



## OVP Guide to Using Processor Models

### Model specific information for ARM\_Cortex-A7UP

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## Model Release Status

This model is released as part of OVP releases and is included in OVPworld packages. Please visit [OVPworld.org](http://OVPworld.org).

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# Chapter 1

## Overview

This document provides the details of an OVP Fast Processor Model variant.

OVP Fast Processor Models are written in C and provide a C API for use in C based platforms. The models also provide a native interface for use in SystemC TLM2 platforms.

The models are written using the OVP VMI API that provides a Virtual Machine Interface that defines the behavior of the processor. The VMI API makes a clear line between model and simulator allowing very good optimization and world class high speed performance. Most models are provided as a binary shared object and also as source. This allows the download and use of the model binary or the use of the source to explore and modify the model.

The models are run through an extensive QA and regression testing process and most model families are validated using technology provided by the processor IP owners. There is a companion document (OVP Guide to Using Processor Models) which explains the general concepts of OVP Fast Processor Models and their use. It is downloadable from the OVPworld website documentation pages.

### 1.1 Description

ARM Processor Model

### 1.2 Licensing

Usage of binary model under license governing simulator usage.

Note that for models of ARM CPUs the license includes the following terms:

Licensee is granted a non-exclusive, worldwide, non-transferable, revocable licence to:

If no source is being provided to the Licensee: use and copy only (no modifications rights are granted) the model for the sole purpose of designing, developing, analyzing, debugging, testing, verifying, validating and optimizing software which: (a) (i) is for ARM based systems; and (ii) does not incorporate the ARM Models or any part thereof; and (b) such ARM Models may not be used

to emulate an ARM based system to run application software in a production or live environment.

If source code is being provided to the Licensee: use, copy and modify the model for the sole purpose of designing, developing, analyzing, debugging, testing, verifying, validating and optimizing software which: (a) (i) is for ARM based systems; and (ii) does not incorporate the ARM Models or any part thereof; and (b) such ARM Models may not be used to emulate an ARM based system to run application software in a production or live environment.

In the case of any Licensee who is either or both an academic or educational institution the purposes shall be limited to internal use.

Except to the extent that such activity is permitted by applicable law, Licensee shall not reverse engineer, decompile, or disassemble this model. If this model was provided to Licensee in Europe, Licensee shall not reverse engineer, decompile or disassemble the Model for the purposes of error correction.

The License agreement does not entitle Licensee to manufacture in silicon any product based on this model.

The License agreement does not entitle Licensee to use this model for evaluating the validity of any ARM patent.

Source of model available under separate Imperas Software License Agreement.

### 1.3 Limitations

Instruction pipelines are not modeled in any way. All instructions are assumed to complete immediately. This means that instruction barrier instructions (e.g. ISB, CP15ISB) are treated as NOPs, with the exception of any undefined instruction behavior, which is modeled. The model does not implement speculative fetch behavior. The branch cache is not modeled.

Caches and write buffers are not modeled in any way. All loads, fetches and stores complete immediately and in order, and are fully synchronous (as if the memory was of Strongly Ordered or Device-nGnRnE type). Data barrier instructions (e.g. DSB, CP15DSB) are treated as NOPs, with the exception of any undefined instruction behavior, which is modeled. Cache manipulation instructions are implemented as NOPs, with the exception of any undefined instruction behavior, which is modeled.

Real-world timing effects are not modeled: all instructions are assumed to complete in a single cycle.

Performance Monitors are implemented as a register interface only except for the cycle counter, which is implemented assuming one instruction per cycle.

TLBs are architecturally-accurate but not device accurate. This means that all TLB maintenance and address translation operations are fully implemented but the cache is larger than in the real device.

## 1.4 Verification

Models have been extensively tested by Imperas. ARM Cortex-A models have been successfully used by customers to simulate SMP Linux, Ubuntu Desktop, VxWorks and ThreadX on Xilinx Zynq virtual platforms.

## 1.5 Features

### 1.5.1 Core Features

Thumb-2 instructions are supported.

Trivial Jazelle extension is implemented.

Virtualization extensions are implemented.

### 1.5.2 Memory System

Large physical address extension is implemented.

Security extensions are implemented (also known as TrustZone). Non-secure accesses can be made visible externally by connecting the processor to a 41-bit physical bus, in which case bits 39..0 give the true physical address and bit 40 is the NS bit.

VMSA stage 1 secure, non-secure and Hypervisor address translation is implemented. VMSA stage 2 address translation is implemented.

TLB behavior is controlled by parameter ASIDCacheSize. If this parameter is 0, then an unlimited number of TLB entries will be maintained concurrently. If this parameter is non-zero, then only TLB entries for up to ASIDCacheSize different ASIDs will be maintained concurrently initially; as new ASIDs are used, TLB entries for less-recently used ASIDs are deleted, which improves model performance in some cases (especially when 16-bit ASIDs are in use). If the model detects that the TLB entry cache is too small (entry ejections are very frequent), it will increase the cache size automatically. In this variant, ASIDCacheSize is 8

### 1.5.3 Advanced SIMD and Floating-Point Features

SIMD and VFP instructions are implemented.

The model implements trapped exceptions if FPTrap is set to 1 in MVFR0 (for AArch32) or MVFR0\_EL1 (for AArch64). When floating point exception traps are taken, cumulative exception flags are not updated (in other words, cumulative flag state is always the same as prior to instruction execution, even for SIMD instructions). When multiple enabled exceptions are raised by a single floating point operation, the exception reported is the one in least-significant bit position in FPSCR (for AArch32) or FPCR (for AArch64). When multiple enabled exceptions are raised by different SIMD element computations, the exception reported is selected from the lowest-index-number SIMD operation. Contact Imperas if requirements for exception reporting differ from these.

Trapped exceptions not are implemented in this variant (FPTrap=0)

### 1.5.4 Generic Timer

Generic Timer is present. Use parameter “override\_timerScaleFactor” to specify the counter rate as a fraction of the processor MIPS rate (e.g. 10 implies Generic Timer counters increment once every 10 processor instructions).

## 1.6 Debug Mask

It is possible to enable model debug features in various categories. This can be done statically using the “override\_debugMask” parameter, or dynamically using the “debugflags” command. Enabled debug features are specified using a bitmask value, as follows:

Value 0x004: enable debugging of MMU/MPU mappings.

Value 0x080: enable debugging of all system register accesses.

Value 0x100: enable debugging of all traps of system register accesses.

Value 0x200: enable verbose debugging of other miscellaneous behavior (for example, the reason why a particular instruction is undefined).

Value 0x400: enable debugging of Performance Monitor timers

Value 0x800: enable dynamic validation of TLB entries against in-memory page table contents (finds some classes of error where page table entries are updated without a subsequent flush of affected TLB entries).

All other bits in the debug bitmask are reserved and must not be set to non-zero values.

## 1.7 AArch32 Unpredictable Behavior

Many AArch32 instruction behaviors are described in the ARM ARM as CONSTRAINED UNPREDICTABLE. This section describes how such situations are handled by this model.

### 1.7.1 Equal Target Registers

Some instructions allow the specification of two target registers (for example, double-width SMULL, or some VMOV variants), and such instructions are CONSTRAINED UNPREDICTABLE if the same target register is specified in both positions. In this model, such instructions are treated as UNDEFINED.



### 1.7.2 Floating Point Load/Store Multiple Lists

Instructions that load or store a list of floating point registers (e.g. VSTM, VLDM, VPUSH, VPOP) are **CONSTRAINED UNPREDICTABLE** if either the uppermost register in the specified range is greater than 32 or (for 64-bit registers) if more than 16 registers are specified. In this model, such instructions are treated as **UNDEFINED**.

### 1.7.3 Floating Point VLD[2-4]/VST[2-4] Range Overflow

Instructions that load or store a fixed number of floating point registers (e.g. VST2, VLD2) are **CONSTRAINED UNPREDICTABLE** if the upper register bound exceeds the number of implemented floating point registers. In this model, these instructions load and store using modulo 32 indexing (consistent with AArch64 instructions with similar behavior).

### 1.7.4 If-Then (IT) Block Constraints

Where the behavior of an instruction in an if-then (IT) block is described as **CONSTRAINED UNPREDICTABLE**, this model treats that instruction as **UNDEFINED**.

### 1.7.5 Use of R13

In architecture variants before ARMv8, use of R13 was described as **CONSTRAINED UNPREDICTABLE** in many circumstances. From ARMv8, most of these situations are no longer considered unpredictable. This model allows R13 to be used like any other GPR, consistent with the ARMv8 specification.

### 1.7.6 Use of R15

Use of R15 is described as **CONSTRAINED UNPREDICTABLE** in many circumstances. This model allows such use to be configured using the parameter “unpredictableR15” as follows:

Value “undefined”: any reference to R15 in such a situation is treated as **UNDEFINED**;

Value “nop”: any reference to R15 in such a situation causes the instruction to be treated as a **NOP**;

Value “raz\_wi”: any reference to R15 in such a situation causes the instruction to be treated as a **RAZ/WI** (that is, R15 is read as zero and write-ignored);

Value “execute”: any reference to R15 in such a situation is executed using the current value of R15 on read, and writes to R15 are allowed (but are not interworking).

Value “assert”: any reference to R15 in such a situation causes the simulation to halt with an assertion message (allowing any such unpredictable uses to be easily identified).

In this variant, the default value of “unpredictableR15” is “undefined”.

### 1.7.7 Unpredictable Instructions in Some Modes

Some instructions are described as `CONSTRAINED UNPREDICTABLE` in some modes only (for example, MSR accessing SPSR is `CONSTRAINED UNPREDICTABLE` in User and System modes). This model allows such use to be configured using the parameter “unpredictableModal”, which can have values “undefined” or “nop”. See the previous section for more information about the meaning of these values.

In this variant, the default value of “unpredictableModal” is “nop”.

## 1.8 Integration Support

This model implements a number of non-architectural pseudo-registers and other features to facilitate integration.

### 1.8.1 Memory Transaction Query

Two registers are intended for use within memory callback functions to provide additional information about the current memory access. Register `transactPL` indicates the processor execution level of the current access (0-3). Note that for load/store translate instructions (e.g. `LDRT`, `STRT`) the reported execution level will be 0, indicating an `EL0` access. Register `transactAT` indicates the type of memory access: 0 for a normal read or write; and 1 for a physical access resulting from a page table walk.

### 1.8.2 Page Table Walk Query

A banked set of registers provides information about the most recently completed page table walk. There are up to six banks of registers: bank 0 is for stage 1 walks, bank 1 is for stage 2 walks, and banks 2-5 are for stage 2 walks initiated by stage 1 level 0-3 entry lookups, respectively. Banks 1-5 are present only for processors with virtualization extensions. The currently active bank can be set using register `PTWBankSelect`. Register `PTWBankValid` is a bitmask indicating which banks contain valid data: for example, the value `0xb` indicates that banks 0, 1 and 3 contain valid data.

Within each bank, there are registers that record addresses and values read during that page table walk. Register `PTWBase` records the table base address, register `PTWInput` contains the input address that starts a walk, register `PTWOutput` contains the result address and register `PTWPgSize` contains the page size (`PTWOutput` and `PTWPgSize` are valid only if the page table walk completes). Registers `PTWAddressL0-PTWAddressL3` record the addresses of level 0 to level 3 entries read, respectively. Register `PTWAddressValid` is a bitmask indicating which address registers contain valid data: bits 0-3 indicate `PTWAddressL0-PTWAddressL3`, respectively, bit 4 indicates `PTWBase`, bit 5 indicates `PTWInput`, bit 6 indicates both `PTWOutput` and `PTWPgSize`. For example, the value `0x73` indicates that `PTWBase`, `PTWInput`, `PTWOutput`, `PTWPgSize` and `PTWAddressL0-L1` are valid but `PTWAddressL2-L3` are not. Register `PTWAddressNS` is a bitmask indicating whether an address is in non-secure memory: bits 0-3 indicate `PTWAddressL0-PTWAddressL3`, respectively, bit 4 indicates `PTWBase`, bit 6 indicates `PTWOutput` (`PTWInput` is a VA and thus has no secure/non-secure info). Registers `PTWValueL0-PTWValueL3` contain page

table entry values read at level 0 to level 3. Register `PTWValueValid` is a bitmask indicating which value registers contain valid data: bits 0-3 indicate `PTWValueL0`-`PTWValueL3`, respectively.

### 1.8.3 Artifact Page Table Walks

Registers are also available to enable a simulation environment to initiate an artifact page table walk (for example, to determine the ultimate PA corresponding to a given VA). Register `PTWI_EL1S` initiates a secure EL1 table walk for a fetch. Register `PTWD_EL1S` initiates a secure EL1 table walk for a load or store (note that current ARM processors have unified TLBs, so these registers are synonymous). Registers `PTW[ID]_EL1NS` initiate walks for non-secure EL1 accesses. Registers `PTW[ID]_EL2` initiate EL2 walks. Registers `PTW[ID]_S2` initiate stage 2 walks. Registers `PTW[ID]_EL3` initiate AArch64 EL3 walks. Finally, registers `PTW[ID]_current` initiate current-mode walks (useful in a memory callback context). Each walk fills the query registers described above.

### 1.8.4 MMU and Page Table Walk Events

Two events are available that allow a simulation environment to be notified on MMU and page table walk actions. Event `mmuEnable` triggers when any MMU is enabled or disabled. Event `pageTableWalk` triggers on completion of any page table walk (including artifact walks).

### 1.8.5 Artifact Address Translations

A simulation environment can trigger an artifact address translation operation by writing to the architectural address translation registers (e.g. `ATS1CPR`). The results of such translations are written to an integration support register `artifactPAR`, instead of the architectural `PAR` register. This means that such artifact writes will not perturb architectural state.

### 1.8.6 TLB Invalidation

A simulation environment can cause TLB state for one or more address translation regimes in the processor to be flushed by writing to the artifact register `ResetTLBs`. The argument is a bitmask value, in which non-zero bits select the TLBs to be flushed, as follows:

Bit 0: EL0/EL1 stage 1 secure TLB

Bit 1: EL0/EL1 stage 1 non-secure TLB

Bit 2: EL2 stage 1 TLB

Bit 3: EL0/EL1 non-secure stage 2 TLB

### 1.8.7 Halt Reason Introspection

An artifact register `HaltReason` can be read to determine the reason or reasons that a processor is halted. This register is a bitfield, with the following encoding: bit 0 indicates the processor

has executed a wait-for-event (WFE) instruction; bit 1 indicates the processor has executed a wait-for-interrupt (WFI) instruction; and bit 2 indicates the processor is held in reset.

### 1.8.8 System Register Access Monitor

If parameter “enableSystemMonitorBus” is True, an artifact 32-bit bus “SystemMonitor” is enabled for each PE. Every system register read or write by that PE is then visible as a read or write on this artifact bus, and can therefore be monitored using callbacks installed in the client environment (use `opBusReadMonitorAdd/opBusWriteMonitorAdd` or `icmAddBusReadCallback/icmAddBusWriteCallback`, depending on the client API). The format of the address on the bus is as follows:

bits 31:26 - zero

bit 25 - 1 if AArch64 access, 0 if AArch32 access

bit 24 - 1 if non-secure access, 0 if secure access

bits 23:20 - CRm value

bits 19:16 - CRn value

bits 15:12 - op2 value

bits 11:8 - op1 value

bits 7:4 - op0 value (AArch64) or coprocessor number (AArch32)

bits 3:0 - zero

As an example, to view non-secure writes to writes to `CNTFRQ_EL0` in AArch64 state, install a write monitor on address range `0x020e0330:0x020e0333`.

### 1.8.9 System Register Implementation

If parameter “enableSystemBus” is True, an artifact 32-bit bus “System” is enabled for each PE. Slave callbacks installed on this bus can be used to implement modified system register behavior (use `opBusSlaveNew` or `icmMapExternalMemory`, depending on the client API). The format of the address on the bus is the same as for the system monitor bus, described above.

## Chapter 2

# Configuration

### 2.1 Location

This model's VLVN is [arm.ovpworld.org/processor/arm/1.0](http://arm.ovpworld.org/processor/arm/1.0).

The model source is usually at:

`$IMPERAS_HOME/ImperasLib/source/arm.ovpworld.org/processor/arm/1.0`

The model binary is usually at:

`$IMPERAS_HOME/lib/$IMPERAS_ARCH/ImperasLib/arm.ovpworld.org/processor/arm/1.0`

### 2.2 GDB Path

The default GDB for this model is: `$IMPERAS_HOME/lib/$IMPERAS_ARCH/gdb/arm-none-eabi-gdb`.

### 2.3 Semi-Host Library

The default semi-host library file is `arm.ovpworld.org/semihosting/armNewlib/1.0`

### 2.4 Processor Endian-ness

This model can be set to either endian-ness (normally by a pin, or the ELF code).

### 2.5 QuantumLeap Support

This processor is qualified to run in a QuantumLeap enabled simulator.

### 2.6 Processor ELF code

The ELF code supported by this model is: `0x28`.

## Chapter 3

# All Variants in this model

This model has these variants

| <b>Variant</b> | Description |
|----------------|-------------|
| ARMv4T         |             |
| ARMv4xM        |             |
| ARMv4          |             |
| ARMv4TxM       |             |
| ARMv5xM        |             |
| ARMv5          |             |
| ARMv5TxM       |             |
| ARMv5T         |             |
| ARMv5TExP      |             |
| ARMv5TE        |             |
| ARMv5TEJ       |             |
| ARMv6          |             |
| ARMv6K         |             |
| ARMv6T2        |             |
| ARMv6KZ        |             |
| ARMv7          |             |
| ARM7TDMI       |             |
| ARM7EJ-S       |             |
| ARM720T        |             |
| ARM920T        |             |
| ARM922T        |             |
| ARM926EJ-S     |             |
| ARM940T        |             |
| ARM946E        |             |
| ARM966E        |             |
| ARM968E-S      |             |
| ARM1020E       |             |
| ARM1022E       |             |
| ARM1026EJ-S    |             |
| ARM1136J-S     |             |
| ARM1156T2-S    |             |

|                |                              |
|----------------|------------------------------|
| ARM1176JZ-S    |                              |
| Cortex-R4      |                              |
| Cortex-R4F     |                              |
| Cortex-A5UP    |                              |
| Cortex-A5MPx1  |                              |
| Cortex-A5MPx2  |                              |
| Cortex-A5MPx3  |                              |
| Cortex-A5MPx4  |                              |
| Cortex-A8      |                              |
| Cortex-A9UP    |                              |
| Cortex-A9MPx1  |                              |
| Cortex-A9MPx2  |                              |
| Cortex-A9MPx3  |                              |
| Cortex-A9MPx4  |                              |
| Cortex-A7UP    | (described in this document) |
| Cortex-A7MPx1  |                              |
| Cortex-A7MPx2  |                              |
| Cortex-A7MPx3  |                              |
| Cortex-A7MPx4  |                              |
| Cortex-A15UP   |                              |
| Cortex-A15MPx1 |                              |
| Cortex-A15MPx2 |                              |
| Cortex-A15MPx3 |                              |
| Cortex-A15MPx4 |                              |
| Cortex-A17MPx1 |                              |
| Cortex-A17MPx2 |                              |
| Cortex-A17MPx3 |                              |
| Cortex-A17MPx4 |                              |
| AArch32        |                              |
| AArch64        |                              |
| Cortex-A32MPx1 |                              |
| Cortex-A32MPx2 |                              |
| Cortex-A32MPx3 |                              |
| Cortex-A32MPx4 |                              |
| Cortex-A35MPx1 |                              |
| Cortex-A35MPx2 |                              |
| Cortex-A35MPx3 |                              |
| Cortex-A35MPx4 |                              |
| Cortex-A53MPx1 |                              |
| Cortex-A53MPx2 |                              |
| Cortex-A53MPx3 |                              |
| Cortex-A53MPx4 |                              |
| Cortex-A55MPx1 |                              |
| Cortex-A55MPx2 |                              |
| Cortex-A55MPx3 |                              |

|                |  |
|----------------|--|
| Cortex-A55MPx4 |  |
| Cortex-A57MPx1 |  |
| Cortex-A57MPx2 |  |
| Cortex-A57MPx3 |  |
| Cortex-A57MPx4 |  |
| Cortex-A72MPx1 |  |
| Cortex-A72MPx2 |  |
| Cortex-A72MPx3 |  |
| Cortex-A72MPx4 |  |
| Cortex-A73MPx1 |  |
| Cortex-A73MPx2 |  |
| Cortex-A73MPx3 |  |
| Cortex-A73MPx4 |  |
| Cortex-A75MPx1 |  |
| Cortex-A75MPx2 |  |
| Cortex-A75MPx3 |  |
| Cortex-A75MPx4 |  |
| MultiCluster   |  |

Table 3.1: All Variants in this model



## Chapter 4

# Bus Master Ports

This model has these bus master ports.

| <b>Name</b> | min | max | Connect?  | Description |
|-------------|-----|-----|-----------|-------------|
| INSTRUCTION | 32  | 41  | mandatory |             |
| DATA        | 32  | 41  | optional  |             |

Table 4.1: Bus Master Ports

## Chapter 5

# Bus Slave Ports

This model has no bus slave ports.

## Chapter 6

# Net Ports

This model has these net ports.

| Name          | Type   | Connect? | Description   |
|---------------|--------|----------|---|
| EVENTI        | input  | optional | Event input signal, active on rising edge                                 |
| EVENTO        | output | optional | Event output signal, active on rising edge                                |
| CNTVIRQ       | output | optional | Virtual timer event (active high)   |
| CNTPSIRQ      | output | optional | Secure physical timer event (active high)                                 |
| CNTPNSIRQ     | output | optional | Non-secure physical timer event (active high)                             |
| CNTPHIRQ      | output | optional | Hypervisor physical timer event (active high)                             |
| CLUSTERIDAFF1 | input  | optional | Configure MPIDR.Aff1  |
| CLUSTERIDAFF2 | input  | optional | Configure MPIDR.Aff2  |
| VINITHI       | input  | optional | Configure HIVECS mode (SCTLR.V)   |
| CFGEND        | input  | optional | Configure exception endianness (SCTLR.EE)                                 |
| CFGTE         | input  | optional | Configure exception state at reset (SCTLR.TE)                             |
| reset         | input  | optional | Processor reset, active high  |
| fiq           | input  | optional | FIQ interrupt, active high (negation of nFIQ)                             |
| irq           | input  | optional | IRQ interrupt, active high (negation of nIRQ)                             |
| sei           | input  | optional | System error interrupt, active on rising edge (negation of nSEI)          |
| vfiq          | input  | optional | Virtual FIQ interrupt, active high (negation of nVFIQ)                    |
| virq          | input  | optional | Virtual IRQ interrupt, active high (negation of nVIRQ)                    |
| vsei          | input  | optional | Virtual system error interrupt, active on rising edge (negation of nVSEI) |
| AXI.SLVERR    | input  | optional | AXI external abort type (DECERR=0, SLVERR=1)                              |
| CP15SDISABLE  | input  | optional | CP15SDISABLE (active high)  |

---

Table 6.1: Net Ports

## Chapter 7

# FIFO Ports

This model has no FIFO ports.

## Chapter 8

# Formal Parameters

| Name                     | Type        | Description   |
|--------------------------|-------------|---|
| variant                  | Enumeration | Selects variant (either a generic ISA or a specific model)  |
| verbose                  | Boolean     | Specify verbosity of output   |
| suppressCPSWarnings      | Boolean     | Suppress duplicate warnings generated using ARM_CP_CPSI or ARM_CP_CPSD message identifiers  |
| showHiddenRegs           | Boolean     | Show hidden registers during register tracing   |
| UAL                      | Boolean     | Disassemble using UAL syntax  |
| enableVFPAtReset         | Boolean     | Enable vector floating point (SIMD and VFP) instructions at reset. (Enables cp10/11 in CPACR and sets FPEXC.EN)   |
| enableSystemBus          | Boolean     | Add 32-bit artifact System bus port, allowing system registers to be externally implemented   |
| enableSystemMonitorBus   | Boolean     | Add 32-bit artifact SystemMonitor bus port, allowing system register accesses to be externally monitored  |
| compatibility            | Enumeration | Specify compatibility mode (ISA, gdb or nopSVC)   |
| unpredictableR15         | Enumeration | Specify behavior for UNPREDICTABLE uses of AArch32 R15 register (undefined, nop, raz_wi, execute or assert)   |
| unpredictableModal       | Enumeration | Specify behavior for UNPREDICTABLE instructions in certain AArch32 modes (for example, MRS using SPSR in System mode) (undefined, nop or assert)                          |
| maxSIMDUnroll            | Uns32       | If SIMD operations are supported, specify the maximum number of parallel SIMD operations to unroll (unrolled operations can be faster, but produce more verbose JIT code) |
| override_debugMask       | Uns32       | Specifies debug mask, enabling debug output for model components  |
| ASIDCacheSize            | Uns32       | Specifies the number of different ASIDs for which TLB entries are cached; a value of 0 implies no limit   |
| endian                   | Endian      | Model endian  |
| override_fcsePresent     | Boolean     | Specifies that FCSE is present (if true)  |
| override_fpexcDexPresent | Boolean     | Specifies that the FPEXC.DEX register field is implemented (if true)  |
| override_advSIMDPresent  | Boolean     | Specifies that Advanced SIMD extensions are present (if true)   |
| override_vfpPresent      | Boolean     | Specifies that VFP extensions are present (if true)   |
| override_physicalBits    | Uns32       | Specifies the implemented physical bus bits (defaults to connected physical bus width)  |
| override_SCTLR_V         | Boolean     | Override SCTLR.V with the passed value (enables high vectors; also configurable using VINITHI pin)  |

|                                |         |   |
|--------------------------------|---------|---|
| override_SCTLR_IE              | Boolean | Override SCTLR.IE with the passed value (configures instruction endianness; also configurable using CFGIE pin)                |
| override_SCTLR_EE              | Boolean | Override SCTLR.EE with the passed value (configures exception data endianness; also configurable using CFGEE pin)             |
| override_SCTLR_TE              | Boolean | Override SCTLR.TE with the passed value (configures Thumb state for exception handling; also configurable using TEINIT pin)   |
| override_SCTLR_NMFI            | Boolean | Override SCTLR.NMFI with the passed value (configures NMFI state for exception handling; also configurable using CFGNMFI pin) |
| override_SCTLR_CP15BEN_Present | Boolean | Enable ARMv7 SCTLR.CP15BEN bit (CP15 barrier enable)  |
| override_MIDR                  | Uns32   | Override MIDR/MIDR_EL1 register   |
| override_CTR                   | Uns32   | Override CTR/CTR_EL0 register   |
| override_TLBTR                 | Uns32   | Override TLBTR register   |
| override_CLIDR                 | Uns32   | Override CLIDR/CLIDR_EL1 register   |
| override_AIDR                  | Uns32   | Override AIDR/AIDR_EL1 register   |
| override_PFR0                  | Uns32   | Override ID_PFR0/ID_PFR0_EL1 register   |
| override_PFR1                  | Uns32   | Override ID_PFR1/ID_PFR1_EL1 register   |
| override_DFR0                  | Uns32   | Override ID_DFR0/ID_DFR0_EL1 register   |
| override_AFR0                  | Uns32   | Override ID_AFR0/ID_AFR0_EL1 register   |
| override_MMFR0                 | Uns32   | Override ID_MMFR0/ID_MMFR0_EL1 register   |
| override_MMFR1                 | Uns32   | Override ID_MMFR1/ID_MMFR1_EL1 register   |
| override_MMFR2                 | Uns32   | Override ID_MMFR2/ID_MMFR2_EL1 register   |
| override_MMFR3                 | Uns32   | Override ID_MMFR3/ID_MMFR3_EL1 register   |
| override_ISAR0                 | Uns32   | Override ID_ISAR0/ID_ISAR0_EL1 register   |
| override_ISAR1                 | Uns32   | Override ID_ISAR1/ID_ISAR1_EL1 register   |
| override_ISAR2                 | Uns32   | Override ID_ISAR2/ID_ISAR2_EL1 register   |
| override_ISAR3                 | Uns32   | Override ID_ISAR3/ID_ISAR3_EL1 register   |
| override_ISAR4                 | Uns32   | Override ID_ISAR4/ID_ISAR4_EL1 register   |
| override_ISAR5                 | Uns32   | Override ID_ISAR5/ID_ISAR5_EL1 register   |
| override_PMCR                  | Uns32   | Override PMCR/PMCR_EL0 register (not functionally significant in the model)   |
| override_PMCEID0               | Uns64   | Override PMCEID0/PMCEID0_EL0 register (not functionally significant in the model)   |
| override_PMCEID1               | Uns64   | Override PMCEID1/PMCEID1_EL0 register (not functionally significant in the model)   |
| override_DBGDIDR               | Uns32   | Override DBGDIDR register (not functionally significant in the model)   |
| override_FPSID                 | Uns32   | Override SIMD/VFP FPSID register  |
| override_MVFR0                 | Uns32   | Override SIMD/VFP MVFR0/MVFR0_EL1 register  |
| override_MVFR1                 | Uns32   | Override SIMD/VFP MVFR1/MVFR1_EL1 register  |
| override_FPEXC                 | Uns32   | Override SIMD/VFP FPEXC/FPEXC32_EL2 register  |
| override_ERG                   | Uns32   | Specifies exclusive reservation granule   |
| override_CCSIDR_1I             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 1 instruction)  |
| override_CCSIDR_1D             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 1 data)   |
| override_CCSIDR_2I             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 2 instruction)  |
| override_CCSIDR_2D             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 2 data)   |
| override_CCSIDR_3I             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 3 instruction)  |
| override_CCSIDR_3D             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 3 data)   |
| override_CCSIDR_4I             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 4 instruction)  |
| override_CCSIDR_4D             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 4 data)   |
| override_CCSIDR_5I             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 5 instruction)  |
| override_CCSIDR_5D             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 5 data)   |
| override_CCSIDR_6I             | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 6 instruction)  |

|                                 |         |  |
|---------------------------------|---------|--|
| override_CCSIDR_6D              | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 6 data)  |
| override_CCSIDR_7I              | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 7 instruction)   |
| override_CCSIDR_7D              | Uns32   | Override CCSIDR/CCSIDR_EL1 (level 7 data)  |
| override_STRoffsetPC12          | Boolean | Specifies that STR/STR of PC should do so with 12:byte offset from the current instruction (if true), otherwise an 8:byte offset is used |
| override_fcseRequiresMMU        | Boolean | Specifies that FCSE is active only when MMU is enabled (if true)   |
| override_ignoreBadCp15          | Boolean | Specifies whether invalid coprocessor 15 access should be ignored (if true) or cause Invalid Instruction exceptions (if false)           |
| override_SGIDisable             | Boolean | Override whether GIC SGIs may be disabled (if true) or are permanently enabled (if false)  |
| override_condUndefined          | Boolean | Force undefined instructions to take Undefined Instruction exception even if they are conditional  |
| override_deviceStrongAligned    | Boolean | Force accesses to Device and Strongly Ordered regions to be aligned  |
| override_Control_V              | Boolean | Override SCTLR.V with the passed value (deprecated, use override_SCTLR_V)  |
| override_MainId                 | Uns32   | Override MIDR register (deprecated, use override_MIDR)   |
| override_CacheType              | Uns32   | Override CTR register (deprecated, use override_CTR)   |
| override_TLBType                | Uns32   | Override TLBTR register (deprecated, use override_TLBTR)   |
| override_InstructionAttributes0 | Uns32   | Override ID_ISAR0 register (deprecated, use override_ISAR0)  |
| override_InstructionAttributes1 | Uns32   | Override ID_ISAR1 register (deprecated, use override_ISAR1)  |
| override_InstructionAttributes2 | Uns32   | Override ID_ISAR2 register (deprecated, use override_ISAR2)  |
| override_InstructionAttributes3 | Uns32   | Override ID_ISAR3 register (deprecated, use override_ISAR3)  |
| override_InstructionAttributes4 | Uns32   | Override ID_ISAR4 register (deprecated, use override_ISAR4)  |
| override_InstructionAttributes5 | Uns32   | Override ID_ISAR5 register (deprecated, use override_ISAR5)  |

Table 8.1: Parameters that can be set in: CPU



## Chapter 9

# Execution Modes

| Mode       | Code |
|------------|------|
| User       | 16   |
| FIQ        | 17   |
| IRQ        | 18   |
| Supervisor | 19   |
| Monitor    | 22   |
| Abort      | 23   |
| Hypervisor | 26   |
| Undefined  | 27   |
| System     | 31   |

Table 9.1: Modes implemented in: CPU

## Chapter 10

# Exceptions

| <b>Exception</b>  | Code |
|-------------------|------|
| Reset             | 0    |
| Undefined         | 1    |
| SupervisorCall    | 2    |
| SecureMonitorCall | 3    |
| HypervisorCall    | 4    |
| PrefetchAbort     | 5    |
| DataAbort         | 6    |
| HypervisorTrap    | 7    |
| IRQ               | 8    |
| FIQ               | 9    |

Table 10.1: Exceptions implemented in: CPU

# Chapter 11

## Hierarchy of the model

A CPU core may be configured to instance many processors of a Symmetrical Multi Processor (SMP). A CPU core may also have sub elements within a processor, for example hardware threading blocks.

OVP processor models can be written to include SMP blocks and to have many levels of hierarchy. Some OVP CPU models may have a fixed hierarchy, and some may be configured by settings in a configuration register. Please see the register definitions of this model.

This model documentation shows the settings and hierarchy of the default settings for this model variant.

### 11.1 Level 1: CPU

This level in the model hierarchy has 5 commands.

This level in the model hierarchy has 19 register groups:

| Group name                    | Registers |
|-------------------------------|-----------|
| Core                          | 16        |
| Control                       | 3         |
| User                          | 7         |
| FIQ                           | 8         |
| IRQ                           | 3         |
| Supervisor                    | 3         |
| Monitor                       | 3         |
| Hypervisor                    | 3         |
| Undefined                     | 3         |
| Abort                         | 3         |
| SIMD_VFP                      | 32        |
| SIMD_VFP_SYS                  | 5         |
| Coprocessor_32_bit            | 167       |
| Coprocessor_32_bit_secure     | 26        |
| Coprocessor_32_bit_non_secure | 26        |
| Coprocessor_64_bit            | 11        |
| Coprocessor_64_bit_secure     | 4         |
| Coprocessor_64_bit_non_secure | 4         |
| Integration_support           | 32        |

---

Table 11.1: Register groups

This level in the model hierarchy has no children.

# Chapter 12

## Model Commands

A Processor model can implement one or more **Model Commands** available to be invoked from the simulator command line, from the OP API or from the Imperas Multiprocessor Debugger.

### 12.1 Level 1: CPU

#### 12.1.1 debugflags

show or modify the processor debug flags

| Argument | Type    | Description   |
|----------|---------|---|
| -get     | Boolean | print current processor flags value                         |
| -mask    | Boolean | print valid debug flag bits                                 |
| -set     | Int32   | new processor flags (only flags 0x000003e4 can be modified) |

Table 12.1: debugflags command arguments

#### 12.1.2 dumpTLB

report TLB contents

| Argument | Type    | Description   |
|----------|---------|---|
| -all     | Boolean | show the contents of all TLBs (if False, show just the current TLB) |

Table 12.2: dumpTLB command arguments

#### 12.1.3 isync

specify instruction address range for synchronous execution

| Argument   | Type  | Description                                  |
|------------|-------|--|
| -addresshi | Uns64 | end address of synchronous execution range   |
| -addresslo | Uns64 | start address of synchronous execution range |

Table 12.3: isync command arguments

### 12.1.4 itrace

enable or disable instruction tracing

| Argument          | Type    | Description                                  |
|-------------------|---------|--|
| -after            | Uns64   | apply after this many instructions           |
| -enable           | Boolean | enable instruction tracing                   |
| -instructioncount | Boolean | include the instruction number in each trace |
| -off              | Boolean | disable instruction tracing                  |
| -on               | Boolean | enable instruction tracing                   |
| -registerchange   | Boolean | show registers changed by this instruction   |
| -registers        | Boolean | show registers after each trace              |

Table 12.4: itrace command arguments

### 12.1.5 validateTLB

check TLB contents against page tables in memory and report incoherent entries

| Argument | Type    | Description   |
|----------|---------|---|
| -all     | Boolean | check all TLBs (if False, validate just the current TLB)      |
| -verbose | Boolean | show all TLB entries (if False, show only incoherent entries) |

Table 12.5: validateTLB command arguments

# Chapter 13

## Registers

### 13.1 Level 1: CPU

#### 13.1.1 Core

Registers at level:1, type:CPU group:Core

| Name | Bits | Initial-Hex | RW | Description     |
|------|------|-------------|----|-----------------|
| r0   | 32   | 0           | rw |                 |
| r1   | 32   | 0           | rw |                 |
| r2   | 32   | 0           | rw |                 |
| r3   | 32   | 0           | rw |                 |
| r4   | 32   | 0           | rw |                 |
| r5   | 32   | 0           | rw |                 |
| r6   | 32   | 0           | rw |                 |
| r7   | 32   | 0           | rw |                 |
| r8   | 32   | 0           | rw |                 |
| r9   | 32   | 0           | rw |                 |
| r10  | 32   | 0           | rw |                 |
| r11  | 32   | 0           | rw | frame pointer   |
| r12  | 32   | 0           | rw |                 |
| sp   | 32   | 0           | rw | stack pointer   |
| lr   | 32   | 0           | rw |                 |
| pc   | 32   | 0           | rw | program counter |

Table 13.1: Registers at level 1, type:CPU group:Core

#### 13.1.2 Control

Registers at level:1, type:CPU group:Control

| Name | Bits | Initial-Hex | RW | Description                  |
|------|------|-------------|----|------------------------------|
| fps  | 32   | 0           | rw | archaic FPSCR view (for gdb) |
| cpsr | 32   | 1d3         | rw |                              |
| spsr | 32   | 0           | rw |                              |

Table 13.2: Registers at level 1, type:CPU group:Control

#### 13.1.3 User

Registers at level:1, type:CPU group:User

| Name    | Bits | Initial-Hex | RW | Description |
|---------|------|-------------|----|-------------|
| r8_usr  | 32   | 0           | rw |             |
| r9_usr  | 32   | 0           | rw |             |
| r10_usr | 32   | 0           | rw |             |
| r11_usr | 32   | 0           | rw |             |
| r12_usr | 32   | 0           | rw |             |
| sp_usr  | 32   | 0           | rw |             |
| lr_usr  | 32   | 0           | rw |             |

Table 13.3: Registers at level 1, type:CPU group:User

### 13.1.4 FIQ

Registers at level:1, type:CPU group:FIQ

| Name     | Bits | Initial-Hex | RW | Description |
|----------|------|-------------|----|-------------|
| r8_fiq   | 32   | 0           | rw |             |
| r9_fiq   | 32   | 0           | rw |             |
| r10_fiq  | 32   | 0           | rw |             |
| r11_fiq  | 32   | 0           | rw |             |
| r12_fiq  | 32   | 0           | rw |             |
| sp_fiq   | 32   | 0           | rw |             |
| lr_fiq   | 32   | 0           | rw |             |
| spsr_fiq | 32   | 0           | rw |             |

Table 13.4: Registers at level 1, type:CPU group:FIQ

### 13.1.5 IRQ

Registers at level:1, type:CPU group:IRQ

| Name     | Bits | Initial-Hex | RW | Description |
|----------|------|-------------|----|-------------|
| sp_irq   | 32   | 0           | rw |             |
| lr_irq   | 32   | 0           | rw |             |
| spsr_irq | 32   | 0           | rw |             |

Table 13.5: Registers at level 1, type:CPU group:IRQ

### 13.1.6 Supervisor

Registers at level:1, type:CPU group:Supervisor

| Name     | Bits | Initial-Hex | RW | Description |
|----------|------|-------------|----|-------------|
| sp_svc   | 32   | 0           | rw |             |
| lr_svc   | 32   | 0           | rw |             |
| spsr_svc | 32   | 0           | rw |             |

Table 13.6: Registers at level 1, type:CPU group:Supervisor

### 13.1.7 Monitor

Registers at level:1, type:CPU group:Monitor

| Name   | Bits | Initial-Hex | RW | Description |
|--------|------|-------------|----|-------------|
| sp_mon | 32   | 0           | rw |             |



|          |    |   |    |  |
|----------|----|---|----|--|
| lr_mon   | 32 | 0 | rw |  |
| spsr_mon | 32 | 0 | rw |  |

Table 13.7: Registers at level 1, type:CPU group:Monitor

### 13.1.8 Hypervisor

Registers at level:1, type:CPU group:Hypervisor

| Name     | Bits | Initial-Hex | RW | Description |
|----------|------|-------------|----|-------------|
| sp_hyp   | 32   | 0           | rw |             |
| elr_hyp  | 32   | 0           | rw |             |
| spsr_hyp | 32   | 0           | rw |             |

Table 13.8: Registers at level 1, type:CPU group:Hypervisor

### 13.1.9 Undefined

Registers at level:1, type:CPU group:Undefined

| Name       | Bits | Initial-Hex | RW | Description |
|------------|------|-------------|----|-------------|
| sp_undef   | 32   | 0           | rw |             |
| lr_undef   | 32   | 0           | rw |             |
| spsr_undef | 32   | 0           | rw |             |

Table 13.9: Registers at level 1, type:CPU group:Undefined

### 13.1.10 Abort

Registers at level:1, type:CPU group:Abort

| Name     | Bits | Initial-Hex | RW | Description |
|----------|------|-------------|----|-------------|
| sp_abt   | 32   | 0           | rw |             |
| lr_abt   | 32   | 0           | rw |             |
| spsr_abt | 32   | 0           | rw |             |

Table 13.10: Registers at level 1, type:CPU group:Abort

### 13.1.11 SIMD\_VFP

Registers at level:1, type:CPU group:SIMD\_VFP

| Name | Bits | Initial-Hex | RW | Description |
|------|------|-------------|----|-------------|
| d0   | 64   | 0           | rw |             |
| d1   | 64   | 0           | rw |             |
| d2   | 64   | 0           | rw |             |
| d3   | 64   | 0           | rw |             |
| d4   | 64   | 0           | rw |             |
| d5   | 64   | 0           | rw |             |
| d6   | 64   | 0           | rw |             |
| d7   | 64   | 0           | rw |             |
| d8   | 64   | 0           | rw |             |
| d9   | 64   | 0           | rw |             |
| d10  | 64   | 0           | rw |             |
| d11  | 64   | 0           | rw |             |

|     |    |   |    |  |
|-----|----|---|----|--|
| d12 | 64 | 0 | rw |  |
| d13 | 64 | 0 | rw |  |
| d14 | 64 | 0 | rw |  |
| d15 | 64 | 0 | rw |  |
| d16 | 64 | 0 | rw |  |
| d17 | 64 | 0 | rw |  |
| d18 | 64 | 0 | rw |  |
| d19 | 64 | 0 | rw |  |
| d20 | 64 | 0 | rw |  |
| d21 | 64 | 0 | rw |  |
| d22 | 64 | 0 | rw |  |
| d23 | 64 | 0 | rw |  |
| d24 | 64 | 0 | rw |  |
| d25 | 64 | 0 | rw |  |
| d26 | 64 | 0 | rw |  |
| d27 | 64 | 0 | rw |  |
| d28 | 64 | 0 | rw |  |
| d29 | 64 | 0 | rw |  |
| d30 | 64 | 0 | rw |  |
| d31 | 64 | 0 | rw |  |

Table 13.11: Registers at level 1, type:CPU group:SIMD\_VFP

### 13.1.12 SIMD\_VFP\_SYS

Registers at level:1, type:CPU group:SIMD\_VFP\_SYS

| Name  | Bits | Initial-Hex | RW | Description                   |
|-------|------|-------------|----|-------------------------------|
| FPSID | 32   | 41033092    | r- | floating-point system ID      |
| FPSCR | 32   | 0           | rw | floating-point status/control |
| FPEXC | 32   | 0           | rw | floating-point exception      |
| MVFR0 | 32   | 10110222    | r- | Media/VFP feature 0           |
| MVFR1 | 32   | 11111111    | r- | Media/VFP feature 1           |

Table 13.12: Registers at level 1, type:CPU group:SIMD\_VFP\_SYS

### 13.1.13 Coprocessor\_32\_bit

Registers at level:1, type:CPU group:Coprocessor\_32\_bit

| Name       | Bits | Initial-Hex | RW | Description  |
|------------|------|-------------|----|--|
| ACTLR      | 32   | 0           | rw | Auxiliary Control  |
| ADFSR      | 32   | 0           | rw | Auxiliary Data Fault Status                                |
| AIDR       | 32   | 0           | r- | Auxiliary ID   |
| AIFSR      | 32   | 0           | rw | Auxiliary Instruction Fault Status                         |
| AMAIR0     | 32   | 0           | rw | Auxiliary Memory Attribute Indirection 0                   |
| AMAIR1     | 32   | 0           | rw | Auxiliary Memory Attribute Indirection 1                   |
| ATS1CPR    | 32   | -           | -w | Address Translate Stage 1 Current State EL1 Read           |
| ATS1CPW    | 32   | -           | -w | Address Translate Stage 1 Current State EL1 Write          |
| ATS1CUR    | 32   | -           | -w | Address Translate Stage 1 Current State Unprivileged Read  |
| ATS1CUW    | 32   | -           | -w | Address Translate Stage 1 Current State Unprivileged Write |
| ATS1HR     | 32   | -           | -w | Address Translate Stage 1 Hyp Mode Read                    |
| ATS1HW     | 32   | -           | -w | Address Translate Stage 1 Hyp Mode Write                   |
| ATS12NSOPR | 32   | -           | -w | Address Translate Stages 1 and 2 Non-Secure Only EL1 Read  |
| ATS12NSOPW | 32   | -           | -w | Address Translate Stages 1 and 2 Non-Secure Only EL1 Write |

|            |    |          |    |   |
|------------|----|----------|----|---|
| ATS12NSOUR | 32 | -        | -w | Address Translate Stages 1 and 2 Non-Secure Only Unprivileged Read  |
| ATS12NSOUW | 32 | -        | -w | Address Translate Stages 1 and 2 Non-Secure Only Unprivileged Write |
| BPIALL     | 32 | -        | -w | Branch Predictor Invalidate All                                     |
| BPIALLIS   | 32 | -        | -w | Branch Predictor Invalidate All (IS)                                |
| BPIMVA     | 32 | -        | -w | Branch Predictor Invalidate by VA                                   |
| CBAR       | 32 | 0        | rw | Configuration Base Address  |
| CCSIDR     | 32 | 201fe00a | r- | Cache Size ID   |
| CDBGDCD    | 32 | -        | -w | Data Cache Data Read  |
| CDBGDCT    | 32 | -        | -w | Data Cache Tag Read   |
| CDBGDR0    | 32 | 0        | r- | Data Register 0   |
| CDBGDR1    | 32 | 0        | r- | Data Register 1   |
| CDBGDR2    | 32 | 0        | r- | Data Register 2   |
| CDBGICD    | 32 | -        | -w | Instruction Cache Data Read   |
| CDBGICT    | 32 | -        | -w | Instruction Cache Tag Read  |
| CDBGTD     | 32 | -        | -w | TLB Data Read   |
| CLIDR      | 32 | a000023  | r- | Cache Level ID  |
| CNTFRQ     | 32 | 4c4b40   | rw | Counter Frequency   |
| CNTHCTL    | 32 | 3        | rw | Timer EL2 Control   |
| CNTHP_CTL  | 32 | 0        | rw | Counter-Timer Hyp Physical Timer Control                            |
| CNTHP_TVAL | 32 | 0        | rw | Counter-Timer Hyp Physical Timer TimerValue                         |
| CNTKCTL    | 32 | 0        | rw | Timer EL1 Control   |
| CNTP_CTL   | 32 | 0        | rw | Counter-Timer Physical Timer Control                                |
| CNTP_TVAL  | 32 | 0        | rw | Counter-Timer Physical Timer TimerValue                             |
| CNTV_CTL   | 32 | 0        | rw | Counter-Timer Virtual Timer Control                                 |
| CNTV_TVAL  | 32 | 0        | rw | Counter-Timer Virtual Timer TimerValue                              |
| CONTEXTIDR | 32 | 0        | rw | Context ID  |
| CP15DMB    | 32 | -        | -w | CP15 Data Memory Barrier  |
| CP15DSB    | 32 | -        | -w | CP15 Data Synchronization Barrier                                   |
| CP15ISB    | 32 | -        | -w | CP15 Instruction Synchronization Barrier                            |
| CP15NOP    | 32 | -        | -w | CP15 NOP  |
| CPACR      | 32 | 0        | rw | Coprocessor Access Control  |
| CSSELR     | 32 | 1        | rw | Cache Size Selection  |
| CTR        | 32 | 84048003 | r- | Cache Type  |
| DACR       | 32 | 0        | rw | Domain Access Control   |
| DBGDIDR    | 32 | 0        | r- | Debug ID  |
| DCCIMVAC   | 32 | -        | -w | Data Cache Line Clean and Invalidate by VA to PoC                   |
| DCCISW     | 32 | -        | -w | Data Cache Line Clean and Invalidate by Set/Way                     |
| DCCMVAC    | 32 | -        | -w | Data Cache Line Clean by VA to PoC                                  |
| DCCMVAU    | 32 | -        | -w | Data Cache Line Clean by VA to PoU                                  |
| DCCSW      | 32 | -        | -w | Data Cache Line Clean by Set/Way                                    |
| DCIMVAC    | 32 | -        | -w | Data Cache Line Invalidate by VA to PoC                             |
| DCISW      | 32 | -        | -w | Data Cache Line Invalidate by Set/Way                               |
| DFAR       | 32 | 0        | rw | Data Fault Address  |
| DFSR       | 32 | 0        | rw | Data Fault Status   |
| DTLBIALL   | 32 | -        | -w | Invalidate Entire Data TLB  |
| DTLBIASID  | 32 | -        | -w | Invalidate Data TLB by ASID   |
| DTLBMVA    | 32 | -        | -w | Invalidate Data TLB by VA   |
| DTLBMVAA   | 32 | -        | -w | Invalidate Data TLB by VA, all ASID                                 |
| HACR       | 32 | 0        | rw | Hyp Auxiliary Configuration   |
| HACTLR     | 32 | 0        | rw | Hyp Auxiliary Control   |
| HADFSR     | 32 | 0        | rw | Hyp Auxiliary Data Fault Status                                     |
| HAIFSR     | 32 | 0        | rw | Hyp Auxiliary Instruction Fault Status                              |
| HAMAIRO    | 32 | 0        | rw | Hyp Auxiliary Memory Attribute Indirection 0                        |
| HAMAIR1    | 32 | 0        | rw | Hyp Auxiliary Memory Attribute Indirection 1                        |

|            |    |          |    |  |
|------------|----|----------|----|--|
| HCPTR      | 32 | 33ff     | rw | Hyp Coprocessor Trap                       |
| HCR        | 32 | 0        | rw | Hyp Configuration                          |
| HDCR       | 32 | 6        | rw | Hyp Debug Configuration                    |
| HDFAR      | 32 | 0        | rw | Hyp Data Fault Address                     |
| HIFAR      | 32 | 0        | rw | Hyp Instruction Fault Address              |
| HMAIR0     | 32 | 0        | rw | Hyp Memory Attribute Indirection 0         |
| HMAIR1     | 32 | 0        | rw | Hyp Memory Attribute Indirection 1         |
| HPFAR      | 32 | 0        | rw | Hyp IPA Fault Address                      |
| HSCTLR     | 32 | 30c50878 | rw | Hyp System Control                         |
| HSR        | 32 | 0        | rw | Hyp Syndrome                               |
| HSTR       | 32 | 0        | rw | Hyp System Trap                            |
| HTCR       | 32 | 80000000 | rw | Hyp Translation Control                    |
| HTPIDR     | 32 | 0        | rw | Hyp Thread and Process ID                  |
| HVBAR      | 32 | 0        | rw | Hyp Vector Base Address                    |
| ICIALLU    | 32 | -        | -w | Instruction Cache Invalidate All           |
| ICIALLUIS  | 32 | -        | -w | Instruction Cache Invalidate All (IS)      |
| ICIMVAU    | 32 | -        | -w | Instruction Cache Invalidate by VA         |
| ID_AFR0    | 32 | 0        | r- | Auxiliary Feature 0                        |
| ID_DFR0    | 32 | 2000000  | r- | Debug Feature 0                            |
| ID_ISAR0   | 32 | 2101110  | r- | Instruction Set Attribute 0                |
| ID_ISAR1   | 32 | 13112111 | r- | Instruction Set Attribute 1                |
| ID_ISAR2   | 32 | 21232041 | r- | Instruction Set Attribute 2                |
| ID_ISAR3   | 32 | 11112131 | r- | Instruction Set Attribute 3                |
| ID_ISAR4   | 32 | 10011142 | r- | Instruction Set Attribute 4                |
| ID_ISAR5   | 32 | 0        | r- | Instruction Set Attribute 5                |
| ID_MMFR0   | 32 | 10101105 | r- | Memory Model Feature 0                     |
| ID_MMFR1   | 32 | 40000000 | r- | Memory Model Feature 1                     |
| ID_MMFR2   | 32 | 1240000  | r- | Memory Model Feature 2                     |
| ID_MMFR3   | 32 | 2102211  | r- | Memory Model Feature 3                     |
| ID_PFR0    | 32 | 1131     | r- | Processor Feature 0                        |
| ID_PFR1    | 32 | 11011    | r- | Processor Feature 1                        |
| IFAR       | 32 | 0        | rw | Instruction Fault Address                  |
| IFSR       | 32 | 0        | rw | Instruction Fault Status                   |
| ISR        | 32 | 0        | r- | Interrupt Status                           |
| ITLBIALL   | 32 | -        | -w | Invalidate Entire Instruction TLB          |
| ITLBIASID  | 32 | -        | -w | Invalidate Instruction TLB by ASID         |
| ITLBIMVA   | 32 | -        | -w | Invalidate Instruction TLB by VA           |
| ITLBIMVAA  | 32 | -        | -w | Invalidate Instruction TLB by VA, all ASID |
| JIDR       | 32 | 0        | rw | Jazelle ID                                 |
| JMCR       | 32 | 0        | rw | Jazelle Main Configuration                 |
| JOSCR      | 32 | 0        | rw | Jazelle OS Control                         |
| L2CTLR     | 32 | 0        | rw | L2 Control                                 |
| L2ECTLR    | 32 | 0        | rw | L2 Extended Control                        |
| MAIR0      | 32 | 0        | rw | Memory Attribute Indirection 0             |
| MAIR1      | 32 | 0        | rw | Memory Attribute Indirection 1             |
| MIDR       | 32 | 410fc073 | r- | Main ID                                    |
| MPIDR      | 32 | c0000000 | r- | Multiprocessor Affinity                    |
| MVBAR      | 32 | 0        | rw | Monitor Vector Base Address                |
| NMRR       | 32 | 44e048e0 | rw | Normal Memory Remap                        |
| NSACR      | 32 | 0        | rw | Non-Secure Access Control                  |
| PAR        | 32 | 0        | rw | Physical Address                           |
| PMCCNTR    | 32 | 0        | rw | Performance Monitors Cycle Count           |
| PMCEID0    | 32 | 3fff0f3f | r- | Performance Monitors Common Event ID 0     |
| PMCEID1    | 32 | 0        | r- | Performance Monitors Common Event ID 1     |
| PMCNTENCLR | 32 | 0        | rw | Performance Monitors Count Enable Clear    |
| PMCNTENSET | 32 | 0        | rw | Performance Monitors Count Enable Set      |

|               |    |          |    |   |
|---------------|----|----------|----|---|
| PMCR          | 32 | 410f3000 | rw | Performance Monitors Control                          |
| PMINTENCLR    | 32 | 0        | rw | Performance Monitors Interrupt Enable Clear           |
| PMINTENSET    | 32 | 0        | rw | Performance Monitors Interrupt Enable Set             |
| PMOVS         | 32 | 0        | rw | Performance Monitors Overflow Flag Status             |
| PMOVSSET      | 32 | 0        | rw | Performance Monitors Overflow Flag Status Set         |
| PMSELR        | 32 | 0        | rw | Performance Monitors Event Counter Selection          |
| PMSWINC       | 32 | -        | -w | Performance Monitors Software Increment               |
| PMUSERENR     | 32 | 0        | rw | Performance Monitors User Enable                      |
| PMXEVCNTR     | 32 | 0        | rw | Performance Monitors Selected Event Count             |
| PMXEVTYPER    | 32 | 0        | rw | Performance Monitors Selected Event Type              |
| PRRR          | 32 | 98aa4    | rw | Primary Region Remap                                  |
| REVIDR        | 32 | 0        | r- | Revision ID   |
| SCR           | 32 | 0        | rw | Secure Configuration                                  |
| SCTLR         | 32 | c50878   | rw | System Control  |
| SDER          | 32 | 0        | rw | Secure Debug Enable                                   |
| TCMTR         | 32 | 0        | r- | TCM Type  |
| TEECR         | 32 | 0        | rw | T32EE Configuration                                   |
| TEEHBR        | 32 | 0        | rw | T32EE Handler Base                                    |
| TLBIALL       | 32 | -        | -w | Invalidate Entire Unified TLB                         |
| TLBIALLH      | 32 | -        | -w | Invalidate Entire Hyp Unified TLB                     |
| TLBIALLHIS    | 32 | -        | -w | Invalidate Entire Hyp TLB (IS)                        |
| TLBIALLIS     | 32 | -        | -w | Invalidate Entire Unified TLB (IS)                    |
| TLBIALLNSNH   | 32 | -        | -w | Invalidate Entire Non-Secure Non-Hyp Unified TLB      |
| TLBIALLNSNHIS | 32 | -        | -w | Invalidate Entire Non-Secure Non-Hyp Unified TLB (IS) |
| TLBIASID      | 32 | -        | -w | Invalidate Unified TLB by ASID                        |
| TLBIASIDIS    | 32 | -        | -w | Invalidate Unified TLB by ASID (IS)                   |
| TLBIMVA       | 32 | -        | -w | Invalidate Unified TLB by VA                          |
| TLBIMVAA      | 32 | -        | -w | Invalidate Unified TLB by VA, all ASID                |
| TLBIMVAAIS    | 32 | -        | -w | Invalidate Unified TLB by VA, all ASID (IS)           |
| TLBIMVAH      | 32 | -        | -w | Invalidate Hyp Unified TLB by VA                      |
| TLBIMVAHIS    | 32 | -        | -w | Invalidate Hyp Unified TLB by VA (IS)                 |
| TLBIMVAIS     | 32 | -        | -w | Invalidate Unified TLB by VA (IS)                     |
| TLBTR         | 32 | 0        | r- | TLB Type  |
| TPIDRPRW      | 32 | 0        | rw | PL0 Read/Write Software Thread ID                     |
| TPIDRURO      | 32 | 0        | rw | PL0 Read-Only Software Thread ID                      |
| TPIDRURW      | 32 | 0        | rw | PL1 Software Thread ID                                |
| TTBCR         | 32 | 0        | rw | Translation Table Base Control                        |
| TTBR0         | 32 | 0        | rw | Translation Table Base 0                              |
| TTBR1         | 32 | 0        | rw | Translation Table Base 1                              |
| VBAR          | 32 | 0        | rw | Vector Base Address                                   |
| VMPIDR        | 32 | c0000000 | rw | Virtualization Multiprocessor ID                      |
| VPIDR         | 32 | 410fc073 | rw | Virtualization Processor ID                           |
| VTCR          | 32 | 80000000 | rw | Virtualization Translation Control                    |

Table 13.13: Registers at level 1, type:CPU group:Coprocessor\_32\_bit

### 13.1.14 Coprocessor\_32\_bit\_secure

Registers at level:1, type:CPU group:Coprocessor\_32\_bit\_secure

| Name       | Bits | Initial-Hex | RW | Description                              |
|------------|------|-------------|----|--|
| ADFSR_S    | 32   | 0           | rw | Auxiliary Data Fault Status              |
| AIFSR_S    | 32   | 0           | rw | Auxiliary Instruction Fault Status       |
| AMAIRO_S   | 32   | 0           | rw | Auxiliary Memory Attribute Indirection 0 |
| AMAIR1_S   | 32   | 0           | rw | Auxiliary Memory Attribute Indirection 1 |
| CNTP_CTL_S | 32   | 0           | rw | Counter-Timer Physical Timer Control     |

|              |    |          |    |   |
|--------------|----|----------|----|---|
| CNTP_TVAL_S  | 32 | 0        | rw | Counter-Timer Physical Timer TimerValue |
| CONTEXTIDR_S | 32 | 0        | rw | Context ID                              |
| CSSELR_S     | 32 | 1        | rw | Cache Size Selection                    |
| DACR_S       | 32 | 0        | rw | Domain Access Control                   |
| DFAR_S       | 32 | 0        | rw | Data Fault Address                      |
| DFSR_S       | 32 | 0        | rw | Data Fault Status                       |
| IFAR_S       | 32 | 0        | rw | Instruction Fault Address               |
| IFSR_S       | 32 | 0        | rw | Instruction Fault Status                |
| MAIR0_S      | 32 | 0        | rw | Memory Attribute Indirection 0          |
| MAIR1_S      | 32 | 0        | rw | Memory Attribute Indirection 1          |
| NMRR_S       | 32 | 44e048e0 | rw | Normal Memory Remap                     |
| PAR_S        | 32 | 0        | rw | Physical Address                        |
| PRRR_S       | 32 | 98aa4    | rw | Primary Region Remap                    |
| SCTLR_S      | 32 | c50878   | rw | System Control                          |
| TPIDRPRW_S   | 32 | 0        | rw | PL0 Read/Write Software Thread ID       |
| TPIDRURO_S   | 32 | 0        | rw | PL0 Read-Only Software Thread ID        |
| TPIDRURW_S   | 32 | 0        | rw | PL1 Software Thread ID                  |
| TTBCR_S      | 32 | 0        | rw | Translation Table Base Control          |
| TTBR0_S      | 32 | 0        | rw | Translation Table Base 0                |
| TTBR1_S      | 32 | 0        | rw | Translation Table Base 1                |
| VBAR_S       | 32 | 0        | rw | Vector Base Address                     |

Table 13.14: Registers at level 1, type:CPU group:Coprocessor\_32\_bit\_secure

### 13.1.15 Coprocessor\_32\_bit\_non\_secure

Registers at level:1, type:CPU group:Coprocessor\_32\_bit\_non\_secure

| Name          | Bits | Initial-Hex | RW | Description                              |
|---------------|------|-------------|----|--|
| ADFSR_NS      | 32   | 0           | rw | Auxiliary Data Fault Status              |
| AIFSR_NS      | 32   | 0           | rw | Auxiliary Instruction Fault Status       |
| AMAIRO_NS     | 32   | 0           | rw | Auxiliary Memory Attribute Indirection 0 |
| AMAIR1_NS     | 32   | 0           | rw | Auxiliary Memory Attribute Indirection 1 |
| CNTP_CTL_NS   | 32   | 0           | rw | Counter-Timer Physical Timer Control     |
| CNTP_TVAL_NS  | 32   | 0           | rw | Counter-Timer Physical Timer TimerValue  |
| CONTEXTIDR_NS | 32   | 0           | rw | Context ID                               |
| CSSELR_NS     | 32   | 1           | rw | Cache Size Selection                     |
| DACR_NS       | 32   | 0           | rw | Domain Access Control                    |
| DFAR_NS       | 32   | 0           | rw | Data Fault Address                       |
| DFSR_NS       | 32   | 0           | rw | Data Fault Status                        |
| IFAR_NS       | 32   | 0           | rw | Instruction Fault Address                |
| IFSR_NS       | 32   | 0           | rw | Instruction Fault Status                 |
| MAIR0_NS      | 32   | 0           | rw | Memory Attribute Indirection 0           |
| MAIR1_NS      | 32   | 0           | rw | Memory Attribute Indirection 1           |
| NMRR_NS       | 32   | 44e048e0    | rw | Normal Memory Remap                      |
| PAR_NS        | 32   | 0           | rw | Physical Address                         |
| PRRR_NS       | 32   | 98aa4       | rw | Primary Region Remap                     |
| SCTLR_NS      | 32   | c50878      | rw | System Control                           |
| TPIDRPRW_NS   | 32   | 0           | rw | PL0 Read/Write Software Thread ID        |
| TPIDRURO_NS   | 32   | 0           | rw | PL0 Read-Only Software Thread ID         |
| TPIDRURW_NS   | 32   | 0           | rw | PL1 Software Thread ID                   |
| TTBCR_NS      | 32   | 0           | rw | Translation Table Base Control           |
| TTBR0_NS      | 32   | 0           | rw | Translation Table Base 0                 |
| TTBR1_NS      | 32   | 0           | rw | Translation Table Base 1                 |
| VBAR_NS       | 32   | 0           | rw | Vector Base Address                      |

Table 13.15: Registers at level 1, type:CPU group:Coprocessor\_32.bit\_non\_secure

### 13.1.16 Coprocessor\_64\_bit

Registers at level:1, type:CPU group:Coprocessor\_64.bit

| Name       | Bits | Initial-Hex | RW | Description                                   |
|------------|------|-------------|----|---|
| CNTHP_CVAL | 64   | 0           | rw | Counter-Timer Hyp Physical Timer CompareValue |
| CNTPCT     | 64   | 0           | r- | Counter-Timer Physical Count                  |
| CNTP_CVAL  | 64   | 0           | rw | Counter-Timer Physical Timer CompareValue     |
| CNTVCT     | 64   | 0           | r- | Counter-Timer Virtual Count                   |
| CNTVOFF    | 64   | 0           | rw | Virtual Offset                                |
| CNTV_CVAL  | 64   | 0           | rw | Counter-Timer Virtual Timer CompareValue      |
| HTTBR      | 64   | 0           | rw | Hyp Translation Table Base                    |
| PARLPA     | 64   | 0           | rw | Physical Address                              |
| TTBR0LPA   | 64   | 0           | rw | Translation Table Base 0                      |
| TTBR1LPA   | 64   | 0           | rw | Translation Table Base 1                      |
| VTTBR      | 64   | 0           | rw | Virtualization Translation Table Base         |

Table 13.16: Registers at level 1, type:CPU group:Coprocessor\_64.bit

### 13.1.17 Coprocessor\_64\_bit\_secure

Registers at level:1, type:CPU group:Coprocessor\_64.bit\_secure

| Name        | Bits | Initial-Hex | RW | Description                               |
|-------------|------|-------------|----|---|
| CNTP_CVAL_S | 64   | 0           | rw | Counter-Timer Physical Timer CompareValue |
| PARLPA_S    | 64   | 0           | rw | Physical Address                          |
| TTBR0LPA_S  | 64   | 0           | rw | Translation Table Base 0                  |
| TTBR1LPA_S  | 64   | 0           | rw | Translation Table Base 1                  |

Table 13.17: Registers at level 1, type:CPU group:Coprocessor\_64.bit\_secure

### 13.1.18 Coprocessor\_64\_bit\_non\_secure

Registers at level:1, type:CPU group:Coprocessor\_64.bit\_non\_secure

| Name         | Bits | Initial-Hex | RW | Description                               |
|--------------|------|-------------|----|---|
| CNTP_CVAL_NS | 64   | 0           | rw | Counter-Timer Physical Timer CompareValue |
| PARLPA_NS    | 64   | 0           | rw | Physical Address                          |
| TTBR0LPA_NS  | 64   | 0           | rw | Translation Table Base 0                  |
| TTBR1LPA_NS  | 64   | 0           | rw | Translation Table Base 1                  |

Table 13.18: Registers at level 1, type:CPU group:Coprocessor\_64.bit\_non\_secure

### 13.1.19 Integration\_support

Registers at level:1, type:CPU group:Integration\_support

| Name        | Bits | Initial-Hex | RW | Description   |
|-------------|------|-------------|----|---|
| transactPL  | 32   | 1           | r- | privilege level of current memory transaction                   |
| transactAT  | 32   | 0           | r- | current memory transaction type: PA=1, VA=0                     |
| artifactPAR | 64   | 0           | r- | result of address translation for artifact write to ATS1CPR etc |

|                 |    |   |    |   |
|-----------------|----|---|----|---|
| PTWBankSelect   | 8  | 0 | rw | select PTW bank (0 is stage 1, 1 is stage 2, 2-5 are stage 2 walks initiated by stage 1 level 0-3 entry lookups, respectively)                    |
| PTWBankValid    | 8  | 0 | r- | bitmask of valid banks (0x01 is stage 1, 0x02 is stage 2, 0x04-0x20 are stage 2 walks initiated by stage 1 level 0-3 entry lookups, respectively) |
| PTWAddressValid | 8  | 0 | r- | bitmask of valid bits for each of PTWAddressL0...PTWAddressL3, PTWBase, PTWInput and PTWOutput in current bank                                    |
| PTWAddressNS    | 8  | 0 | r- | bitmask of Non-Secure bits for each of PTWAddressL0...PTWAddressL3, PTWBase and PTWOutput in current bank (PTWInput bit is always 0)              |
| PTWValueValid   | 8  | 0 | r- | bitmask of valid bits for each of PTWValueL0...PTWValueL3 in current bank   |
| PTWAddressL0    | 64 | 0 | r- | current bank PTW address, level 0   |
| PTWAddressL1    | 64 | 0 | r- | current bank PTW address, level 1   |
| PTWAddressL2    | 64 | 0 | r- | current bank PTW address, level 2   |
| PTWAddressL3    | 64 | 0 | r- | current bank PTW address, level 3   |
| PTWValueL0      | 64 | 0 | r- | current bank PTW value, level 0   |
| PTWValueL1      | 64 | 0 | r- | current bank PTW value, level 1   |
| PTWValueL2      | 64 | 0 | r- | current bank PTW value, level 2   |
| PTWValueL3      | 64 | 0 | r- | current bank PTW value, level 3   |
| PTWBase         | 64 | 0 | r- | current bank PTW table base address   |
| PTWInput        | 64 | 0 | r- | current bank PTW input address  |
| PTWOutput       | 64 | 0 | r- | current bank PTW output address   |
| PTWPgSize       | 64 | 0 | r- | current bank PTW page size (Valid only when PTWOutput is valid)   |
| PTWLEL1S        | 64 | - | -w | perform EL1(S) stage 1 page table walk for fetch, filling PTW query registers   |
| PTWD_EL1S       | 64 | - | -w | perform EL1(S) stage 1 page table walk for load/store, filling PTW query registers  |
| PTWLEL1NS       | 64 | - | -w | perform EL1(NS) stage 1 page table walk for fetch, filling PTW query registers  |
| PTWD_EL1NS      | 64 | - | -w | perform EL1(NS) stage 1 page table walk for load/store, filling PTW query registers   |
| PTWLEL2         | 64 | - | -w | perform EL2 page table walk for fetch, filling PTW query registers  |
| PTWD_EL2        | 64 | - | -w | perform EL2 page table walk for load/store, filling PTW query registers   |
| PTWLS2          | 64 | - | -w | perform stage 2 page table walk for fetch, filling PTW query registers  |
| PTWD_S2         | 64 | - | -w | perform stage 2 page table walk for load/store, filling PTW query registers   |
| PTWI_current    | 64 | - | -w | perform current mode page table walk for fetch, filling PTW query registers   |
| PTWD_current    | 64 | - | -w | perform current mode page table walk for load/store, filling PTW query registers  |
| ResetTLBs       | 8  | - | -w | reset all implemented TLBs to initial state   |
| HaltReason      | 8  | 0 | r- | bit field indicating halt reason  |

Table 13.19: Registers at level 1, type:CPU group:Integration\_support