provide level 1 or level 2 support for page table resizing. 	Not feasible. This is a Secure platform test.
-	SMMU_01	All SMMU translation table walks and all SMMU accesses to SMMU memory structures and queues are I/O coherent (SMMU_IDR0.COHAAC == 1).	Covered by Test 354.
-	SMMU_02	The system must be constructed so the act of the SMMU stalling on a fault from a device must not stall the progress of any other device or PE that is not under the control of the same operating system as the stalling device.	Not tested, this test requires a platform with multiple SMMU units.

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.

Test Number	Rule ID	Scenario	Algorithm
401	B_TIME_02	The system counter of the Generic Timer must run at a minimum frequency of 10MHz.	1. Read the CNTFREQ register. 2. If the read value is greater than 10 MHz, test has passed. 3. Otherwise, the test failed.
-	B_TIME_03	The counter must not roll over inside a 10-year period.	Not feasible. This is a Secure platform test.
-	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.	Not feasible. This is a Secure platform test.
-	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.	Not feasible. This is a Secure platform test.
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.	1. If any platform timer available, the test passes. 2. Else if all PE timers are always on, the test passes. 3. Otherwise, the test fails.
403	B_TIME_07	The system wakeup timer must in the form of the memory-mapped timer.	1. Check if timer is secured or not. 2. For NS timer, check CNTLBase is accessible or not. 3. If CNTLBase is accessible, then timer is in the form of memory mapped timer.
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.	1. Generate the timer interrupt. 2. Check if the interrupt is reaching GIC. 3. Check the system specific interrupt controller with interrupt id.
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.	1. Check any always on timer is available or not. 2. The second part is not tested, since the secondary PE required interrupt handler support
-	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

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	RB_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"> 1. Suspend PE. 2. Get intid of wakeup interrupt. 3. Generate interrupt. 4. PE should wakeup irrespective of the mask bits. 5. Fail if does not wakeup.
-	RB_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 testing, requires multi-PE interrupt handling support.
501-505	RB_WAK_03	Whenever a PE is woken from a 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"> 1. Install interrupt handlers. 2. Suspend PE. 3. Wake PE by providing interrupt. 4. Check if OS raises an interrupt once PE is woken. 5. Find which device has caused this interrupt.
501-505	RB_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"> 1. Generate interrupt. 2. Install interrupt handlers. 3. In ISR read the interrupt pending bit (it must be '1') 4. Clear interrupt and ISR.
501-505	RB_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"> 1. Generate the interrupt. 2. Check if the interrupt is reaching GIC. 3. Check the system specific interrupt controller with interrupt id.
-	RB_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 other wakeup rules.

2.8 Power

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

Power semantics rules RB_WAK_07 to RB_WAK_11 are derived from the above table.

Test Number	Rule ID	Scenario	Algorithm
-	RB_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 wakeup rules.

Test Number	Rule ID	Scenario	Algorithm
-	RB_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.
-	RB_WAK_09	When the system is in a state where the GIC is powered down, devices must not send messaged interrupts to the GIC.	Not testing, requires multi-PE interrupt handling support.
501-505	RB_WAK_10	Schematic check.	Perform like rule 7 for other schematics.
-	RB_WAK_11	Component check.	Covered by wakeup rules.

2.9 Watchdog

Test Number	Rule ID	Scenario	Algorithm
701	RB_WD_01	The generic watchdog must be implemented as specified in Section C of BSA specification 1.0 [3].	Read and verify watchdog refresh and control registers.
-	RB_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	RB_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"> 1. Generate the watchdog interrupt. 2. Check if the interrupt is reaching GIC. 3. Check the system specific interrupt controller with interrupt id.
-	RB_WD_04	Watchdog Signal 1 must be routed to the platform.	Not testing, IMPLEMENTATION SPECIFIC.
-	RB_WD_05	The action taken on the raising of watchdog signal 1 is IMPLEMENTATION SPECIFIC.	Not testing, IMPLEMENTATION SPECIFIC.

2.10 Peripherals

Test Number	Rule ID	Scenario	Algorithm
601	RB_PER_01	If the system has a USB2.0 host controller peripheral, it must conform to EHCI v1.1 or later.	Test depends on UEFI PCIIO protocol which is not supported on U-boot.
601	RB_PER_02	If the system has a USB3.0 host controller peripheral it must conform to XHCI v1.0 or later.	Test depends on UEFI PCIIO protocol which is not supported on U-boot.
602	RB_PER_03	If the system has a SATA host controller peripheral it must conform to AHCI v1.3 or later.	Test depends on UEFI PCIIO protocol which is not supported on U-boot.
-	RB_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
603	RB_PER_05	<p>For the purpose of 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"> • The Generic UART as specified in Section B [3]. 	<ol style="list-style-type: none"> 1. Install handlers to catch unexpected exceptions 2. Get the base address for each UART present 3. Validate the read-only registers UARTFR, UARTRIS, UARTRMIS, UARTDR if they conform to BSA specification

Test Number	Rule ID	Scenario	Algorithm
604	RB_PER_06	The UART interrupt output is connected to the GIC as an SPI or an LPI.	<ol style="list-style-type: none"> 1. Get the interrupt ID of the UART peripheral 2. Install the ISR for the interrupt ID 3. Generate an UART transaction 4. Check if the interrupt is received in the ISR
-	RB_PER_07	UART must be mapped on to Non-secure address space. This is called the Non-secure UART.	Covered by Test-603
-	RB_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	RB_PER_09	<p>The memory attributes of DMA traffic must be one of the following:</p> <ul style="list-style-type: none"> • Inner Write-Back, Outer Write-Back, Inner Shareable. • Inner Non-cacheable, Outer Non-cacheable. • A device type. 	<ol style="list-style-type: none"> 1. Get the DMA controllers present in the system 2. Allocate a memory for a DMA transaction 3. Read the memory attributes of the allocated memory 4. If DMA supports coherent memory, then the attributes of the allocated memory should be inner/outer writeback, inner shareable. 5. If the DMA doesn't support coherent memory, then the attributes of the allocated memory should be inner/outer writeback inner shareable, inner/outer non-cacheable, or device type
-	RB_PER_10	I/O coherent DMA traffic must have the attribute - Inner Write-Back, Outer Write-Back, Inner Shareable.	Covered by Test-605
-	RB_PER_11	If a TCG TPM based security model is supported, the base system needs to provide a TPM implementation that is compliant to TPM Library Specification, Family 2.0 [4].	Not implemented in current release
-	RB_PER_12	To ensure standard software support, a device claiming to follow the PCI Express specification [1] must follow all the rules in PCIe specification [1] 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 amount of detected ECAM regions.

Test Number	Rule ID	Scenario	Algorithm
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.	Manual verification required by user.
844	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: 1. Find the Root Port it is under. 2. Check if the RP and the device are in the same ECAM region.
-	PCI_IN_05	Root Port must appear as a PCI-PCI bridge to software (See Section 7.1 [1]). This implies that a Root Port: *must have all registers that are part of the Type 1 header, as specified in PCIe specification (See Section 7.5.1.3 [1]). * 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 [1]). * registers must follow the access attributes (RW/RO, etc.) specified in the PCIe specification.	Register checks. Covered by Test 820-844
-	PCI_IN_06	PHB, in conjunction 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. 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 [1]).	Covered by PCIe Table creation.

Test Number	Rule ID	Scenario	Algorithm
-	PCI_IN_07	PHB in conjunction with Root Port must return all 1s as read response data for Configuration read requests to non-existent 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.	Covered by PCIe Table creation.
-	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: Not Feasible on Silicon.
-	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 [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: Not Feasible on Silicon.
-	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.	Not Implemented: Not Feasible on Silicon.
-	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 [1]).	Not Implemented: Not Feasible on Silicon.

Test Number	Rule ID	Scenario	Algorithm
-	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 [1]).	Not Implemented Test depends on UEFI PCIIO protocol which is not supported by U-boot.
848	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: 1. Detect the Non-Prefetchable address range. 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 all the following are true: <ul style="list-style-type: none"> • CRS software visibility is disabled or not present. • 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. 	Not implemented: Not Feasible on Silicon.
--	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: <ul style="list-style-type: none"> • CRS software visibility is enabled • The Configuration read is not targeting the Vendor ID register • 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. 	Not Implemented: Not Feasible on Silicon.

Test Number	Rule ID	Scenario	Algorithm
860	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 all of the following are true:</p> <ul style="list-style-type: none"> • Target bus number of the request is not within the secondary bus to subordinate bus range of any of the Root Ports. • Target Bus, Device and Function (BDF) of the request does not match BDF of any on-chip functions. • Target BDF of the request does not match the BDF of any of the Root Ports. 	<ol style="list-style-type: none"> 1. Get the maximum bus value from the PCIe info table 2. Get highest BDF of the segment 3. Get least high of max bus number 4. Form BDF using the segment, bus, device, and function numbers. 5. Read should return all 1's
836	PCI_IN_17	The Root port must comply with the following (as per section 6.13 of [1]).	<p>Currently only checking.</p> <p>If ARI forwarding is disabled and target device number of the request > 0, then the access is terminated and all 1s data is returned to the requestor PE.</p>
--	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 [1]) and must support 1 byte, 2 byte and 4 byte Configuration read and write requests.	Not part of current release.
-	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 [1].	Covered by other PCIe test.
861	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 [1]:</p> <ul style="list-style-type: none"> • Vendor Specific Capability • Vendor Specific Extended Capability (VSEC) • Designated Vendor Specific Extended Capability (DVSEC). 	For all the Root Ports in the system, search through the base and extended PCIe configuration spaces for non-PCIe compliant capabilities.
805	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.

Test Number	Rule ID	Scenario	Algorithm
-	PCI_MM_02	All systems must support mapping PCI Express memory space as non-cacheable memory.	Covered by Test 805.
-	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 805.
816	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, whilst 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>
806	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 Info table, which are behind an SMMU, verify there are no additional translations before address is given to SMMU.</p> <p>Check if IOMMU ops is 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>
-	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 806.
-	PCI_MM_07	For accesses from a PCIe endpoint to the host memory system, in a system with a 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 806.

Test Number	Rule ID	Scenario	Algorithm
807	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 each exerciser in the system: 1. Perform LPI ID assignment. 2. Install ISRs on the designated IDs. 3. Generate an MSI. 4. Check if the MSI was received.
412	PCI_LI_01	PCI Express legacy Interrupt messages must be converted to an SPI.	SKIPPED. Depends on ACPI calls which are not supported on U boot.
806, 412	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. 2. Get the exerciser BDF. 3. Register an interrupt handler to verify legacy interrupt functionality. 4. Trigger the legacy interrupt. 5. Check the completion of interrupt service routine. 6. Return the interrupt.
850	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: 1. Detect whether the legacy IRQ map exists. 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.	Not implemented: 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 required must use a System MMU compliant with the Arm System MMU specification.	Not implemented: OS boot covers this.

Test Number	Rule ID	Scenario	Algorithm
--	PCI_SM_02	Functions intended for VM assignment, or assignment to a user space driver must implement function level reset.	Not part of current release.
--	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.	Not Implemented. Test depends on UEFI PCIIO protocol which is not supported by U-boot.
811	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.
-	PCI_IC_03	This means that if a PCI Express device is accessing cached memory, then the transactions from the PCI Express devices will snoop the PE caches.	Not implemented. Test depends on UEFI PCIIO protocol which is not supported by U-boot.
-	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.	Not Implemented. Test depends on UEFI CPU Arch protocol which is not supported on U-boot.
915	PCI_IC_05	If there is no SMMU or a 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. 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.	Not Implemented. Test depends on UEFI CPU Arch protocol which is not supported by U-boot.

Test Number	Rule ID	Scenario	Algorithm
-	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.	Not Implemented. Test depends on UEFI CPU Arch protocol which is not supported by U-boot.
-	PCI_IC_08	IO Coherency Table.	Not Implemented Test depends on UEFI CPU Arch protocol which is not supported by U-boot.
-	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: Not Feasible on Silicon.
-	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: Not Feasible on Silicon.
-	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.	Not Covered in this release.
-	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.	Not feasible to test.

Test Number	Rule ID	Scenario	Algorithm
853	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"> 1. Source validation is supported. 2. Translation blocking is supported. 3. P2P request redirect is supported. 4. P2P completion redirect is supported. 5. Upstream forwarding is supported.
912, 913	PCI_PP_04	<p>For Root ports this means that the following must be supported:</p> <ol style="list-style-type: none"> 1. ACS Source Validation. (V) 2. ACS Translation Blocking. (B) 3. ACS P2P Request Redirect (R). 4. ACS P2P Completion Redirect (C). 5. ACS Upstream Forwarding (U). 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. 7. The root port must support ACS violation error detection, logging, and reporting. Logging and reporting must be through the usage of AER mechanism. 	<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"> 1. Get RP of the exerciser. 2. If ACS supported, Enable Source Validation & Transaction Blocking. 3. Find another exerciser on other root port, Break from the test if no such exerciser if found. 4. If Both RP's Supports ACS, then Check for ACS Functionality.

Test Number	Rule ID	Scenario	Algorithm
854, 855	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"> • 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. • 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). 	<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"> 1. If ACS is supported, direct translated P2P is supported. 2. AER is supported.
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"> 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). 2. Check whether there is support for at least 16-bit PASIDs. 3. Configure the exerciser DMA engine to access the IOVA region base. 4. Configure the exerciser to perform a DMA accesses with PASID1 in its transactions (Accesses must target PA region 1). 5. Configure the exerciser to perform DMA accesses with PASID2 in its transactions (Accesses must target PA region 2).
-	PCI_PTM_1	<p>Any system that implements PCIe Precision Time Measurement (PTM) [1] must use the Arm architecture defined System Counter [2] as PTM Requester time source at the PTM root(s).</p>	Not Feasible

Test Number	Rule ID	Scenario	Algorithm
858	RE_PCI_01	A RCiEP must obey all the rules that are specified in Section 1.3.2.3 of the PCIe 5.0 specification [1].	Check if header type of an RCiEP is 0 and if it supports link capabilities by checking the link capabilities in the PCI Express capability structure.
859	RE_PCI_02	The RCEC must obey all the rules that are specified in Section 1.3.4 of the PCIe 5.0 specification [1].	Root Complex Event Collector has the Base Class 08h, Sub-Class 07h and Programming Interface 00h by reading the class code. Root Complex Event Collector Endpoint Association Extended Capability must be supported.
-	RE_CFG_1	Ability to recognize read or write requests coming in from PEs as PCIe configuration requests if the requests address is within the ECAM range that is allocated to the host bridge of RCiEP.	Checked in multiple tests as part of read or write to BAR or config space.
-	RE_CFG_2	An IMPLEMENTATION DEFINED mechanism for providing the bus and device number to each RCiEP.	Manual verification required by user by checking number of RCiEP discovered.
-	RE_CFG_3	An IMPLEMENTATION DEFINED mechanism for providing the bus and device number to each RCEC.	Manual verification required by user by checking number of RCEC discovered.

Test Number	Rule ID	Scenario	Algorithm
-	RE_CRS_1	<p>When a RCiEP or RCEC function is temporarily unable to process a configuration request following a reset and the reset is one of the valid reset conditions defined in Section 2.3.1 of the PCIe specification [1], the following are response options:</p> <ul style="list-style-type: none"> Respond as defined in PCIe specification if the following are true: <ul style="list-style-type: none"> a) Configuration Retry Status (CRS) visibility is present and is enabled. b) The request is a configuration read to an address that includes the two bytes of the Vendor ID field. Otherwise, all 1s data must be sent back to the requestor PE. 	Not Implemented: Not Feasible for Silicon.
862	RE_BAR_1	All BAR registers in an RCiEP must be writeable and readable as per the PCIe specification.	<p>For every RCiEP:</p> <ol style="list-style-type: none"> Read the BAR value. Write a value to BAR register and read back. The original read and the read after write should not be same.
-	RE_BAR_2	Dynamic re-programming of these BAR registers must be allowed.	Covered by Test 905.
834	RE_BAR_3	A RCiEP must not support I/O space claimed through BARs.	<p>For every RCiEP device,</p> <ol style="list-style-type: none"> Read the BAR register. Check if 32 bit or 64-bit BAR. Check if BAR supports MMIO.
841	RE_INT_1	RCiEP Endpoint must support MSI or MSI-X interrupt generation.	For every RCiEP device, check if MSI capability structure and MSI-X capability structure is supported.

Test Number	Rule ID	Scenario	Algorithm
-	RE_ORD_1	The RCiEP must obey PCIe ordering rules for the configuration and BAR mapped memory spaces when accessed in the inbound direction, towards the RCiEP.	Covered by Test 915.
-	RE_ORD_2	PCIe ordering rules must be obeyed while sending out completions for configuration space and BAR mapped memory space accesses.	Covered by Test 915.
-	RE_ORD_3	<p>If the RCiEP uses the PCIe producer-consumer model for the interaction with software or peer devices, then the following must be ensured by the RCiEP in collaboration with rest of the system:</p> <ul style="list-style-type: none"> • Write requests from the RCiEP are observed by other agents in the order required for the producer-consumer model to work. • A read request from the RCiEP must not overtake previously issued write requests from the same RCiEP if there is a Read after Write dependency between the Read and previously issued write or writes. 	Not Implemented: Not Feasible for Silicon.
-	RE_ORD_4	The Transactions Pending bit must be cleared only after all outstanding reads, atomic requests and write requests have received responses.	Not Feasible.
852	RE_SMU_2	PCIe ATS capability must be supported if the RCiEP has a software visible cache for address translations.	<p>Check if Address Translation Cache is Present in this device.</p> <p>If ATC Present, Check ATS Capability is present.</p>

Test Number	Rule ID	Scenario	Algorithm
-	RE_SMU_3	PCIe PRI mechanism must be supported if RCiEP requires memory pages dynamically.	Not feasible as there is no way to know if endpoint requires memory pages dynamically.
-	RE_SMU_4	If the RCiEP supports PASIDs, the PASID is used as SubStreamID as specified in the SMMU architecture specification.	Covered by Test 905.
-	RE_SMU_5	RCiEP must use its BDF to generate StreamID using rules that are described in Section H [3].	Not Implemented: Not Feasible for Silicon.
835	RE_RST_1	RCiEP must have Function Level Reset (FLR) support.	<ol style="list-style-type: none"> 1. Read FLR capability bit value. 2. If FLR capability is not set, move to next entry. 3. Allocate 4KB of space for saving function configuration space. 4. Get function configuration space address. 5. Save the function config space to restore after FLR. 6. Initiate FLR by setting the FLR bit. 7. Vendor Id should not be 0xFF after max FLR period.
842	RE_PWR_1	RCiEP must have D state support and must have PCI Power management capability as specified in the PCIe specification.	For every RCiEP, check If Power Management capability is supported.

Test Number	Rule ID	Scenario	Algorithm
-	RE_PWR_2	RCiEP must support PME messages for wake up signaling if the RCiEP needs to have a wake-up notification mechanism.	Not Implemented: Not Feasible for Silicon.
-	RE_PWR_3	PM_PME wake messages must be logged in the Root Complex Event collector that is associated with the RCiEP.	Not Implemented: Not Feasible for Silicon.
857	RE_ACS_1	ACS capability must be present in the RCiEP if the RCiEP is a multi-function device and supports peer-to-peer traffic between its functions. It must comply with the PCIe specification on specific ACS access controls that must be supported.	For every RCiEP device, check if following is supported: 1. Multifunction support. 2. P2P supported. 3. If ACS is supported, then AER should be supported. 4. Request Redirect P2P. 5. Completion Redirect P2P. 6. Direct Translated P2P.
857	RE_ACS_2	If the RCiEP has ACS capability, then it must have AER capability for reporting ACS violation errors.	Covered by Test 857.
-	RE_ACS_3	RCiEP requests that target peer Endpoints have to be mediated by the SMMU before proceeding to the target.	Not Implemented: Not Feasible for Silicon.
820-833	RE_REC_01	The registers that are specified in Section 7.5.3 of the PCIe specification [1] for Root Complex Event Collectors must be implemented for RCEC. The registers must be implemented as described in Table 27.	Register checks

Test Number	Rule ID	Scenario	Algorithm
820-833	RE_REC_02	All registers of the Root Complex Event Collector Endpoint Association Extended Capability must be implemented by the RCEC. The registers must be implemented as shown in Table 28.	Register checks

2.12 DeviceID Generation and ITS Groups

Test Number	Rule ID	Scenario	Algorithm
	ITS_01	An ITS group can contain one or more ITS blocks.	Not implemented as part of current release.
	ITS_02	An ITS block is associated with one ITS group.	Not implemented as part of current release.
	ITS_03	A device that is expected to send an MSI is associated with one ITS group.	Not implemented as part of current release.
	ITS_04	Devices can be programmed to send MSIs to any ITS block within the group.	Not implemented as part of current release.
	ITS_05	If a device sends an MSI to an ITS block outside of its assigned group, the MSI write is illegal and does not trigger an interrupt that could appear to originate from a different device. See Section H.2.2 for permitted behavior of illegal MSI writes.	Not implemented as part of current release.
	ITS_06	An ITS group represents a DeviceID namespace independent of any other ITS group.	Not implemented as part of current release.

Test Number	Rule ID	Scenario	Algorithm
	ITS_07	All ITS blocks within an ITS group support a common DeviceID namespace size, a common input EventID namespace size and are capable of receiving an MSI from any device within the group.	Not implemented as part of current release.
	ITS_08	All ITS blocks within an ITS group observe the same DeviceID for any given device in the same ITS group.	Not implemented as part of current release.
	ITS_DEV_1	Every device Requester that is expected to send MSIs has a DeviceID associated with it.	Not implemented as part of current release.
	ITS_DEV_2	The system designer assigns a Requester unique StreamID to device traffic input to the SMMU.	Not implemented as part of current release.
	ITS_DEV_3	When a device is not behind an SMMU, its DeviceID appears to high-level software as though it is assigned directly by the system designer.	Not implemented as part of current release.
	ITS_DEV_4	The system must not allow this behavior to trigger an MSI that masquerades as originating from a different Requester. The system must anticipate that PEs also have the potential to be misused in this manner.	Not implemented as part of current release.
	ITS_DEV_5	Every device that is expected to originate MSIs is associated with a DeviceID.	Not implemented as part of current release.
	ITS_DEV_6	DeviceID arrangement and system design prevents any mechanism that any software that is not the most privileged in the system, for example VM, or application, can exploit to trigger interrupts associated with a different body of software, for example, a different VM, or OS driver.	Not implemented as part of current release.
	ITS_DEV_7	If a device is a client of an SMMU, the associated DeviceID is derived from the SMMU's StreamID with an identity or simple offset function:	Not implemented as part of current release.
	ITS_DEV_8	DeviceIDs derived from other kinds of system IDs are also created from an identity or simple offset function. For a Root Complex without an SMMU, the relationship is: $\text{DeviceID} = \text{zero_extend}(\text{RequesterID}[N-1:0]) + (1 < N) * \text{Constant_C}$	Not implemented as part of current release.

Test Number	Rule ID	Scenario	Algorithm
	ITS_DEV_9	The relationships between a device, its StreamID and its DeviceID are considered static by OS or hypervisor software. If the mapping is not fixed by hardware, the relationship between a StreamID and a DeviceID must not change after system initialization, and OS drivers must not be required to set it up.	Not implemented as part of current release.

References

This section lists publications by Arm and by third parties.

See Arm Developer (<http://developer.arm.com>) for access to Arm documentation.

[1] PCI Express Base Specification Revision 5.0, version 1.0. PCI-SIG.

[2] DDI 0487 Arm® Architecture Reference Manual ARMv8, for the ARMv8-A architecture profile. Arm Ltd.

[3] DEN0094A Arm® Base System Architecture version 1.0. Arm Ltd.

[4] PCI-To-PCI Bridge Architecture Specification 1.2. PCI-SIG.

Appendix A Revisions

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

Table A-1 Issue 01

Change	Location
First release	-