



Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library

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FIPS 140-3 Non-Proprietary Security Policy

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1 Table of Contents

1 GENERAL	4
1.1 THIS SECURITY POLICY DOCUMENT.....	4
1.2 HOW THIS SECURITY POLICY WAS PREPARED.....	4
2 CRYPTOGRAPHIC MODULE SPECIFICATION	6
2.1 MODULE DESCRIPTION.....	6
2.2 MODULE DETAILS.....	6
2.3 TESTED OPERATIONAL ENVIRONMENTS.....	7
2.4 SECURITY FUNCTIONS.....	7
2.5 DESCRIPTION OF MODES OF OPERATION.....	11
2.6 CRYPTOGRAPHIC MODULE BOUNDARY.....	11
2.7 RULES OF OPERATION.....	13
3 CRYPTOGRAPHIC MODULE PORTS AND INTERFACES	14
4 ROLES, SERVICES, AND AUTHENTICATION	15
4.1 ROLES.....	15
4.2 AUTHENTICATION.....	15
4.3 SERVICES.....	16
4.3.1 <i>Approved Services</i>	16
4.3.2 <i>Non-approved Services</i>	18
5 SOFTWARE/FIRMWARE SECURITY	20
5.1 INTEGRITY TECHNIQUES.....	20
5.2 ON-DEMAND INTEGRITY TEST.....	20
5.3 EXECUTABLE CODE.....	20
6 OPERATIONAL ENVIRONMENT	21
6.1 APPLICABILITY.....	21
6.2 TESTED OPERATIONAL ENVIRONMENT.....	21
6.3 SPECIFICATIONS FOR THE OPERATIONAL ENVIRONMENT.....	21
7 PHYSICAL SECURITY	22
8 NON-INVASIVE SECURITY	23
9 SENSITIVE SECURITY PARAMETER MANAGEMENT	24
9.1 SSP ESTABLISHMENT/SSP DERIVATION.....	25
9.2 SSP GENERATION.....	25
9.3 SSP ENTRY AND OUTPUT.....	26
9.4 SSP STORAGE.....	26
9.5 SSP ZEROIZATION.....	26
10 SELF-TESTS	27
10.1 PRE-OPERATIONAL SELF-TESTS.....	28
10.1.1 <i>Software Integrity Test</i>	28
10.2 CONDITIONAL SELF-TESTS.....	28
10.2.1 <i>Cryptographic Algorithm Self-Tests</i>	28
10.2.2 <i>Pair-wise Consistency Tests</i>	28
10.2.3 <i>Periodic/On-Demand Self-Tests</i>	28
10.3 ERROR STATES.....	28

11 LIFE-CYCLE ASSURANCE.....30
11.1 CONFIGURATION MANAGEMENT..... 30
11.2 DELIVERY AND OPERATION..... 30
11.3 MAINTENANCE REQUIREMENTS..... 30
11.4 END OF LIFE..... 30
11.5 CRYPTO OFFICER GUIDANCE..... 30
12 MITIGATION OF OTHER ATTACKS.....32
APPENDIX A. GLOSSARY AND ABBREVIATIONS.....33
APPENDIX A. GLOSSARY AND ABBREVIATIONS.....33
APPENDIX B. REFERENCES.....34
APPENDIX B. REFERENCES.....34

1 General

1.1 This Security Policy Document

This Security Policy describes the features and design of the module named Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library using the terminology contained in the FIPS 140-3 specification. The FIPS 140-3 Security Requirements for Cryptographic Module specifies the security requirements that will be satisfied by a cryptographic module utilized within a security system protecting sensitive but unclassified information. The NIST/CCCS Cryptographic Module Validation Program (CMVP) validates cryptographic module to FIPS 140-3. Validated products are accepted by the Federal agencies of both the USA and Canada for the protection of sensitive or designated information.

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1.2 How this Security Policy was Prepared

In preparing the Security Policy document, the laboratory formatted the vendor-supplied documentation for consolidation without altering the technical statements therein contained. The further refining of the Security Policy document was conducted iteratively throughout the conformance testing, wherein the Security Policy was submitted to the vendor, who would then edit, modify, and add technical contents. The vendor would also supply additional documentation, which the laboratory formatted into the existing Security Policy, and resubmitted to the vendor for their final editing.

This document is the non-proprietary FIPS 140-3 Security Policy for the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library. It has a one-to-one mapping to the [SP800-140B] starting with section B.2.1 named “General” that maps to section 1 in this document and ending with section B.2.12 named “Mitigation of other attacks” that maps to section 12 in this document.

ISO/IEC 24759 Section 6. [Number Below]	FIPS 140-3 Section Title	Security Level
1	General	1
2	Cryptographic Module Specification	1
3	Cryptographic Module Interfaces	1
4	Roles, Services, and Authentication	1
5	Software/Firmware Security	1
6	Operational Environment	N/A
7	Physical Security	2
8	Non-invasive Security	N/A
9	Sensitive Security Parameter Management	1
10	Self-tests	1

11	Life-cycle Assurance	2
12	Mitigation of Other Attacks	1

Table 1 - Security Levels

2 Cryptographic Module Specification

2.1 Module Description

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is used by secure applications. It is part of the common library and provides APIs to the secure applications for cryptography and hashing functions.

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is determined to be a FIPS 140-3 validated module by blowing the TZ_SW_CRYPTO_FIPS_ENABLE fuse and by determining the version number based on its HMAC value combined with the register value of fuse. The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library uses the ARMv8 instruction set architecture for hash operations for SHA-1, SHA-224 and SHA-256.

2.2 Module Details

The software-hybrid cryptographic module consists of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library, the ARMv8 processor and FIPS enablement fuse. The cryptographic functions are implemented within the library. The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is bound to the on-chip Pseudo Random Number Generator module with version 3.0.0 validated under FIPS 140-3 certificate #4732. The bound module resides within the same physical perimeter of the binding module.

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library cryptographic module (hereafter referred to as “the module”) is a Software-Hybrid Single-Chip cryptographic module.

Component	Type	Version Number	Operating System
Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library	Software	bb1535e33256786b753f8632877c9f4e11e267deaa65234d8f3703943d6a6888	Qualcomm Trusted Execution Environment (TEE) TZ.XF.5.1x
ARMv8 processor ¹	Hardware	bb1535e33256786b753f8632877c9f4e11e267deaa65234d8f3703943d6a6888	N/A
TZ_SW_CRYPTO_FIPS_ENABLE fuse			

Table 2 - Components of the Software-hybrid Cryptographic Module

Table 3 describes the software component versions that comprise the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library while Table 4 describes the fuse setting that enables the FIPS validated module. The FIPS validated Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library comprises a combination of the software component versions and fuse setting combined together.

Software Component	HMAC hash value
Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library (64 bit)	bb1535e33256786b753f8632877c9f4e11e267deaa65234d8f3703943d6a6888

¹ The ARMv8.5-a is the instruction set version used within the Snapdragon 8 Gen 1 Mobile Platform. Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

Table 3 - Software component versions for Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library

Fuse name	1-bit fuse value	Description
TZ_SW_CRYPTOFIPS_ENABLE	1	Enable FIPS compliance for Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library. Disabled by default and blow to enable.

Table 4 - Fuse setting

2.3 Tested Operational Environments

The module has been tested on the operational environments indicated in Table 5 with the corresponding module variants and configuration options.

#	Operating System	Hardware Platform	Processor	PAA/Acceleration
1	Qualcomm Trusted Execution Environment (TEE) TZ.XF.5.1x	Snapdragon 8 Gen 1 Mobile Platform	Snapdragon 8 Gen 1 Mobile Platform	ARMv8 instruction set architecture (SHA-1, SHA-224 and SHA-256)

Table 5 - Tested operational environments

2.4 Security Functions

Table 6 lists all approved security functions (cryptographic algorithms) of the module, including specific key lengths employed for approved services, and implemented modes or methods of operation of the algorithms.

CAVP Cert	Algorithm and Standard	Mode / Method	Description / Key Size(s) / Key Strength(s)	Use / Function
#A2300	AES FIPS 197, SP800-38A	CBC, ECB, CTR, CFB128, OFB	128, 192, 256 bits	Encryption, Decryption
#A2300	AES FIPS 197, SP800-38E	XTS	128, 256 bits	Encryption, Decryption
#A2300	AES FIPS 197, SP800-38C	CCM	128, 192, 256 bits	Encryption, Decryption
#A2300	AES SP800-38A Addendum	CBC-CS2	128, 192, 256 bits	Encryption, Decryption

CAVP Cert	Algorithm and Standard	Mode / Method	Description / Key Size(s) / Key Strength(s)	Use / Function
#A2300	SHA-1 (ARMv8) FIPS 180-4	N/A	N/A	Hash
#A2300	SHA-224 (ARMv8) FIPS 180-4	N/A	N/A	Hash
#A2300	SHA-256 (ARMv8) FIPS 180-4	N/A	N/A	Hash
#A2300	SHA-384 (software) FIPS 180-4	N/A	N/A	Hash
#A2300	SHA-512 (software) FIPS 180-4	N/A	N/A	Hash
#A2300	HMAC FIPS 198-1	SHA-1, SHA-224, SHA-256, SHA-384, SHA-512	Key sizes are between 112-4096 bits in length 112-256 bits of key strength	Message Authentica- tion
#A2300	ECDSA Key Pair Generation FIPS 186-4	B.4.2 (Testing Can- didates)	112 - 256 bits of security strength P-224, P-256, P-384, P- 521	Key Pair Genera- tion
#A2300	ECDSA Signature Generation FIPS 186-4	SHA-224, SHA-256, SHA-384, SHA-512	112 - 256 bits of security strength P-224, P-256, P-384, P- 521	Signature Genera- tion
#A2300	ECDSA Signature Verification FIPS 186-4	SHA-1, SHA-224, SHA-256, SHA-384, SHA-512	96 - 256 bits of security strength P-192, P-224, P-256, P- 384, P-521 (ECDSA SigVer with P- 192 is a legacy algo- rithm)	Signature Verifica- tion

CAVP Cert	Algorithm and Standard	Mode / Method	Description / Key Size(s) / Key Strength(s)	Use / Function
#A2300	ECDSA Signature Generation - Component (CVL) FIPS 186-4	N/A	112 - 256 bits of security strength P-224, P-256, P-384, P-521	Signature Generation - Component or Primitive
#A2300	RSA Key Pair Generation FIPS 186-4	B.3.3 (Probable Prime Generation)	2048, 3072, 4096 bit modulus 112 - 150 bits of security strength	Key Pair Generation
#A2300	RSA Signature Generation (PKCS#1 v1.5) FIPS 186-4	SHA-224, SHA-256, SHA-384- SHA-512	2048, 3072, 4096 bit modulus 112 - 150 bits of security strength	Signature Generation
#A2300	RSA Signature Verification (PKCS#1 v1.5) FIPS 186-4	SHA-1, SHA-224, SHA-256, SHA-384, SHA-512	1024, 2048, 3072, 4096 bit modulus 80 - 150 bits of security strength (RSA SigVer with a modulus length of 1024 is a legacy algorithm)	Signature Verification
#A2300	RSA Signature Generation (PSS) FIPS 186-4	SHA-224, SHA-256, SHA-384, SHA-512	2048, 3072, 4096 bit modulus 112 - 150 bits of security strength	Signature Generation
#A2300	RSA Signature Verification (PSS) FIPS 186-4	SHA-1, SHA-224, SHA-256, SHA-384, SHA-512	1024, 2048, 3072, 4096 bit modulus 80 - 150 bits of security strength (RSA SigVer with a modulus length of 1024 is a legacy algorithm)	Signature Verification
#A2300	RSA Signature Generation - Primitive (CVL) FIPS 186-4	N/A	2048 bit modulus 112 bits of security strength	Signature Generation - Component or Primitive
#A2300	PBKDF SP800-132	SHA-1, SHA-256, SHA-512	128-256 bits	Key Derivation

CAVP Cert	Algorithm and Standard	Mode / Method	Description / Key Size(s) / Key Strength(s)	Use / Function
Vendor Affirmed	CKG SP800-133rev2 (section 4, direct DRBG output without XOR)	RSA ECDSA	2048, 3072, 4096 bit modulus P-224, P-256, P-384, P-521 112 - 256 bits of security strength	Key Generation
Pseudo Random Number Generator bound module				
#A2064 and #A2065	SHA-256 FIPS 180-4	N/A	N/A	Hash for DRBG
#A2065	Hash DRBG SP800-90Arev1	SHA-256	256 bits of entropy	Random Number Generation

Table 6 - Approved Algorithms

Table 7 lists all non-approved security functions not allowed in approved services of the module.

Algorithm/Functions	Use/Function
DES	Encryption, Decryption
Triple DES ²	Encryption, Decryption
GCM/GMAC ³	Encryption, Decryption, Message Authentication
HMAC (key sizes below 112 bits)	Message Authentication
RIPEMD-160	Hash
MD5	Hash
SM2	Signature Generation, Signature Verification, Hybrid Encryption, Hybrid Decryption
SM3	Hash
SM4	Encryption, Decryption
SHA-1, SHA-224 and SHA-256 (software)	Hash
ECDSA (secp160r1, P-192)	Key Pair Generation, Signature Generation

² Triple DES is CAVP certified with CAVP Cert. #A2300. However, there are two requirements from FIPS 140-3 IG C.G below that contribute to the non-compliance: 1) FIPS 140-3 requires that only 2^{16} encryptions are performed with a given key; 2) the aforementioned requirement must be enforced by the module itself, not by policy.

³ GCM is CAVP certified with CAVP Cert. #A2300. However, there are two requirements from FIPS 140-3 IG C.H below that contribute to the non-compliance: 1) the IV uniqueness must be enforced by the module; 2) FIPS 140-3 requires that only 2^{32} cipher operations are performed with a given key.

ECDSA (secp160r1)	Signature Verification
ECDSA (P-192, P-224, P-256, P-384 and P-521)	Signature Verification - Component
Elliptic Curve Integrated Encryption Scheme (ECIES)	Hybrid Encryption, Hybrid Decryption
RSA-OAEP	Key Encapsulation
RSA (1024 bit modulus)	Key Pair Generation, Signature Generation
Ed25519	Key Pair Generation, Signature Generation, Signature Verification
ECDH ⁴	Shared Secret Computation

Table 7 - Non-Approved Algorithms Not Allowed in Approved Services

NOTE: There are no non-approved algorithms allowed in approved mode, and no non-approved algorithms allowed in the approved mode with no security claimed.

2.5 Description of Modes of Operation

The module implements two modes of operation: (1) the approved mode, in which the approved services are available; and (2) the non-approved mode, in which the non-approved services are available. The current mode of operation of the module can be inferred by the service indicator, which indicates the approved state of the current service being invoked. No configuration is necessary for the module to operate and remain in the approved or non-approved modes. All SSPs are kept separate between the two modes. To transition to the non-approved mode, one of the non-approved services in section 4 of this security policy can be requested. To transition to the approved mode, one of the approved services in section 4 of this security policy can be requested.

Table 10 and 11 list the services available in approved and non-approved mode of operation, respectively.

2.6 Cryptographic Module Boundary

The physical perimeter of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is the physical perimeter of the device that contains it. Consequently, the embodiment of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is a single-chip cryptographic module. Figure 1 shows a block diagram of the module, with the cryptographic boundary indicated in red, the bound module in the dark green box, and the physical perimeter in black.

⁴ ECDH shared secret computation is CAVP certified with Cert #A2300. However, the shared secret generation does not check the key assurance requirements from SP800-56A Rev 3 regarding trusted third parties during key import. There is a self-test for ECDH but is not listed since it is non-approved.

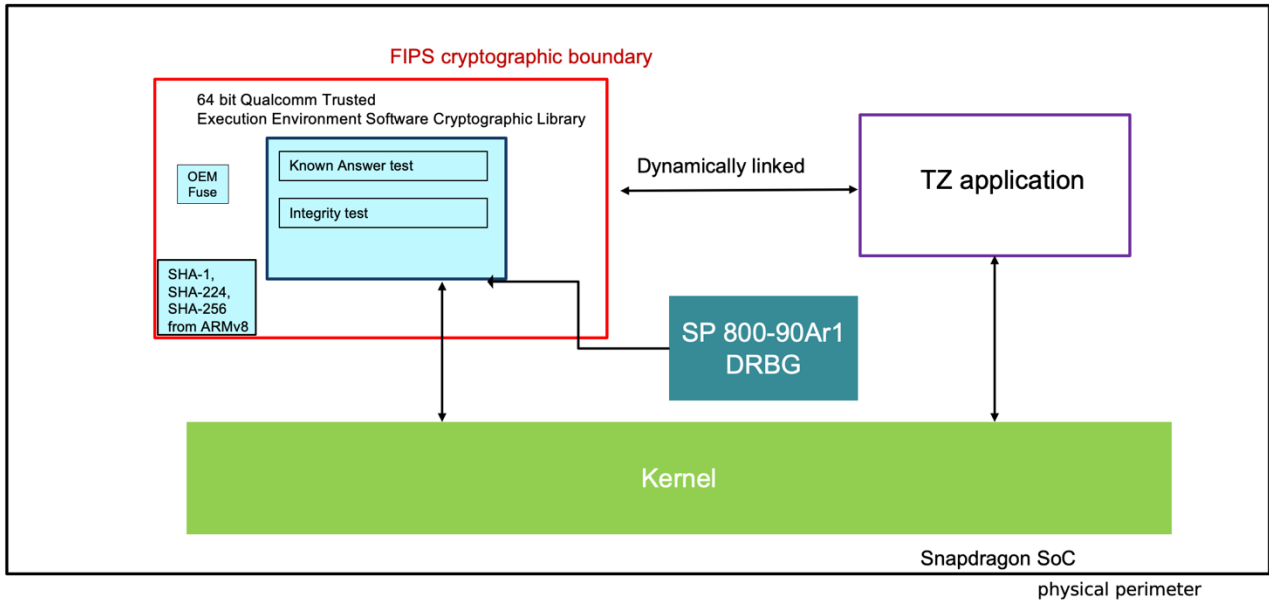


Figure 1: Block diagram depicting the cryptographic boundary and physical perimeter, and data flow between the components in the Snapdragon SoC

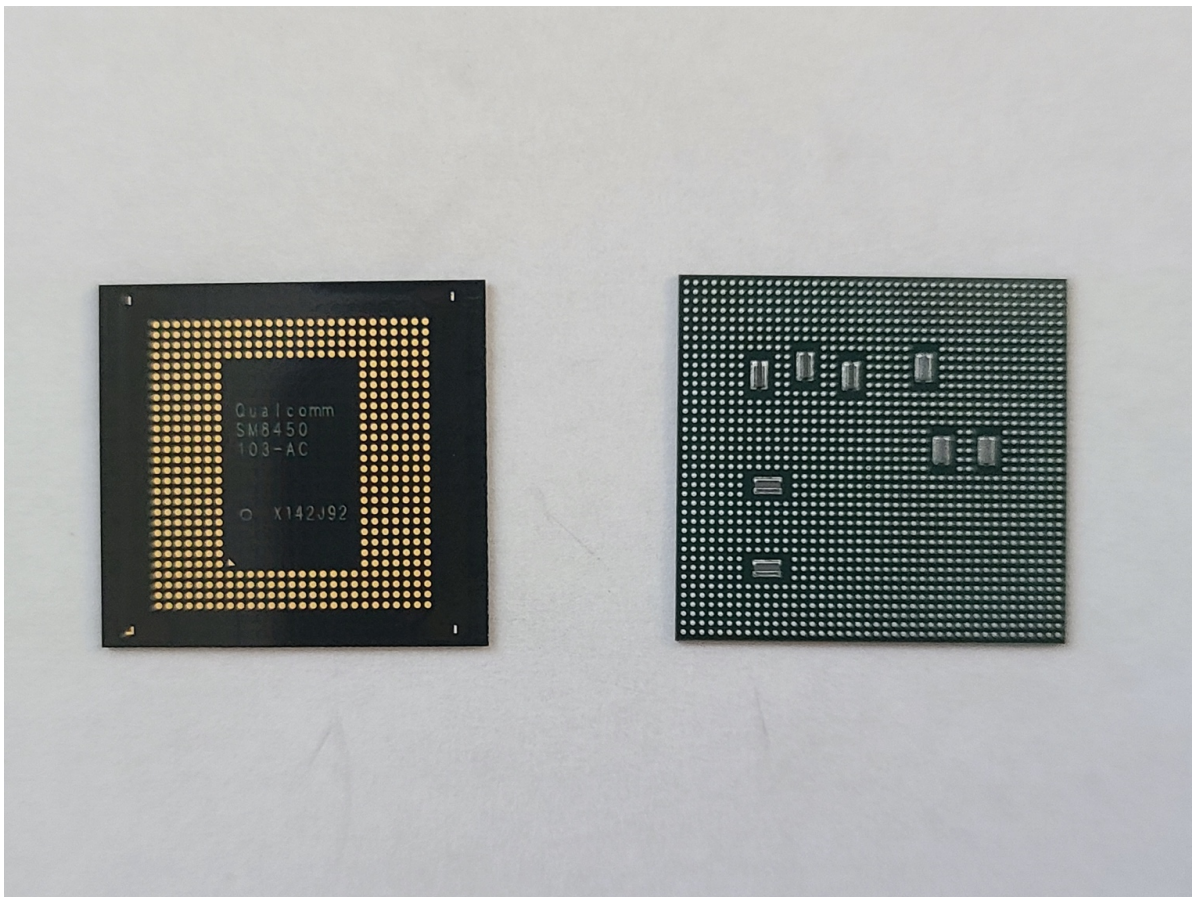


Figure 2: Snapdragon 8 Gen 1 Mobile Platform

2.7 Rules of Operation

The Crypto Officer interacts with the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library in two distinct ways:

1. Initializing the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library
2. The application services (APIs) invoked by users

Once Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library initializes and the self-tests complete successfully, all cryptographic functions are made available. If its integrity test or KATs fail, the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library goes into error state. To recover from a failure, the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library will need to be re-initialized. When the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is in the error state, the data output is inhibited. The only way to recover from an integrity test failure is to reset the module.

Caller-induced or internal errors do not reveal any sensitive material to callers. The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library ensures that there is no means to obtain data from itself by performing key zeroization. There is no means to obtain sensitive information from the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library.

3 Cryptographic Module Ports and Interfaces

Physical port	Logical Interface	Data that passes over port/interface
N/A	Data Input	Input parameters for data
	Data Output	Output parameters for data
	Control Input	Function calls, input parameters for control
	Status Output	Return code, status values
Physical power connector	Power Input	Power port or pin for single-chip

Table 8 - Ports and Interfaces

The module does not implement a control output interface.

4 Roles, services, and authentication

4.1 Roles

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library supports the Crypto Officer role. The role is implicitly assumed based on the services requested.

Table 9 lists the roles supported by the module with corresponding services with input and output.

Role	Service	Input	Output
From module			
Crypto Officer	Encryption	Key, Plaintext	Ciphertext, Success/Fail
	Decryption	Key, Ciphertext	Plaintext, Success/Fail
	Hash	Input data	Hash value
	Message Authentication	HMAC key, Input data	HMAC value
	Key Pair Generation	Key size	Key pair (public key + private key)
	Signature Generation	Private key, Input data, Hash algorithm	Signature
	Signature Verification	Public key, Input data, Signature, Hash algorithm	Success/Fail
	Signature Generation - Component or Primitive	Private key, Pre-hashed data	Signature
	Key Derivation	PRF algorithm, Salt, Iteration count, Password	Derived key
	Get FIPS Info	enum value of MODULE_HMAC	Versioning information Self-test Success/Fail
	Show Status	None	Current status (as return codes and/or log messages)
	Zeroization	None	None
	Hybrid Encryption	Key, Plaintext	Ciphertext, Success/Fail
	Hybrid Decryption	Key, Ciphertext	Plaintext, Success/Fail
	Signature Verification - Component	Public key, Input data, Signature, pre-hashed data	Success/Fail
	Key Wrapping	Key wrapping key, key to be wrapped	Wrapped key
Shared Secret Computation	Private key, public key from peer	Shared secret	

Table 9 - Roles, Service Commands, Input and Output

4.2 Authentication

The module does not support authentication for roles.

4.3 Services

The module provides services to operators that assume the available role. Services are accessed through documented API interfaces from the calling application.

Additional services are provided by the bound Pseudo Random Number Generator module on the Snapdragon 8 Gen 1 Mobile Platform SoC. This Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library utilizes the random number generation service from the bound Pseudo Random Number Generator module.

The next tables define the services that utilize approved, allowed, and non-approved security functions in this module. For the respective tables, the convention below applies when specifying the access permissions (types) that the service has for each SSP.

- **G = Generate:** The module generates or derives the SSP.
- **R = Read:** The SSP is read from the module (e.g. the SSP is output).
- **W = Write:** The SSP is updated, imported, or written to the module.
- **E = Execute:** The module uses the SSP in performing a cryptographic operation.
- **Z = Zeroise:** The module zeroises the SSP.
- **N/A:** The service does not access any SSP or key during its operation.

An operator can read the service indicator from a service by invoking the `qsee_get_fips_approval_status()` function with enum value for `QSEE_FIPS_CRYPTO_SVC_TYPE`. For details on the enum values please see the product documentation

4.3.1 Approved Services

Table 10 lists the approved services in this module, the roles that can request the service, the algorithms involved, the Sensitive Security Parameters (SSPs) involved and how they are accessed, and the respective service indicator. In the service tables, CO specifies the Crypto Officer role.

Service	Description	Approved Security Functions	Keys and/or SSPs	Roles	Access rights	Indicator
Encryption	Encrypts data using symmetric cryptography	AES	AES key	CO	W, E	0 return value with enum <code>QSEE_FIPS_AES_*</code>
Decryption	Decrypts data using symmetric cryptography	AES	AES key	CO	W, E	0 return value with enum <code>QSEE_FIPS_AES_*</code>
Hash	Computes the hash value of data	SHA-1 (ARMv8) SHA-224 (ARMv8) SHA-256 (ARMv8) SHA-384 (software) SHA-512 (software)	N/A	CO	N/A	0 return value with enum <code>QSEE_FIPS_SHA*</code>
Message Authentication	Computes the HMAC value of data	HMAC	HMAC key	CO	W, E	0 return value with enum <code>QSEE_FIPS_HMAC*</code>
Key Pair Generation	Generates asymmetric key pairs using the bound module	ECDSA Key Pair Generation	ECDSA private key, ECDSA public key	CO	G, R	0 return value with enum <code>QSEE_FIPS_ECDS</code>

Service	Description	Approved Security Functions	Keys and/or SSPs	Roles	Access rights	Indicator
			Intermediate key generation value		G, E, Z	A_KEY_PAIR_GEN_*
		RSA Key Pair Generation	RSA private key, RSA public key		G, R	0 return value with enum QSEE_FIPS_RSA_KEY_PAIR_GEN_*
			Intermediate key generation value		G, E, Z	
Signature Generation	Generates cryptographic signatures of data	ECDSA Signature Generation	ECDSA private key			0 return value with enum QSEE_FIPS_ECDSA_SIG_GEN_*
		RSA Signature Generation (PKCS#1 v1.5)	RSA private key	CO	W, E	0 return value with enum QSEE_FIPS_RSA_SIG_GEN_*
		RSA Signature Generation (PSS)				
Signature Verification	Verifies cryptographic signatures of data	ECDSA Signature Verification	ECDSA public key			
		RSA Signature Verification (PKCS#1 v1.5)	RSA public key	CO	W, E	0 return value with enum QSEE_FIPS_RSA_SIG_VER_*
		RSA Signature Verification (PSS)				
Signature Generation - Component or Primitive	Generates cryptographic signatures of pre-hashed data	ECDSA Signature Generation - Component	ECDSA private key			
		RSA Signature Generation - Primitive	RSA private key	0 return value with enum QSEE_FIPS_RSA_SIG_GEN_PRIMITIVE_*		
Key Derivation	Derives a secret key	PBKDF	Password	CO	W, E	0 return value with enum QSEE_FIPS_PBKDF_*
			Derived key		G, R	
Miscellaneous						
Show Status	Show the status of the module	None	N/A	CO	N/A	N/A

Service	Description	Approved Security Functions	Keys and/or SSPs	Roles	Access rights	Indicator
Get FIPS Info	Show the versioning information of the module and execute self-tests on demand (pre-operational and CAST)	HMAC	N/A	CO	N/A	N/A
		AES				
		RSA Signature Generation (PKCS#1 v1.5)				
		RSA Signature Verification (PKCS#1 v1.5)				
		ECDSA Signature Generation				
		ECDSA Signature Verification				
		PBKDF				
Zeroization	Zeroizes all SSPs in the module	None	All SSPs	CO	Z	N/A

Table 10 - Approved Services

4.3.2 Non-approved Services

Table 11 lists the non-approved services that utilize the non-approved security functions listed in Table 7.

Service	Description	Algorithms Accessed	Role	Indicator
Encryption	Encrypts data using symmetric cryptography	DES, Triple DES, GCM, SM4	CO	N/A
Decryption	Decrypts data using symmetric cryptography	DES, Triple DES, GCM, SM4	CO	N/A
Hybrid Encryption	Encrypts data using hybrid cryptography	SM2, ECIES	CO	N/A
Hybrid Decryption	Decrypts data using hybrid cryptography	SM2, ECIES	CO	N/A
Hash	Computes the hash value of data	RIPEND-160, MD5, SM3, SHA-1, SHA-224 and SHA-256 (software)	CO	N/A
Message Authentication	Computes the MAC value of data	GMAC, HMAC (key sizes below 112 bits)	CO	N/A
Key Pair Generation	Generates asymmetric key pairs	ECDSA (secp160r1, P-192) RSA (1024-bit modulus) Ed25519	CO	N/A
Signature Generation	Generates cryptographic signatures of data	ECDSA (secp160r1, P-192) RSA (1024-bit modulus) Ed25519, SM2	CO	N/A
Signature Verification	Verifies cryptographic signatures of data	ECDSA (secp160r1) Ed25519, SM2	CO	N/A

Service	Description	Algorithms Accessed	Role	Indicator
Signature Verification - Component	Verifies cryptographic signatures of pre-hashed data	ECDSA	CO	N/A
Key Wrapping	Wraps a key using asymmetric cryptography	RSA OAEP	CO	N/A
Shared Secret Computation	Computes a shared secret	ECDH	CO	N/A

Table 11 - Non-Approved Services

5 Software/Firmware security

5.1 Integrity Techniques

The integrity of the module is verified by comparing a HMAC-SHA-256 value calculated at run time with the HMAC-SHA-256 value stored in the module that was computed at build time.

5.2 On-Demand Integrity Test

The software integrity test is performed as part of the pre-operational self-tests. The software integrity test can also be invoked on-demand by calling the Get FIPS Info service.

5.3 Executable Code

The module consists of code that will perform algorithmic services for trusted applications. The code is compiled into a shared library.

6 Operational Environment

6.1 Applicability

The procurement, build and configuring procedure are controlled. The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is installed into a commercial off-the-shelf (COTS) mobile device by the customer.

The software components of this module are executed in the Qualcomm Trusted Execution Environment (TEE) TZ.XF.5.1x. Therefore, the operational environment is considered limited.

6.2 Tested Operational Environment

Please see Section 2.3 for the tested operational environment.

6.3 Specifications for the Operational Environment

There are no security rules, settings or restrictions to the configuration of the operational environment.

- The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library does not have the capability of loading software or firmware from an external source.
- The module does not support concurrent operators.

7 Physical Security

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is a software-hybrid module implemented as part of the Snapdragon 8 Gen 1 Mobile Platform SoC, which is the physical perimeter of the single-chip software-hybrid module. The single-chip conforms to the Level 2 requirements for physical security.

At the time of manufacturing, the die of the Snapdragon 8 Gen 1 Mobile Platform SoC is embedded within a printed circuit board (PCB), which prevents visibility into the internal circuitry of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library. The layering process which is used to embed the die into the PCB also prevents tampering of the physical components without leaving tamper evidence.

The Snapdragon 8 Gen 1 Mobile Platform SoC is further protected by being enclosed in commercial off the shelf mobile device utilizing production grade, commercially available components and said mobile device enclosure completely surrounds the Snapdragon 8 Gen 1 Mobile Platform SoC.

There are no steps required to ensure that physical security is maintained.

8 Non-invasive Security

The module does not support any non-invasive security techniques; therefore, this section is not applicable.

9 Sensitive Security Parameter Management

Table 12 summarizes the Sensitive Security Parameters (SSPs) that are used by the cryptographic services implemented in the module in the approved services (Table 10).

SSP	Strength	Security Function and Cert. #	Generation	Import /Export	Establishment	Storage	Zeroization	Use and related keys
AES key	128, 192, 256 bits	AES #A2300	N/A	Input in plaintext via API input parameters. No output.	N/A	RAM	See 9.5	Use: Encryption, Decryption
HMAC key	112-256 bits	HMAC #A2300						Use: Message Authentication
ECDSA private key	112-256 bits (P-224, P-256, P-384, P-521)	ECDSA #A2300	FIPS 186-4 compliant method described in Appendix B.4.2. random values obtained using the SP800-90Arev1 DRBG provided by the bound module.	Input in plaintext via API input parameters. Output in plaintext via API output parameters.	N/A	RAM		Use: Signature Generation Related keys: paired with ECDSA public key, generated from Intermediate key generation value
ECDSA public key	96-256 bits (P-192, P-224, P-256, P-384, P-521)							Use: Signature Verification Related keys: paired with ECDSA private key, generated from Intermediate key generation value
RSA private key	112-150 bits (2048, 3072, 4096 bit modulus)	RSA #A2300	FIPS 186-4 compliant method described in Appendix B.3.3. random values obtained using the SP800-90Arev1 DRBG provided by the bound module.	Input in plaintext via API input parameters. Output in plaintext via API output parameters.	N/A	RAM		Use: Signature Generation Related keys: paired with RSA public key, generated from Intermediate key generation value
RSA public key	80-150 bits (1024, 2048, 3072, 4096 bit modulus)							Use: Signature Verification Related keys: paired with RSA private key, generated

SSP	Strength	Security Function and Cert. #	Generation	Import /Export	Establishment	Storage	Zeroization	Use and related keys
								from Intermediate key generation value
Password	N/A	PBKDF #A2300	N/A	Input in plaintext via API input parameters. No output.	N/A	RAM	See 9.5	Use: Key Derivation Related keys: used to derive Derived key
Derived key	128 - 256 bits		Generated during the PBKDF	No input. Output in plaintext via API output parameters.	N/A			Use: Key Derivation Related SSPs: derived from Password
Intermediate key generation value	112-256 bits	CKG (vendor affirmed)	N/A	No input. No output.	N/A	RAM		Use: Key pair generation Related keys: used to generate ECDSA private key, ECDSA public key, RSA private key, RSA public key

Table 12 - SSPs

9.1 SSP Establishment/SSP Derivation

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library implements Password-Based Key Derivation version 2 (PBKDF) as defined in [SP800-132]. The PBKDF function is provided as a service and returns the key derived from the provided password to the caller. The supported option is 1a from Section 5.4 of SP 800-132, whereby the Master Key (MK) is used directly as the Data Protection Key (DPK). The length of the salt should be at least 128 bits and the length of the password or passphrase should be at least 8 characters, which provides the probability of guessing this password or passphrase to be $(1/10)^8$ assuming a scenario where all characters are digits. The caller shall observe all requirements and should consider all recommendations specified in SP800-132 with respect to the strength of the generated key, including the quality of the password, the quality of the salt as well as the number of iterations. The keys derived from passwords, as shown in SP 800-132, may only be used for storage applications.

9.2 SSP Generation

The SSP generation methods implemented in the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library for approved services are compliant with SP 800-133Rev2. ECDSA key pair generation is done according to FIPS 186-4, Appendix B.4.2 (Testing Candidates). RSA key pair generation is done according to FIPS 186-4, Appendix B.3.3 (Probable Prime Genera-

tion). The seeds (i.e., the random values) used in asymmetric key pair generation are directly obtained from the SP 800-90Arev1 Hash DRBG provided by the bound Qualcomm® Pseudo Random Number Generator module, compliant with SP 800-133r2 section 4 without the use of V (as specified in additional comment #2 to IG D.H).

- The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library does not generate symmetric keys.
- Intermediate key generation values are not output from the module during or after processing the service.

9.3 SSP Entry and Output

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library only supports manual, electronic SSP entry or output. The SSPs are provided to the module via API input parameters in plaintext form and output via API output parameters in plaintext form. During SSP entry, all data output through the data output interface is inhibited.

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library does not enter or output SSPs in plaintext format outside its physical perimeter.

9.4 SSP Storage

All SSPs are output from and entered into the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library to and from the calling process and are destroyed from memory when released. The module does not perform persistent storage of SSPs. The SSPs will be stored temporarily in plaintext in the RAM.

9.5 SSP Zeroization

The module's functions deallocate and zeroize temporary SSP values in volatile memory used during the function's execution. The zeroization consists of writing zeroes to the memory location used by the SSP before deallocating the area. The module does not overwrite SSPs with another SSP.

The zeroization service for the SSPs in volatile memory consists of powering off the module, which will remove power from the volatile memory. This action will cause the value of the SSPs in volatile memory to be overwritten by random values the next time the module is powered on. The successful act of powering off the module serves as the implicit indicator of zeroization.

10 Self-tests

The module performs pre-operational self-tests and conditional self-tests. While the module is executing the self-tests, services are not available, and data output (via the data output interface) is inhibited until the tests are successfully completed. The module is not available to be used by the calling application until the pre-operational self-tests and cryptographic algorithm self-tests are completed successfully.

All the self-tests are listed in Table 13, with the respective condition under which those tests are performed. The software integrity test is performed after the HMAC cryptographic algorithm self-tests (CASTs) are performed. The self-tests for the DRBG and SHA used from the bound module are implemented by the bound module.

Algorithm	Parameters	Condition for test	Type	Test
HMAC-SHA-256	SHA-256	Power up (after HMAC CASTs)	Pre-Operational Self-Test	Software integrity test
AES 128 and 256 key size	CCM	Power up	Cryptographic Algorithm Self-Test	KAT encryption
				KAT decryption
	ECB			KAT decryption
HMAC	SHA-1, SHA-256, SHA-512	Power up	Cryptographic Algorithm Self-Test	KAT HMAC computation
RSA	PKCS#1 v1.5 with SHA-256 and 2048 bit modulus	Power up	Cryptographic Algorithm Self-Test	KAT signature generation
				KAT signature verification
ECDSA	P-256 with SHA-256	Power up	Cryptographic Algorithm Self-Test	KAT signature generation
				KAT signature verification
PBKDF	SHA-1, SHA-256, SHA-512	Power up	Cryptographic Algorithm Self-Test	KAT key derivation
RSA	N/A	Key pair generation	Pair-wise Consistency Test	PCT signature generation/verification
ECDSA	N/A	Key pair generation	Pair-wise Consistency Test	PCT signature generation/verification

Table 13 - Self-tests

10.1 Pre-Operational Self-Tests

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library performs pre-operational self-tests when it is loaded into memory, without operator intervention. Pre-operational self-tests ensure that the module is not corrupted. The module transitions to the operational state only after the pre-operational self-tests are passed successfully.

The types of pre-operational self-tests are described in the next sub-sections.

10.1.1 Software Integrity Test

The integrity of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is verified by comparing a HMAC-SHA-256 value calculated at run time with the HMAC-SHA-256 value stored in the module that was computed at build time. If the comparison verification fails, the module transitions to the error state (Section 10.3) The HMAC-SHA-256 algorithm goes through its cryptographic algorithm self-test before the integrity test is performed (Table 13).

10.2 Conditional Self-Tests

10.2.1 Cryptographic Algorithm Self-Tests

The module performs self-tests on all approved cryptographic algorithms as part of the approved services using the tests shown in Table 13. Data output through the data output interface is inhibited during the self-tests. The module transitions to the operational state only after the cryptographic algorithm self-tests are passed successfully.

10.2.2 Pair-wise Consistency Tests

Pair-wise consistency tests are run whenever the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library generates an asymmetric (RSA or ECDSA) key pair.

If the pair-wise consistency check fails, the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library enters an error state and returns an error status code.

10.2.3 Periodic/On-Demand Self-Tests

The module performs on-demand self-tests initiated by calling the Get FIPS Info service. All self-tests in Table 13 marked as “Power up” are then executed. An operator can perform the pair-wise consistency tests on demand by requesting the Key Pair Generation service for RSA or ECDSA. The same procedures may be employed by the operator to perform periodic self-tests.

10.3 Error States

If the module fails any of the self-tests, the module enters the error state. In the error state, the module outputs the error type through the status output interface. In the error state, the data output interface is inhibited, and the module accepts no more inputs or requests. To recover from the error state, re-initialization is possible by successful execution of the pre-operational self-tests and cryptographic algorithm self-tests, which can be triggered by a power-off/power-on cycle.

Table 14 lists the error state and the status indicator (through calling the `qsee_get_fips_info()` function with the `info_type` parameter set to `QSEE_FIPS_SELFTEST_STATUS`) values that explains the error that has occurred.

Error State	Error Condition	Status Indicator
Error	Cryptographic Algorithm Self-Test, or Software Integrity Test	The module has halted and is unable to boot.

Error State	Error Condition	Status Indicator
Error	Pair-wise Consistency Test	The module returns ICryptoSelfTest_CRYPTO_SELF-TEST_FAILED and enters "Error" state and no further operations is allowed.

Table 14 - Error states

11 Life-cycle assurance

11.1 Configuration Management

Perforce Visual Client (P4V), a version control system from Perforce, is used to manage the revision control of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library software code. The Perforce Visual Client provides version control, branching and merging of code lines, and concurrent development.

Git, an open-source version control system, is also used to manage the revision control of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library unified crypto software code. Git provides version control, branching and merging of code lines, and concurrent development.

11.2 Delivery and Operation

The Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is a software-hybrid module that runs on the Snapdragon 8 Gen 1 Mobile Platform. This SoC is delivered from the vendor via a trusted delivery courier.

On the reception of the SoC, the operator shall first check all sides of the box to verify that it has not been tampered during the shipment. Then, after opening the box the operator shall verify that the moisture barrier bag is still sealed and does not present any trace of tampering. Finally, after retrieving the SoC, the operator shall perform a visual inspection of the external SoC package of the module, it should look similar to the pictures in Figure 2.

If one of these verifications fail, the operator shall contact their Qualcomm representative which released the delivery before operating the module.

Once the product is received by the customer, configured as defined in section 11.5, and powered up, the test defined in section 10 will be executed.

11.3 Maintenance Requirements

There are no maintenance requirements.

11.4 End of Life

As stated in Section 9.4 the module does not possess persistent storage of SSPs. The SSP values only exist in volatile memory and these values vanish when the module is powered off. The procedure for secure sanitization of the module at the end of life is simply to power it off, which is the action of zeroization of the SSPs (Section 9.5). As a result of this sanitization via power-off, all SSPs are removed from the module, so that the module may either be distributed to other operators or disposed.

11.5 Crypto Officer Guidance

To enable FIPS for the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library, the fuse must be set according to Table 4. The fuse enablement is mandatory to run as a FIPS validated module. This step needs to be performed only once during initial installation. The information required for the Crypto Officer to verify the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is provided by the `qsee_get_fips_info()` function in

qsee_fips_services.h. To verify that a Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is FIPS certified, the Crypto Officer should verify the following:

- The HMAC of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library is on a list of HMACs of certified crypto modules.
 - This can be done by invoking the `qsee_get_fips_info()` function with the `info_type` parameter set to `QSEE_FIPS_MODULE_HMAC` (0). The buffer parameter should point to a buffer which is at least 32 bytes long, and the `buffer_len` parameter should be at least 32.
 - The result buffer should contain the HMAC-SHA-256 of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library.
 - To get the HMAC of the 64-bit Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library, this should be run from a 64-bit Trusted Application.
- The FIPS enablement fuse is blown
 - This can be done by invoking the `qsee_get_fips_info()` function with the `info_type` parameter set to `QSEE_FIPS_FUSE_STATUS` (1). The buffer parameter should point to a 4-byte buffer (`sizeof(uint32)`) and the `buffer_len` parameter should equal 4.
 - The result buffer should contain the value `QSEE_FIPS_FUSE_BLOWN` (1).
- The pre-operational self-tests and cryptographic algorithm self-tests have passed.
 - This can be done by calling `qsee_get_fips_info()` with the `info_type` parameter set to `QSEE_FIPS_SELFTEST_STATUS` (2). The buffer parameter should point to a 4-byte buffer (`sizeof(uint32)`) and the `buffer_len` parameter should equal 4.
 - The result buffer should contain the value `QSEE_CRYPTO_SELFTEST_PASSED` (1).
 - If one or more of the self-tests failed, the TZ runtime environment will not be able to load Trusted Applications.

The operation of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library does not need FIPS 140-3 specific guidance. The FIPS 140-3 functional requirements are always invoked. Once operational, if the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library enters the Error state, the Crypto Officer needs to re-initialize the library instance in order to recover from the Error state.

To use the cryptographic services of the Qualcomm® Trusted Execution Environment (TEE) Software Cryptographic Library, please refer to 80-NH537-4: Qualcomm Trusted Execution Environment Version 5.0 User Guide.

NOTES:

- The AES algorithm in XTS mode can be only used for the cryptographic protection of data on storage devices, as specified in [SP 800-38E]. In addition, the length of a single data unit encrypted with the AES-XTS shall not exceed 2^{20} AES blocks. In compliance with IG C.I, the module verifies that the two keys used in AES-XTS are not equal.
- The keys derived from passwords, as shown in SP 800-132, may only be used in storage applications.
- In compliance with IG C.F, the module supports RSA signature generation with modulus lengths of 2048, 3072, and 4096 bits, and RSA signature generation has been CAVP tested for all of these modulus lengths. The number of Miller-Rabin tests are consistent with Appendix B of FIPS 186-4. The module performs RSA signature verification according to FIPS 186-4 with modulus lengths of 1024, 2048, 3072, and 4096 bits; RSA signature verification has been CAVP tested for all of these modulus lengths.

12 Mitigation of other attacks

The elliptic curve implementation uses the Montgomery Ladder, as well as blinding of base points and private key multiplication. The RSA implementation uses base and modulus blinding to mitigate timing-based side-channel attacks. Blinding countermeasures add randomness to private key operations, making determination of secrets from observations more difficult for the attacker.

Appendix A. Glossary and Abbreviations

AES	Advanced Encryption Standard
CAVP	Cryptographic Algorithm Validation Program
CBC	Cipher Block Chaining
CCM	Counter with Cipher Block Chaining-Message Authentication Code
CFB	Cipher Feedback
CMT	Cryptographic Module Testing
CMVP	Cryptographic Module Validation Program
CSP	Critical Security Parameter
CTR	Counter Mode
DES	Data Encryption Standard
DF	Derivation Function
DRBG	Deterministic Random Bit Generator
ECB	Electronic Code Book
ECC	Elliptic Curve Cryptography
FIPS	Federal Information Processing Standards Publication
HMAC	Hash Message Authentication Code
KAT	Known Answer Test
MAC	Message Authentication Code
NIST	National Institute of Science and Technology
OFB	Output Feedback
O/S	Operating System
PSS	Probabilistic Signature Scheme
RNG	Random Number Generator
RSA	Rivest, Shamir, Adleman
SHA	Secure Hash Algorithm
SHS	Secure Hash Standard
XTS	XEX-based Tweaked-codebook mode with cipher text Stealing

Appendix B. References

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