



# Arm<sup>®</sup> Cortex-A720 Core Cryptographic Extension

Revision: r0p1

## Technical Reference Manual

**Non-Confidential**

**Issue 04**

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# Arm® Cortex-A720 Core Cryptographic Extension

## Technical Reference Manual

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## Release Information

### Document history

Issue	Date	Confidentiality	Change
0000-01	18 November 2021	Confidential	First beta release for r0p0
0000-02	1 April 2022	Confidential	First limited access release for r0p0
0001-03	29 July 2022	Confidential	First early access release for r0p1
0001-04	29 May 2023	Non-Confidential	Second early access release for r0p1

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# 1. Introduction

## 1.1 Product revision status

The  $r_xp_y$  identifier indicates the revision status of the product described in this manual, for example,  $r1p2$ , where:

<b><math>r_x</math></b>	Identifies the major revision of the product, for example, $r1$ .
<b><math>p_y</math></b>	Identifies the minor revision or modification status of the product, for example, $p2$ .

## 1.2 Intended audience

This manual is for system designers, system integrators, and programmers who are designing or programming a *System-on-Chip* (SoC) that uses the Cortex-A720 core with the optional Cryptographic Extension.

## 1.3 Conventions

The following subsections describe conventions used in Arm documents.

### Glossary

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

See the Arm Glossary for more information: [developer.arm.com/glossary](https://developer.arm.com/glossary).

Convention	Use
<i>italic</i>	Citations.
<b>bold</b>	Terms in descriptive lists, where appropriate.
monospace	Text that you can enter at the keyboard, such as commands, file and program names, and source code.
monospace <u>underline</u>	A permitted abbreviation for a command or option. You can enter the underlined text instead of the full command or option name.

Convention	Use
<and>	Encloses replaceable terms for assembler syntax where they appear in code or code fragments.  For example:  <pre>MRC p15, 0, &lt;Rd&gt;, &lt;CRn&gt;, &lt;CRm&gt;, &lt;Opcode_2&gt;</pre>
<b>SMALL CAPITALS</b>	Terms that have specific technical meanings as defined in the <i>Arm® Glossary</i> . For example, <b>IMPLEMENTATION DEFINED</b> , <b>IMPLEMENTATION SPECIFIC</b> , <b>UNKNOWN</b> , and <b>UNPREDICTABLE</b> .



Recommendations. Not following these recommendations might lead to system failure or damage.



Requirements for the system. Not following these requirements might result in system failure or damage.



Requirements for the system. Not following these requirements will result in system failure or damage.



An important piece of information that needs your attention.



A useful tip that might make it easier, better or faster to perform a task.



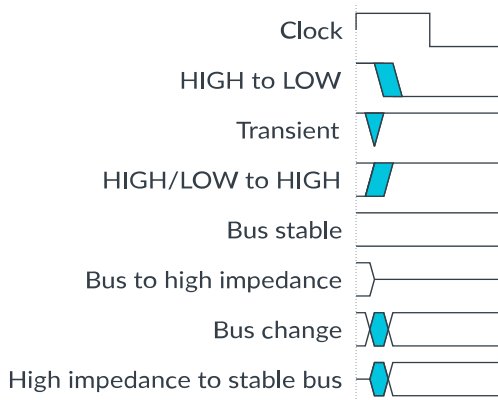
A reminder of something important that relates to the information you are reading.

## Timing diagrams

The following figure explains the components used in timing diagrams. Variations, when they occur, have clear labels. You must not assume any timing information that is not explicit in the diagrams.

Shaded bus and signal areas are undefined, so the bus or signal can assume any value within the shaded area at that time. The actual level is unimportant and does not affect normal operation.

**Figure 1-1: Key to timing diagram conventions**



## Signals

The signal conventions are:

### Signal level

The level of an asserted signal depends on whether the signal is active-HIGH or active-LOW. Asserted means:

- HIGH for active-HIGH signals.
- LOW for active-LOW signals.

### Lowercase n

At the start or end of a signal name, n denotes an active-LOW signal.

## Register descriptions

### Reset definitions

#### Replication Operator {}

Verilog replication operators are used for reset values over 8-bits.

For example, {16{1'b0}} indicated a binary value of 16 zeros.

**x**

Resets that are unknown are indicated with x.

## 1.4 Useful resources

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

Access to Arm documents depends on their confidentiality:



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

Arm product resources	Document ID	Confidentiality
<a href="#">Arm® Cortex-A720 Core Configuration and Integration Manual</a>	102531	Confidential
<a href="#">Arm® Cortex-A720 Core Technical Reference Manual</a>	102530	Non-Confidential
<a href="#">Arm® DynamIQ™ Shared Unit-120 Technical Reference Manual</a>	102547	Non-Confidential
<a href="#">Arm® DynamIQ™ Shared Unit-120 Configuration and Integration Manual</a>	102548	Confidential

Arm architecture and specifications	Document ID	Confidentiality
<a href="#">Arm® Architecture Reference Manual for A-profile architecture</a>	DDI 0487	Non-Confidential
<a href="#">Arm® Architecture Reference Manual Supplement, Memory System Resource Partitioning and Monitoring (MPAM), for A-profile architecture</a>	DDI 0598	Non-Confidential
<a href="#">Arm® Architecture Reference Manual Supplement, The Scalable Vector Extension</a>	DDI 0584	Non-Confidential
<a href="#">AMBA® 5 CHI Architecture Specification</a>	IHI 0050	Non-Confidential
<a href="#">Arm® Generic Interrupt Controller Architecture Specification, GIC architecture version 3 and version 4</a>	IHI 0069	Non-Confidential
<a href="#">Arm® CoreSight™ Architecture Specification v3.0</a>	IHI 0029	Non-Confidential
<a href="#">Arm® CoreSight™ ELA-600 Embedded Logic Analyzer Technical Reference Manual</a>	101088	Non-Confidential



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## 2. Cryptographic Extension support in the Cortex-A720 core

The Cortex-A720 core supports the optional Arm® Cryptographic Extension.

The Arm® Cryptographic Extension adds A64 instructions to Advanced SIMD to:

- Accelerate *Advanced Encryption Standard* (AES) encryption and decryption
- Implement the *Secure Hash Algorithm* (SHA) functions
- Perform *Polynomial Multiply Long* (PMULL) instructions

### Supported features

The Arm® Cryptographic Extension supports the following features:

**Table 2-1: Features supported by the Arm® Cryptographic Extension**

Feature	Description	Architecture version
FEAT_AES	Advanced SIMD AES instructions	Arm®v8.0
FEAT_PMULL	Advanced SIMD PMULL instructions	
FEAT_SHA1	Advanced SIMD SHA1 instructions	
FEAT_SHA256	Advanced SIMD SHA256 instructions	
FEAT_SHA512	Advanced SIMD SHA512 instructions	Arm®v8.2
FEAT_SHA3	Advanced SIMD EOR3, RAX1, XAR, and BCAX instructions	
FEAT_SM3	Advanced SIMD SM3 instructions	
FEAT_SM4	Advanced SIMD SM4 instructions	
FEAT_SVE_AES	SVE AES instructions	Arm®v9.0
FEAT_SVE_PMULL128	SVE PMULL instructions	
FEAT_SVE_SHA3	SVE SHA3 instructions	
FEAT_SVE_SM4	SVE SM4 instructions	

### 2.1 Disabling the Cryptographic Extension

Disabling the Cryptographic Extension applies to all Cortex-A720 cores in a cluster.

To disable the Cryptographic Extension, assert the CRYPTODISABLE signal.

When the CRYPTODISABLE signal is asserted:

- Executing a cryptographic instruction results in an **UNDEFINED** exception.
- ID\_AA64ISAR0\_EL1 and ID\_AA64ZFR0\_EL1 indicate that the Cryptographic Extension is not implemented.

## Related information

[3.2 ID\\_AA64ISAR0\\_EL1, AArch64 Instruction Set Attribute Register 0](#) on page 12

[3.3 ID\\_AA64ZFR0\\_EL1, SVE Feature ID register 0](#) on page 16

## 2.2 Product revisions

The product revision increments at each release.

The following table indicates the main differences in functionality between product revisions.

**Table 2-2: Product revisions**

Revision	Notes
r0p0	First release
r0p1	Added support for FEAT_ECBHB, Exploitative Control using Branch History buffer information between exception levels.

Changes in functionality that have an impact on the documentation also appear in [A.1 Revisions](#) on page 19.

## 3. AArch64 instruction identification system registers

This chapter describes the ID\_AA64ISAR0\_EL1 and ID\_AA64ZFR0\_EL1 registers. These identification registers provide information about the instructions implemented in the Cortex-A720 core, including the instructions provided by the Cryptographic Extension.

### 3.1 Cryptographic Extensions register summary

Software can identify the cryptographic instructions that are implemented in the Cortex-A720 core by reading the identification registers.

The following table shows the identification registers for the Cortex-A720 core Cryptographic Extension.

**Table 3-1: Cryptographic Extension register summary**

Name	Description
ID_AA64ISAR0_EL1	See 3.2 ID_AA64ISAR0_EL1, AArch64 Instruction Set Attribute Register 0 on page 12
ID_AA64ZFR0_EL1	See 3.3 ID_AA64ZFR0_EL1, SVE Feature ID register 0 on page 16

### 3.2 ID\_AA64ISAR0\_EL1, AArch64 Instruction Set Attribute Register 0

Provides information about the instructions implemented in AArch64 state.

For general information about the interpretation of the ID registers, see *Principles of the ID scheme for fields in ID registers* in the [Arm® Architecture Reference Manual for A-profile architecture](#).

#### Configurations

This register is available in all configurations.

#### Attributes

##### Width

64

##### Functional group

Identification registers

##### Access type

See bit descriptions

## Reset value

0000	0010	0010	0001	0001	xxxx	xxxx	xxxx	0001	0000	0010	0001	xxxx	xxxx	xxxx	xxxx
63	59	55	51	47	43	39	35	31	27	23	19	15	11	7	3
															0



Where the reset reads xxxx, see individual bits.

## Bit descriptions

Figure 3-1: AArch64\_id\_aa64isar0\_el1 bit assignments

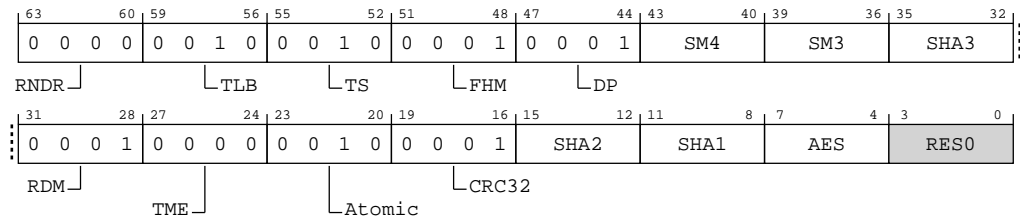


Table 3-2: ID\_AA64ISAR0\_EL1 bit descriptions

Bits	Name	Description	Reset
[63:60]	RNDR	Indicates support for Random Number instructions in AArch64 state.  When FEAT_RNG_TRAP is implemented, the value returned by a direct read of ID_AA64ISAR0_EL1.RNDR is further controlled by the value of AArch64-SCR_EL3.TRNDR.  Defined values are: <b>0b0000</b> No Random Number instructions are implemented.	0b0000
[59:56]	TLB	Indicates support for Outer Shareable and TLB range maintenance instructions. Defined values are: <b>0b0010</b> Outer Shareable and TLB range maintenance instructions are implemented.	0b0010
[55:52]	TS	Indicates support for flag manipulation instructions. Defined values are: <b>0b0010</b> CFINV, RMIF, SETF16, SETF8, AXFLAG, and XAFLAG instructions are implemented.	0b0010
[51:48]	FHM	Indicates support for FMLAL and FMLSL instructions. Defined values are: <b>0b0001</b> FMLAL and FMLSL instructions are implemented.	0b0001

Bits	Name	Description	Reset
[47:44]	DP	Indicates support for Dot Product instructions in AArch64 state. Defined values are:  <b>0b0001</b> UDOT and SDOT instructions implemented.	0b0001
[43:40]	SM4	Indicates support for SM4 instructions in AArch64 state. Defined values are:  <b>0b0000</b> No SM4 instructions implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0001</b> SM4E and SM4EKEY instructions implemented. This value is reported when the Cryptographic Extension is implemented and enabled.  When the CRYPTO configuration parameter is true and the CRYPTODISABLE input is low at reset the Cryptographic Extension is implemented	The reset values can be the following: 0b0000, 0b0001, respective to the value.
[39:36]	SM3	Indicates support for SM3 instructions in AArch64 state. Defined values are:  <b>0b0000</b> No SM3 instructions implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0001</b> SM3SS1, SM3TT1A, SM3TT1B, SM3TT2A, SM3TT2B, SM3PARTW1, and SM3PARTW2 instructions implemented. This value is reported when the Cryptographic Extension is implemented and enabled.  When the CRYPTO configuration parameter is true and the CRYPTODISABLE input is low at reset the Cryptographic Extension is implemented	The reset values can be the following: 0b0000, 0b0001, respective to the value.
[35:32]	SHA3	Indicates support for SHA3 instructions in AArch64 state. Defined values are:  <b>0b0000</b> No SHA3 instructions implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0001</b> EOR3, RAX1, XAR, and BCAX instructions implemented. This value is reported when the Cryptographic Extension is implemented and enabled.  When the CRYPTO configuration parameter is true and the CRYPTODISABLE input is low at reset the Cryptographic Extension is implemented	The reset values can be the following: 0b0000, 0b0001, respective to the value.
[31:28]	RDM	Indicates support for SQRDMLAH and SQRDMLSH instructions in AArch64 state. Defined values are:  <b>0b0001</b> SQRDMLAH and SQRDMLSH instructions implemented.	0b0001
[27:24]	TME	Indicates support for TME instructions. Defined values are:  <b>0b0000</b> TME instructions are not implemented.	0b0000
[23:20]	Atomic	Indicates support for Atomic instructions in AArch64 state. Defined values are:  <b>0b0010</b> LDADD, LDCLR, LDEOR, LDSET, LDSMAX, LDSMIN, LDUMAX, LDUMIN, CAS, CASP, and SWP instructions implemented.	0b0010

Bits	Name	Description	Reset
[19:16]	CRC32	Indicates support for CRC32 instructions in AArch64 state. Defined values are:  <b>0b0001</b> CRC32B, CRC32H, CRC32W, CRC32X, CRC32CB, CRC32CH, CRC32CW, and CRC32CX instructions implemented.	0b0001
[15:12]	SHA2	Indicates support for SHA2 instructions in AArch64 state. Defined values are:  <b>0b0000</b> No SHA2 instructions implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0010</b> SHA256H, SHA256H2, SHA256SU0, SHA256SU1, SHA512H, SHA512H2, SHA512SU0, and SHA512SU1 instructions implemented. This value is reported when the Cryptographic Extension is implemented and enabled.  When the CRYPTO configuration parameter is true and the CRYPTODISABLE input is low at reset the Cryptographic Extension is implemented	The reset values can be the following: 0b0000, 0b0010, respective to the value.
[11:8]	SHA1	Indicates support for SHA1 instructions in AArch64 state. Defined values are:  <b>0b0000</b> No SHA1 instructions implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0001</b> SHA1C, SHA1P, SHA1M, SHA1H, SHA1SU0, and SHA1SU1 instructions implemented. This value is reported when the Cryptographic Extension is implemented and enabled.  When the CRYPTO configuration parameter is true and the CRYPTODISABLE input is low at reset the Cryptographic Extension is implemented	The reset values can be the following: 0b0000, 0b0001, respective to the value.
[7:4]	AES	Indicates support for AES instructions in AArch64 state. Defined values are:  <b>0b0000</b> No AES instructions implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0010</b> AESE, AESD, AESMC, and AESIMC instructions are implemented plus PMULL/PMULL2 instructions operating on 64-bit data quantities. This value is reported when the Cryptographic Extension is implemented and enabled.  When the CRYPTO configuration parameter is true and the CRYPTODISABLE input is low at reset the Cryptographic Extension is implemented	The reset values can be the following: 0b0000, 0b0010, respective to the value.
[3:0]	RES0	Reserved	RES0

## Access

MRS <Xt>, ID\_AA64ISAR0\_EL1

op0	op1	CRn	CRm	op2
0b11	0b000	0b0000	0b0110	0b000

## Accessibility

MRS <Xt>, ID\_AA64ISAR0\_EL1

```
if PSTATE.EL == EL0 then
    if EL2Enabled() && HCR_EL2.TGE == '1' then
        AArch64.SystemAccessTrap(EL2, 0x18);
    else
        AArch64.SystemAccessTrap(EL1, 0x18);
elseif PSTATE.EL == EL1 then
    if EL2Enabled() && HCR_EL2.TID3 == '1' then
        AArch64.SystemAccessTrap(EL2, 0x18);
    else
        return ID_AA64ISAR0_EL1;
elseif PSTATE.EL == EL2 then
    return ID_AA64ISAR0_EL1;
elseif PSTATE.EL == EL3 then
    return ID_AA64ISAR0_EL1;
```

## 3.3 ID\_AA64ZFR0\_EL1, SVE Feature ID register 0

Provides additional information about the implemented features of the AArch64 Scalable Vector Extension, when the AArch64-ID\_AA64PFR0\_EL1.SVE field is not zero.

For general information about the interpretation of the ID registers see *Principles of the ID scheme for fields in ID registers* in the [Arm® Architecture Reference Manual for A-profile architecture](#).

### Configurations



Prior to the introduction of the features described by this register, this register was unnamed and reserved, RES0 from EL1, EL2, and EL3.

### Attributes

#### Width

64

#### Functional group

Identification registers

#### Access type

See bit descriptions

#### Reset value

xxxx	xxxx	xxxx	xxxx	0001	xxxx	xxxx	xxxx	xxxx	xxxx	0001	0001	xxxx	xxxx	xxxx	0001
63	59	55	51	47	43	39	35	31	27	23	19	15	11	7	3 0





Where the reset reads xxxx, see individual bits.

## Bit descriptions

Figure 3-2: AArch64\_id\_aa64zfr0\_el1 bit assignments

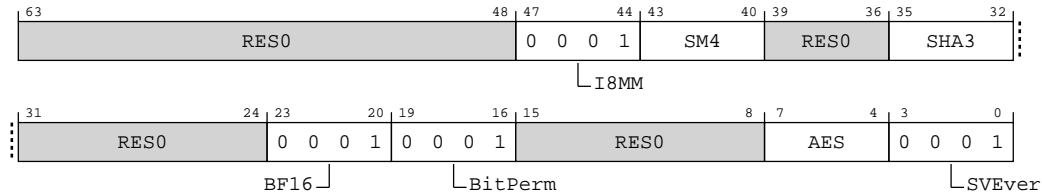


Table 3-4: ID\_AA64ZFR0\_EL1 bit descriptions

Bits	Name	Description	Reset
[63:48]	RES0	Reserved	RES0
[47:44]	I8MM	Indicates support for SVE Int8 matrix multiplication instructions. Defined values are:  <b>0b0001</b> SMMLA, SUDOT, UMMLA, USMMLA, and USDOT instructions are implemented.	0b0001
[43:40]	SM4	Indicates support for SVE SM4 instructions. Defined values are:  <b>0b0000</b> SVE2 SM4 instructions are not implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0001</b> SVE2 SM4E and SM4EKEY instructions are implemented. This value is reported when the Cryptographic Extension is implemented and enabled.	The reset values can be the following: 0b0000, 0b0001, respective to the value.
[39:36]	RES0	Reserved	RES0
[35:32]	SHA3	Indicates support for the SVE SHA3 instructions. Defined values are:  <b>0b0000</b> SVE2 SHA3 instructions are not implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0001</b> SVE2 RAX1 instruction is implemented. This value is reported when the Cryptographic Extension is implemented and enabled.	The reset values can be the following: 0b0000, 0b0001, respective to the value.
[31:24]	RES0	Reserved	RES0
[23:20]	BF16	Indicates support for SVE BFloat16 instructions. Defined values are:  <b>0b0001</b> BFCVT, BFCVTNT, BFDOT, BFMLALB, BFMLALT, and BFMMMLA instructions are implemented.	0b0001

Bits	Name	Description	Reset
[19:16]	BitPerm	Indicates support for SVE bit permute instructions. Defined values are:  <b>0b0001</b> SVE BDEP, BEXT, and BGRP instructions are implemented.	0b0001
[15:8]	RES0	Reserved	RES0
[7:4]	AES	Indicates support for SVE AES instructions. Defined values are:  <b>0b0000</b> SVE2-AES instructions are not implemented. This value is reported when the Cryptographic Extension is not implemented or is disabled.  <b>0b0010</b> SVE2 AESE, AESD, AESMC, and AESIMC instructions are implemented plus SVE2 PMULLB and PMULLT instructions with 64-bit source. This value is reported when the Cryptographic Extension is implemented and enabled.	The reset values can be the following: 0b0000, 0b0010, respective to the value.
[3:0]	SVEver	Indicates support for SVE. Defined values are:  <b>0b0001</b> The SVE and non-optional SVE2 instructions are implemented.	0b0001

## Access

MRS <Xt>, ID\_AA64ZFR0\_EL1

op0	op1	CRn	CRm	op2
0b11	0b000	0b0000	0b0100	0b100

## Accessibility

MRS <Xt>, ID\_AA64ZFR0\_EL1

```

if PSTATE.EL == EL0 then
    if EL2Enabled() && HCR_EL2.TGE == '1' then
        AArch64.SystemAccessTrap(EL2, 0x18);
    else
        AArch64.SystemAccessTrap(EL1, 0x18);
elseif PSTATE.EL == EL1 then
    if EL2Enabled() && HCR_EL2.TID3 == '1' then
        AArch64.SystemAccessTrap(EL2, 0x18);
    else
        return ID_AA64ZFR0_EL1;
elseif PSTATE.EL == EL2 then
    return ID_AA64ZFR0_EL1;
elseif PSTATE.EL == EL3 then
    return ID_AA64ZFR0_EL1;

```

# Appendix A Document revisions

This appendix records the changes between released issues of this document.

## A.1 Revisions

Changes between released issues of this book are summarized in tables.

The first table is for the first release. Then, each table compares the new issue of the book with the last released issue of the book. Release numbers match the revision history in [Release Information](#) on page 2.

**Table A-1: Issue 0000-01**

Change	Location
First Confidential beta release for r0p0	-

**Table A-2: Differences between issue 0000-01 and issue 0000-02**

Change	Location
First Confidential limited access release for r0p0	-
Editorial changes	Throughout document
Removed information about long polynomials from PMULL description	<a href="#">2. Cryptographic Extension support in the Cortex-A720 core</a> on page 10
Additional information about how to implement the Cryptographic Extension was added to SM3, SM4, and SHA3 bit descriptions	<a href="#">3.2 ID_AA64ISAR0_EL1, AArch64 Instruction Set Attribute Register 0</a> on page 12
Updated reset values for register	<a href="#">3.2 ID_AA64ISAR0_EL1, AArch64 Instruction Set Attribute Register 0</a> on page 12
Updated reset value for register	<a href="#">3.3 ID_AA64ZFR0_EL1, SVE Feature ID register 0</a> on page 16

**Table A-3: Differences between Issue 0000-02 and 0001-03**

Change	Location
First draft release for r0p1	-
Editorial changes	Throughout document
Updated reset values for register	<a href="#">3.2 ID_AA64ISAR0_EL1, AArch64 Instruction Set Attribute Register 0</a> on page 12
Updated reset value for register	<a href="#">3.3 ID_AA64ZFR0_EL1, SVE Feature ID register 0</a> on page 16

**Table A-4: Differences between Issue 0001-03 and Issue 0001-04**

Change	Location
Second early access release for r0p1	-
Editorial changes	Throughout document