FalconStor Cryptographic Module

Version 3.12.4

FIPS 140-2 Non-Proprietary Security Policy

Level 1 Validation

FalconStor Software, Inc.

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Introduction

The FalconStor Cryptographic Module (FCM) is derived from the NSS Cryptographic Module version 3.12.4, an open-source, general-purpose cryptographic library, with an API based on the industry standard PKCS #11 version 2.20 [1]. It is available for free under the Mozilla Public License, the GNU General Public License, and the GNU Lesser General Public License. The NSS cryptographic module was jointly developed by Red Hat and Sun engineers and is used in Mozilla Firefox, Thunderbird, and many server applications from Red Hat and Sun. The security policy contents are directly inherited from the original NSS Cryptographic Module version 3.11.4, FIPS 140-2 Non-Proprietary Security Policy Level 1 and 2 Validation, Document version 1.19.

The FCM has two modes of operation: the *FIPS Approved* mode and *non-FIPS Approved* mode. By default, the module operates in the non-FIPS Approved mode. To operate the module in the FIPS Approved mode, an application must adhere to the security rules in the **Security Rules** section and initialize the module properly. If an application initializes the FCM by calling the standard PKCS #11 function `C_GetFunctionList` and calls the API functions via the function pointers in that list, it selects the non-FIPS Approved mode. To operate the FCM in the FIPS Approved mode, an application must call the API functions via an alternative set of function pointers. Rule 7 of the **Security Rules** section specifies how to do this.

Platform List

FIPS 140-2 conformance testing of the FCM was performed on the platform listed below.

- Security Level 1
  Dell PowerEdge SC440 (x64), Oracle Enterprise Linux 5.3.

The FCM supports many other platforms. If you would like to have the module validated on other platforms, please contact us.

Note on Calling the API Functions

The FCM has two parallel sets of API functions, `FC_xxx` and `NSC_xxx`, that implement the FIPS Approved and non-FIPS Approved modes of operation, respectively. For example, `FC_Initialize` initializes the module's library for the FIPS Approved mode of operation, whereas its counterpart `NSC_ Initialize` initializes the library for the non-FIPS Approved mode of operation. All the API functions for the FIPS Approved mode of operation are listed in the **Specification of Services** section.

Among the module's API functions, only FC_GetFunctionList and NSC_GetFunctionList are exported and therefore callable by their names. (The C_GetFunctionList function mentioned in the **Introduction** section is also exported and is just a synonym of NSC_GetFunctionList.) All the other API functions must be called via the function pointers returned by FC_GetFunctionList or NSC_GetFunctionList. FC_GetFunctionList and NSC_GetFunctionList each return a CK_GetFunctionList structure containing function pointers named C_xxx such as C_Initialize and C_Finalize. The C_xxx function pointers in the CK_FUNCTION_LIST structure returned by FC_GetFunctionList point to the FC_xxx functions, whereas the C_xxx function pointers in the CK_FUNCTION_LIST structure returned by NSC_FUNCTION_LIST point to the NSC_xxx functions.

For brevity, we use the following convention to describe API function calls. Again we use FC_Finalize and NSC_Finalize as examples:

- When we say "call FC_Initialize," we mean "call the FC_Initialize function via the C_Initialize function pointer in the CK_FUNCTION_LIST structure returned by FC_GetFunctionList."

- When we say "call NSC_Initialize," we mean "call the NSC_Initialize function via the C_Initialize function pointer in the CK_FUNCTION_LIST structure returned by NSC_GetFunctionList."

Security Rules

The following list specifies the security rules that the FCM and each product using the module shall adhere to:

1. The FCM shall consist of software libraries compiled for the supported platform.
2. The cryptographic module shall rely on the underlying operating system to ensure the integrity of the cryptographic module loaded into memory.
3. Applications running in the FIPS Approved mode all FC_GetFunctionList for the list of function pointers and call the API functions via the function pointers in that list for all cryptographic operations. (See the **Note on Calling the API functions** section.) The module changes from FIPS Approved mode to non-FIPS Approved mode when a FC_Finalize/ NSC_Finalize sequence is executed; it changes from non- FIPS Approved mode to FIPS Approved mode

when a NSC_Finalize/ FC_Finalize sequence is executed.

4. The FCM can be configured to use different private key database formats: key3.db or key4.db. "key3.db" format is based on the Berkeley DataBase engine and should not be used by more than one process concurrently. "key4.db" format is based on SQL DataBase engine and can be used concurrently by multiple processes. Both databases are considered outside the cryptographic boundary. The interface code of the FCM that accesses data stored in the database is considered part of the cryptographic boundary as the interface code encrypts/decrypts data.
5. Secret and private keys, plaintext passwords, and other security-relevant data items are maintained under the control of the cryptographic module. Secret and private keys shall are only to be passed to higher-level callers in encrypted (wrapped) form with FC_WrapKey using Triple DES or AES (symmetric key algorithms) or RSA (asymmetric key algorithm). **Note:** If the secret and private keys passed to higher-level callers are encrypted using a symmetric key algorithm, the encryption key may be derived from a password. In such a case, they should be considered to be in plaintext form in the FIPS Approved mode.
6. Once the FIPS Approved mode of operation has been selected, the user shall only use the FIPS 140-2 cipher suite.
7. The FIPS 140-2 cipher suite shall consist solely of:

    - Triple DES (FIPS 46-3) or AES (FIPS 197) for symmetric key encryption and decryption.
    - Secure Hash Standard (SHA-1, SHA-256, SHA-384, and SHA-512) (FIPS 180-2) for hashing.

HMAC (FIPS 198) for keyed hash.

- random number generator Hash DRBG (NIST SP800-90).
- Diffie-Hellman primitives or Key Wrapping using RSA keys for key establishment.
- DSA (FIPS 186-2 with Change Notice 1), RSA (PKCS #1 v2.1), for signature generation and verification.

Algorithm validation certificates:

Algorithm	Cert#	Description
Triple-DES	850	TECB(e/d; KO 1,2,3); TCBC(e/d; KO 1,2,3)
AES	1173	ECB(e/d; 128, 192, 256); CBC(e/d; 128, 192, 256)
SHS	1085	SHA-1, SHA-256, SHA-284, SHA-512 (BYTE-only)
HMAC	674	HMAC-SHA1 (Key Size Ranges Tested: KS<BS KS=BS KS>BS) HMAC-SHA256 (Key Size Ranges Tested: KS<BS KS=BS KS>BS) HMAC-SHA384 (Key Size Ranges Tested: KS<BS KS=BS KS>BS) HMAC-SHA512 (Key Size Ranges Tested: KS<BS KS=BS KS>BS)
DRBG	22	SP 800-90 [Hash_DRBG: SHA-256]
RSA	558	ALG[RSASSA-PKCS1_V1_5]; SIG(gen); SIG(ver); 1024, 1536, 2048, 3072, 4096, SHS: SHA-1, SHA-256, SHA-384, SHA-512
DSA	384	PQG(gen) MOD(1024); PQG(ver) MOD(1024); KEYGEN(Y) MOD(1024); SIG(gen) MOD(1024); SIG(ver) MOD(1024);

Caveats:

The FCM implements the following non-Approved algorithms, which must not be used in the FIPS Approved mode of operation:

- RC2 , RC4, DES, SEED, or CAMELLIA for symmetric key encryption and decryption.
- MD2 or MD5 for hashing.

8. Once the FIPS Approved mode of operation has been selected, Triple DES and AES must be limited in their use to performing encryption and decryption using either ECB or CBC mode.
9. Once the FIPS Approved mode of operation has been selected, SHA-1, SHA-256, SHA-386, and SHA-512 must be the only algorithms used to perform one-way hashes of data.
10. Once the FIPS Approved mode of operation has been selected, RSA must be limited in its use to generating and verifying PKCS #1 signatures, and to encrypting and decrypting key material for key exchange.
11. Once the FIPS Approved mode of operation has been selected, DSA can be used in addition to RSA to generate and verify signatures.
12. The module does not share CSPs between an Approved mode of operation and a non-Approved mode of operation
13. All cryptographic keys used in the FIPS Approved mode of operation must be generated in the FIPS Approved mode or imported while running in the FIPS Approved mode.
14. The cryptographic module shall perform explicit zeroization steps to clear the memory region previously occupied by a plaintext secret key, private key, or password. A plaintext secret or private key shall be zeroized when it is passed to a `FC_DestroyObject` call. All plaintext secret and private keys must be zeroized when the FCM is shut down (with a `FC_Finalize` call) or reinitialized (with a `FC_InitToken` call), or when the state changes between the FIPS Approved mode and non-FIPS Approved mode (with a `NSC_Finalize/FC_Initialize` or `FC_Finalize/NSC_Initialize` sequence). All zeroization is to be performed by storing the value 0 into every byte of the memory region previously occupied by a plaintext secret key, private key, or password.
15. The environment variable NSS_ENABLE_AUDIT must be set to 1 before the application starts.
16. The FCM consists of the following shared libraries/DLLs and the associated .chk files:
    - libsoftokn3.so
    - libsoftokn3.chk
    - libfreebl3.so
    - libfreebl3.chk
    - libnssdbm3.so
    - libnssdbm3.chk

The FCM requires the Netscape Portable Runtime (NSPR) libraries. NSPR provides a cross-platform API for non-GUI operating system facilities, such as threads, thread synchronization, normal file and network I/O, interval timing and calendar time, atomic operations, and shared library linking. NSPR also provides utility functions for strings, hash tables, and memory pools. NSPR is outside the cryptographic boundary because none of the NSPR functions are security-relevant. NSPR consists of the following shared libraries/DLLs:

- libplc4.so
- libplds4.so
- libnspr4.so

17. The installation instructions are:

Step 1: Install the shared libraries/DLLs and the associated `.chk` files in a directory on the shared library/DLL search path, which could be a system library directory (`/usr/lib`) or a directory specified in the following environment variable:

- `LD_LIBRARY_PATH`

Step 2: Use the `chmod` utility to set the file mode bits of the shared libraries/DLLs to **0755** so that all users can execute the library files, but only the files' owner can modify (i.e., write, replace, and delete) the files. For example,

```
$ chmod 0755 libsoftokn3.so libfreebl*3.so libplc4.so
libplds4.so libnspr4.so
```

The discretionary access control protects the binaries stored on disk from being tampered with.

Step 3: Use the `chmod` utility to set the file mode bits of the associated `.chk` files to **0644**. For example,

```
$ chmod 0644 libsoftokn3.chk libfreebl*3.chk
libnssdbm3.chk
```

Step 4: As specified in Rule 7, to operate the FCM in the FIPS Approved mode, an application must call the alternative PKCS #11 function `FC_GetFunctionList` and call the API functions via the function pointers in that list. The user must initialize the password when using the module for the first time. Before the user password is initialized, access to the module must be controlled. See the **Sample Cryptographic Module Initialization Code** section below for sample code.

(End of Security Rules)

Authentication Policy

Specification of Roles

The FCM supports two authorized roles for operators.

- The FCM User role provides access to all cryptographic and general-purpose services (except those that perform an initialization function) and all keys stored in the private key database. An FCM User utilizes secure services and is also responsible for the retrieval, updating, and deletion of keys from the private key database.
- The Crypto Officer role is supported for the installation and initialization of the module. The Crypto Officer must control the access to the module both before and after installation. Control consists of management of physical access to the computer executing the FCM code as well as management of the security facilities provided by the operating system. The FCM does not have a maintenance role.

Role-Based Authentication

The FCM uses **role-based authentication** to control access to the module. To perform sensitive services using the cryptographic module, an operator must explicitly request to assume the FCM User role by logging into the module and performing an authentication procedure using information unique to that operator (**password**). The password is initialized by FCM User as part of module initialization. Role-based authentication is used to safeguard a user's **private key** information. However, discretionary access control is used to safeguard all other information (e.g., the public key certificate database).

If a function that requires authentication is called before the operator is authenticated, it returns the `CKR_USER_NOT_LOGGED_IN` error code. Call the `FC_Login` function to provide the required authentication.

A known password check string, encrypted with a Triple-DES key derived from the password, is stored in an encrypted form in the private key database (either key3.db or key4.db) in secondary storage. **Note**: This database lies outside the cryptographic boundary.

Once a password has been established for the FCM, the module allows the user to use the private services if and only if the user successfully authenticates to the module. Password establishment and authentication are required for the operation of the module. Password authentication does not imply that any of the roles are considered to be authorized for the purposes of Level 2 FIPS 140-2 validation.

In order to authenticate to the cryptographic module, the user enters the password, and the cryptographic module verifies that the password is correct by deriving a Triple-DES key from the password, using an extension of the PKCS #5 PBKDF1 key derivation function with an 16-octet salt, an iteration count of 1, and SHA-1 as the underlying hash function, decrypting the stored encrypted password check string with the Triple-DES key, and comparing the decrypted string with the known password check string.

The user's password acts as the key material to encrypt/decrypt secret and private keys.
Note: Since password-based encryption such as PKCS #5 is not FIPS Approved, password-encrypted secret and private keys should be considered to be in plaintext form in the FIPS Approved mode. Secret and private keys are only stored in encrypted form (using a Triple-DES key derived from the password) in the private key database (key3.db/key4.db) in secondary storage. **Note**: Password-encrypted secret and private keys in the private key database should be considered to be in plaintext form in the FIPS Approved mode.

Strength of Authentication Mechanism

In the FIPS Approved mode, the FCM imposes the following requirements on the password. These requirements are enforced by the module on password initialization or change.

- The password must be at least **seven** characters long.
- The password must consist of characters from **three or more character classes**. We define five character classes: digits (0-9), ASCII lowercase letters, ASCII uppercase letters, ASCII non-alphanumeric characters (such as space and punctuation marks), and non-ASCII characters. If an ASCII uppercase letter is the first character of the password, the uppercase letter is not counted toward its character class. Similarly, if a digit is the last character of the password, the digit is not counted toward its character class.

To estimate the probability that a random guess of the password will succeed, we assume that

- the characters of the password are independent with each other, and
- the probability of guessing an individual character of the password is less than 1/10.

Since the password is at least 7 characters long, the probability that a random guess of the password will succeed is less than (1/10)^7 = 1/10,000,000.

After each failed authentication attempt in the FIPS Approved mode, the FCM inserts a one-second delay before returning to the caller, allowing at most 60 authentication attempts during a one-minute period. Therefore, the probability of a successful random guess of the password during a one-minute period is less than 60 * 1/10,000,000 = 0.6 * (1/100,000).

Multiple Concurrent Operators

The FCM doesn't allow concurrent operators.

- On a multi-user operating system, this is enforced by making the FCM certificate and private key databases readable and writable by the owner of the files only.

Note: FIPS 140-2 Implementation Guidance Section 6.1 clarifies the use of a cryptographic module on a server.

When a cryptographic module is implemented in a server environment, the server application is the user of the cryptographic module. The server application makes the calls to the cryptographic module. Therefore, the server application is the single user of the cryptographic module, even when the server application is serving multiple clients.

Access Control Policy

This section identifies the cryptographic keys and CSPs that the user has access to while performing a service, and the type of access the user has to the CSPs.

Security-Relevant Information

The FCM employs the following cryptographic keys and CSPs in the FIPS Approved mode of operation. Note that the private key database (key3.db/key4.db) mentioned below is outside the cryptographic boundary.

- AES secret keys: The module supports 128-bit, 192-bit, and 256-bit AES keys. The keys may be stored in memory or in the private key database (key3.db/key4.db).
- Hash_DRBG: Hash DRBG entropy - 880-bit value externally-obtained for module DRBG; stored in plaintext in volatile memory. Hash DRBG V value - Internal Hash DRBG state value; stored in plaintext in volatile memory. Hash DRBG C value - Internal Hash DRBG state value; stored in plaintext in volatile memory.
- Triple-DES secret keys: 168-bit. The keys may be stored in memory or in the private key database (key3.db/key4.db).
- HMAC secret keys: HMAC key size must be greater than or equal to half the size of the hash function output. The keys may be stored in memory or in the private key database (key3.db/key4.db).
- DSA public keys and private keys: The module supports DSA key sizes of 512-1024 bits. DSA keys of 1024 bits be used in the FIPS Approved mode of operation. The keys may be stored in memory or in the private key database (key3.db/key4.db).
- RSA public keys and private keys (used for digital signatures and key transport):

The module supports RSA key sizes of 1024-8192 bits. The keys may be stored in memory or in the private key database (key3.db/key4.db).

- Diffie-Hellman public keys and private keys: The module supports Diffie-Hellman public key sizes of 1024-2236 bits. The keys may be stored in memory or in the private key database (key3.db/key4.db).
- TLS premaster secret (used in deriving the TLS master secret): 48-byte. Stored in memory.
- TLS master secret (a secret shared between the peers in TLS connections, used in the generation of symmetric cipher keys, IVs, and MAC secrets for TLS): 48-byte. Stored in memory.
- authentication data (passwords): Stored in the private key database (key3.db/key4.db).
- audited events and audit data (Security Level 2 only): Stored in the system audit logs.

Note: The FCM does not implement the TLS protocol. The FCM implements the cryptographic operations, including TLS-specific key generation and derivation operations, that can be used to implement the TLS protocol.

Self-Tests

In the FIPS Approved mode of operation the cryptographic module does not allow critical errors to compromise security. Whenever a critical error (e.g., a self-test failure) is encountered, the cryptographic module enters an error state and the library needs to be reinitialized to resume normal operation. Reinitialization is accomplished by calling `FC_Finalize` followed by `FC_Initialize`.

Upon initialization of the cryptographic module library for the FIPS Approved mode of operation, the following power-up self-tests are performed:
a) Triple DES-ECB encrypt/decrypt,
b) Triple DES-CBC encrypt/decrypt,
c) AES-ECB encrypt/decrypt (128-bit, 192-bit, and 256-bit keys),
d) AES-CBC encrypt/decrypt (128-bit, 192-bit, and 256-bit keys),
e) SHA-1 hash,
f) SHA-256 hash,
g) SHA-384 hash,
h) SHA-512 hash,
i) HMAC-SHA-1/-SHA-256/-SHA-384/-SHA-512 keyed hash (296-bit key),
j) RSA encrypt/decrypt (1024-bit modulus n),
k) RSA-SHA-256/-SHA-384/-SHA-512 signature generation (2048-bit modulus n),
l) RSA-SHA-256/-SHA-384/-SHA-512 signature verification (2048-bit modulus n),
m) DSA key pair generation (1024-bit prime modulus p),
n) DSA signature generation (1024-bit prime modulus p),
o) DSA signature verification (1024-bit prime modulus p),
p) random number generation, and

q) software/firmware integrity test (the authentication technique is DSA with 1024-bit prime modulus p).

Shutting down and restarting the FCM with the `FC_Finalize` and `FC_Initialize` functions executes the same power-up self-tests detailed above when initializing the module library for the FIPS Approved mode. This allows a user to execute these power-up self-tests on demand as defined in Section 4.9.1 of FIPS 140-2.

In the FIPS Approved mode of operation, the cryptographic module performs a pair-wise consistency test upon each invocation of RSA, and DSA key pair generation as defined in Section 4.9.2 of FIPS 140-2.

In the FIPS Approved mode of operation, the cryptographic module performs a continuous random number generator test upon each invocation of the pseudorandom number generator as defined in Section 4.9.2 of FIPS 140-2.

Random Number Generator

The cryptographic module performs pseudorandom number generation using NIST SP 800-90 Hash Deterministic Random Bit Generators.

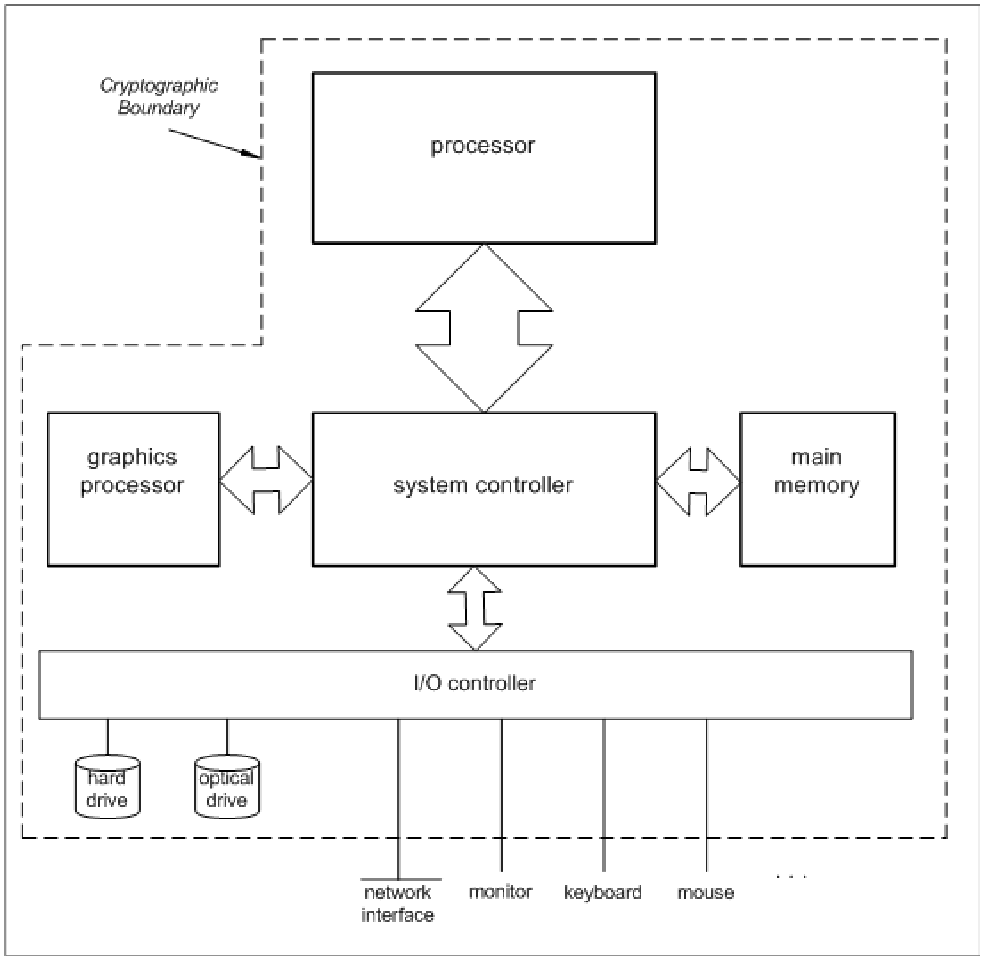
The cryptographic module initializes its pseudorandom number generator by obtaining at least 110 bytes of random data from the operating system. The data obtained contains at least 440 bits of entropy. Extra entropy input is added by invoking a noise generator. Both initialization and noise generation are specific to the platform on which it was implemented. The pseudorandom number generator is seeded with noise derived from the execution environment such that the noise is not predictable. The source of noise is considered to be outside the logical boundary of the cryptographic module.

A product using the cryptographic module should periodically reseed the module's pseudorandom number generator with unpredictable noise by calling `FC_SeedRandom`. After 246 calls to the random number generator the cryptographic module obtains another 110 bytes of random data from the operating system to reseed the random number generator.

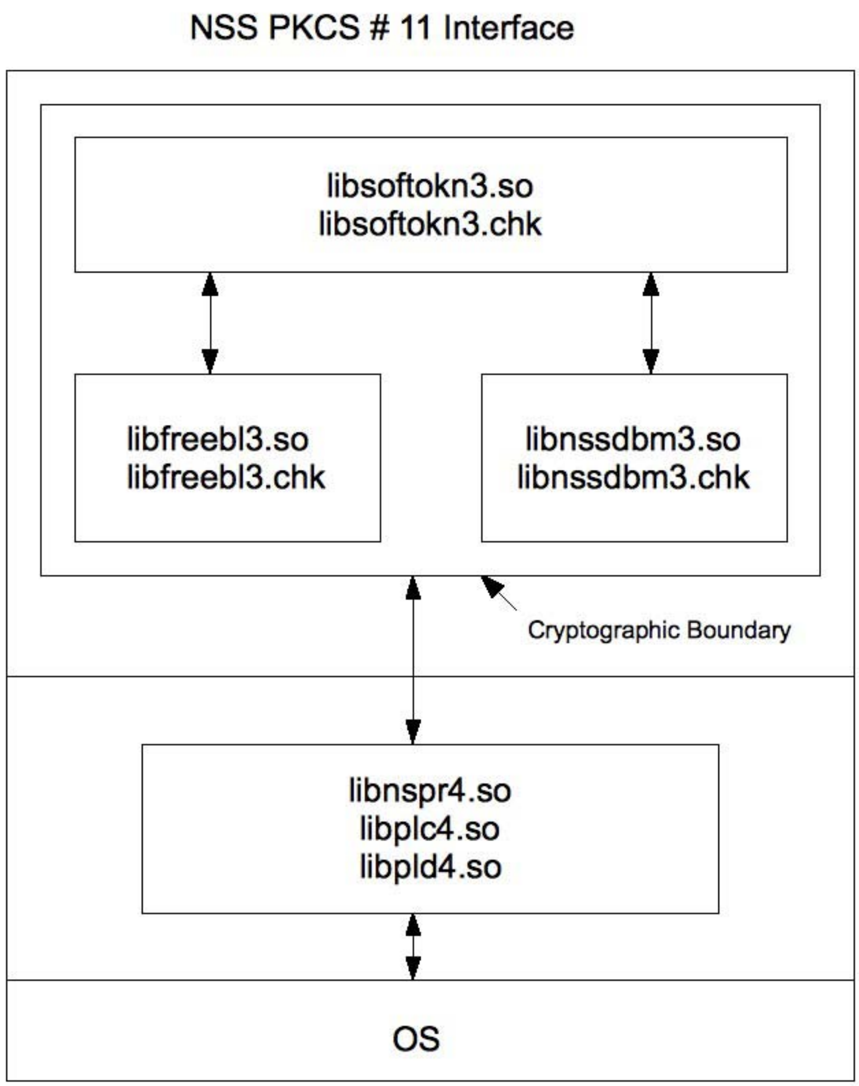
Module Ports and Interfaces

The FCM is a software cryptographic implementation. No hardware or firmware components are included. All input to the module is via function arguments; all output is returned to the caller either as return codes or as updated memory objects pointed to by some of the arguments. All keys, encrypted data, and control information are exchanged through calls to library functions (logical interfaces). The physical ports, physical covers, doors, or openings; manual controls; and physical status indicators of the FCM are those of the general purpose computer it runs on.

Physical Cryptographic Boundary



Logical Cryptographic Boundary



Logical Interfaces

The following four logical interfaces have been designed within the FCM.

1. Data input interface: function input arguments that specify plaintext data; ciphertext or signed data; cryptographic keys (plaintext or encrypted) and initialization vectors; and passwords that are to be input to and processed by the FCM.
2. Data output interface: function output arguments that receive plaintext data; ciphertext data and digital signatures; and cryptographic keys (plaintext or encrypted) and initialization vectors from the FCM.
3. Control input interface: function calls, or input arguments that specify commands and control data (e.g., algorithms, algorithm modes, or module settings) used to control the operation of the FCM.
4. Status output interface: function return codes, error codes, or output arguments that receive status information used to indicate the status of the FCM

The FCM uses different function arguments for input and output to distinguish between data input, control input, data output, and status output, to disconnect the logical paths followed by data/control entering the module and data/status exiting the module. The FCM doesn't use the same buffer for input and output. After the FCM is done with an input buffer that holds security-related information, it always zeroizes the buffer so that if the memory is later reused as an output buffer, no sensitive information may be inadvertently leaked.

PKCS #11

The logical interfaces of the FCM consist of the PKCS #11 (Cryptoki) API. The API itself defines the cryptographic boundary, i.e., all access to the cryptographic module is through this API. The module has three PKCS #11 tokens: two tokens that implement the non-FIPS Approved mode of operation, and one token that implements the FIPS Approved mode of operation. The FIPS PKCS #11 token is designed specifically for FIPS 140-2, and allows applications using the FCM to operate in a strictly FIPS mode.

The functions in the PKCS #11 API are listed in the table in the Specification of Services section.

Inhibition of Data Output

All data output via the data output interface is inhibited when the FCM is in the Error state or performing self-tests.

- In Error State: The Boolean state variable sftk_fatalError tracks whether the FCM is in the Error state. Most PKCS #11 functions, including all the functions that output data via the data output interface, check the sftk_fatalError state variable and, if it is true, return the CKR_DEVICE_ERROR error code immediately. Only the functions that shut down and restart the module, reinitialize the module, or output status information can be invoked in the Error state. These functions are FC_GetFunctionList, FC_Initialize, FC_Finalize, FC_GetInfo, FC_GetSlotList, FC_GetSlotInfo, FC_GetTokenInfo, FC_InitToken, FC_CloseSession, FC_CloseAllSessions, and FC_WaitForSlotEvent.

- During Self-Tests: The FCM performs power-up self-tests in the FC_Initialize function. Since no other PKCS #11 function (except FC_GetFunctionList) may be called before FC_Initialize returns successfully, all data output via the data output interface is inhibited while FC_Initialize is performing the self-tests.

Disconnecting the Output Data Path From the Key Processes

During key generation and key zeroization, the FCM may perform audit logging at Security Level 2, but the audit records do not contain sensitive information. The FCM doesn't return the function output arguments until key generation or key zeroization is finished. Therefore, the logical paths used by output data exiting the module are logically disconnected from the processes/threads performing key generation and key zeroization.

Specification of Services

Cryptographic module services consists of public services, which require no user authentication, and private services, which require user authentication. Public services do not require access to the secret and private keys and other critical security parameters (CSPs) associated with the user. Note: CSPs are security-related information (e.g., secret and private keys, and authentication data such as passwords) whose disclosure or modification can compromise the security of a cryptographic module. Message digesting services are public only when CSPs are not accessed. Services which access CSPs (e.g., FC_GenerateKey, FC_GenerateKeyPair) require authentication. Some services require the user to assume the Crypto Officer or FCM User role. In the table below, the role is specified for each service. If the Role column is blank, no role needs to be assumed for that service; such a service (e.g., random number generation and hashing) does not affect the security of the module because it does not require access to the secret and private keys and other CSPs associated with the user. The table lists each service as an API function and correlates role, service type, and type of access to the cryptographic keys and CSPs. Access types **R**, **W**, and **Z** stand for Read, Write, and Zeroize, respectively.

Service Category	Role	Function Name	Description	Cryptographic Keys and CSPs Accessed	Access type, RWZ
FIPS 140-2 specific		FC_GetFunctionList	Returns the list of function pointers for the FIPS Approved mode of operation	None	-
Module Initialization		FC_InitToken	Initializes or reinitializes a token	Password and all keys	Z
		FC_InitPIN	Initializes the	password	W

			user's password, i.e., sets the user's initial password		
General purpose		FC_Initialize	Initializes the module library for the FIPS Approved mode of operation. This function provides the power-up self-test service.	None	-
		FC_Finalize	Finalizes (shuts down) the module library	All keys	Z
		FC_GetInfo	Obtains general information about the module library	none	-
Slot and token management		FC_GetSlotList	Obtains a list of slots in the system	None	-
		FC_GetSlotInfo	Obtains information about a particular slot	None	-
		FC_GetTokenInfo	Obtains information about the token. This function provides the Show Status service.	None	-
		FC_WaitForSlotEvent	This function is not supported by the FCM	None	-
		FC_GetMechanismList	Obtains a list of mechanisms (cryptographic algorithms) supported by a token	None	-
		FC_GetMechanismInfo	Obtains information about a particular mechanism	None	-
	FCM User	FC_SetPIN	Changes the user's password	Password	RW
Object Management	FCM User	FC_CreateObject	creates an object	key	W
	FCM User	FC_CopyObject	Creates a copy of an object	Original key	R
				New key	W
	FCM User	FC_DestroyObject	Destroys an object	Key	Z
	FCM User	FC_GetObjectSize	Obtains the size of an object in bytes	Key	R
	FCM User	FC_GetAttributeValue	Obtains an attribute value of an object	Key	R
	FCM	FC_SetAttributeValue	Modifies an	Key	W

	User		attribute value of an object		
	FCM User	FC_FindObjectsInit	Initializes an object seasrach operation	None	-
	FCM User	FC_FindObjects	Continues an object search operation	Keys matching the search criteria	R
	FCM User	FC_FindObjectsFinal	Finishes an object search operation	None	-
Encryption and decryption	FCM User	FC_EncryptInit	Initializes an encryption operation	Encryption key	R
	FCM User	FC_Encrypt	Encrypts single-part data	Encryption key	R
	FCM User	FC_EncryptUpdate	Continues a multiple-part encryption operation	Encryption key	R
	FCM User	FC_EncryptFinal	Finishes a multiple-part encryption operation	Encryption key	R
	FCM User	FC_DecryptInit	Initializes a decryption operation	Decryption key	R
	FCM User	FC_Decrypt	decrypts single-part data	Decryption key	R
	FCM User	FC_DecryptUpdate	Continues a multiple-part decryption operation	Decryption key	R
	FCM User	FC_DecryptFinal	Finishes a multiple-part decryption operation	Decryption key	R
Message digesting		FC_DigestInit	Initializes a message-digesting operation	None	-
		FC_Digest	Digests single-part data	None	-
		FC_DigestUpdate	Continues a multiple-part digesting operation	None	-
	FCM User (see the note at the end of the table)	FC_DigestKey	Continues a multi-part message-digesting operation by digesting the value of a secret key as part of the data already digested	Key	R
		FC_DigestFinal	Finishes a	None	-

			multiple-part digesting operation		
Signature and Verification	FCM User	FC_SignInit	Initializes a signature operation	Signing/HMAC key	R
	FCM User	FC_Sign	Signs single-part data	Signing/HMAC key	R
	FCM User	FC_SignUpdate	Continues a multiple-part signature operation	Signing/HMAC key	R
	FCM User	FC_SignFinal	Finishes a multiple-part signature operation	Signing/HMAC key	R
	FCM User	FC_SignRecoverInit	Initializes a signature operation, where the data can be recovered from a signature	RSA signing key	R
	FCM User	FC_SignRecover	Signs single-part data, where the data can be recovered from a signature	RSA signing key	R
	FCM User	FC_VerifyInit	Initializes a verification operation	Verification/HMAC key	R
	FCM User	FC_Verify	Verifies a signature on single-part data	Verification/HMAC key	R
	FCM User	FC_VerifyUpdate	Continues a multiple-part verification operation	Verification/HMAC key	R
	FCM User	FC_VerifyFinal	Finishes a multiple-part verification operation	Verification/HMAC key	R
	FCM User	FC_VerifyRecoverInit	Initializes a verification operation where the data is recovered from the signature	RSA verification key	R
	FCM User	FC_VerifyRecover	Verifies a signature on single-part data, where the data is recovered from the signature	RSA verification key	R
Dual-function cryptographic	FCM User	FC_DigestEncryptUpdate	Continues a multiple-part	Encryption key	R

operations			digesting and encryption operation		
	FCM User	FC_DecryptDigestUpdate	Continues a multiple-part decryption and digesting operation	Decryption key	R
	FCM User	FC_SignEncryptUpdate	Continues a multiple-part signing and encryption operation	Signing/HMAC key	R
				Encryption key	R
	FCM User	FC_DecryptVerifyUpdate	Continues a multiple-part decryption and verify operation	Decryption key	R
				Verification/ HMAC key	R
Key management	FCM User	FC_GenerateKey	Generates a secret key (used by TLS to generate premaster secrets)	Key	W
	FCM User	FC_GenerateKeyPair	Generates a public / private key pair. This function performs the pair-wise consistency tests.	Key pair	W
	FCM User	FC_WrapKey	Wraps (encrypts) a key	Wrapping key	R
				Key to be wrapped	R
	FCM User	FC_UnwrapKey	Unwraps (decrypts) a key	Unwrapping key	R
				Unwrapped key	W
	FCM User	FC_DeriveKey	Derives a key from a base key (used by TLS to derive keys from the master secret)	Base key	R
				Derived key	W
Random number generation		FC_SeedRandom	Mixes in additional seed material to the random number generator	None	RW
		FC_GenerateRandom	Generates random data. This function performs the continuous random number generator test.	None	RW
Parallel function management		FC_GetFunctionStatus	A legacy function, which simply returns the value 0x00000051 (function not parallel)	None	-
		FC_CancelFunction	A legacy function, which simply	None	-

			returns the value 0x00000051 (function not parallel)		

Note: The message digesting functions (except `FC_DigestKey`) don't require the user to assume an authorized role because they don't use any keys. `FC_DigestKey` computes the message digest (hash) of the value of a secret key, therefore the user needs to assume the FCM User role for this service.

Mitigation of Other Attacks

The FCM is designed to mitigate the following attacks.

Other Attacks	Mitigation Mechanism	Specific Limitations
Timing attacks on RSA	**RSA blinding** Timing attack on RSA was first demonstrated by Paul Kocher in 1996 [2], who contributed the mitigation code to our module. Most recently Boneh and Brumley [3] showed that RSA blinding is an effective defense against timing attacks on RSA.	None
Cache-timing attacks on the modular exponentiation operation used in RSA and DSA	**Cache invariant modular Exponentiation** This is a variant of a modular exponentiation implementation that Colin Percival [4] showed to defend against cache-timing attacks.	This mechanism requires intimate knowledge of the cache line sizes of the processor. The mechanism may be ineffective when the module is running on a processor whose cache line sizes are unknown.
Arithmetic errors in RSA signatures	**Double-checking RSA Signatures** Arithmetic errors in RSA signatures might leak the private key. Ferguson and Schneier [5] recommend that every RSA signature generation should verify the signature just generated.	None

Sample Cryptographic Module Initialization Code

The following sample code uses NSPR functions (declared in the header file "`prlink.h`") for dynamic library loading and function symbol lookup.

```
#include "prlink.h"
#include "cryptoki.h"
#include <assert.h>
#include <stdio.h>
#include <string.h>
/*
* An extension of the CK_C_INITIALIZE_ARGS structure for the
* FCM. The 'LibraryParameters' field is
* used to pass instance-specific information to the library
* (like where to find its config files, etc).
*/
typedef struct CK_C_INITIALIZE_ARGS_NSS {
CK_CREATEMUTEX CreateMutex;
CK_DESTROYMUTEX DestroyMutex;
CK_LOCKMUTEX LockMutex;
CK_UNLOCKMUTEX UnlockMutex;
CK_FLAGS flags;
CK_CHAR_PTR *LibraryParameters;
CK_VOID_PTR pReserved;
} CK_C_INITIALIZE_ARGS_NSS;
int main()
{
char *libname;
PRLibrary *lib;
CK_C_GetFunctionList pFC_GetFunctionList;
CK_FUNCTION_LIST_PTR pFunctionList;
CK_RV rv;
CK_C_INITIALIZE_ARGS_NSS initArgs;
CK_SLOT_ID slotList[2], slotID;
CK_ULONG ulSlotCount;
CK_TOKEN_INFO tokenInfo;
CK_SESSION_HANDLE hSession;
CK_UTF8CHAR password[] = "1Mozilla";
PRStatus status;
/*
* Get the platform-dependent library name of the FCM
*/
libname = PR_GetLibraryName(NULL, "softokn3");
assert(libname!= NULL);
lib = PR_LoadLibrary(libname);
assert(lib!= NULL);
PR_FreeLibraryName(libname);
pFC_GetFunctionList = (CK_C_GetFunctionList)
PR_FindFunctionSymbol(lib, "FC_GetFunctionList");
assert(pFC_GetFunctionList!= NULL);
rv = (*pFC_GetFunctionList)(&pFunctionList);
assert(rv == CKR_OK);
/* Call FC_xxx via the function pointer pFunctionList->C_xxx */
initArgs.CreateMutex = NULL;
```

```
initArgs.DestroyMutex = NULL;
initArgs.LockMutex = NULL;
initArgs.UnlockMutex = NULL;
initArgs.flags = CKF_OS_LOCKING_OK;
initArgs.LibraryParameters = (CK_CHAR_PTR *)
"configdir='.' certPrefix='' keyPrefix='' "
"secmod='secmod.db' flags= ";
initArgs.pReserved = NULL;
rv = pFunctionList->C_Initialize(&initArgs);
assert(rv == CKR_OK);
ulSlotCount = sizeof(slotList)/sizeof(slotList[0]);
rv = pFunctionList->C_GetSlotList(CK_TRUE, slotList, &ulSlotCount);
assert(rv == CKR_OK);
slotID = slotList[0];
rv = pFunctionList->C_OpenSession(slotID,
CKF_RW_SESSION | CKF_SERIAL_SESSION, NULL, NULL, &hSession);
assert(rv == CKR_OK);
/* set the operator's initial password, if necessary */
rv = pFunctionList->C_GetTokenInfo(slotID, &tokenInfo);
assert(rv == CKR_OK);
if (!(tokenInfo.flags & CKF_USER_PIN_INITIALIZED)) {
/*
* As a formality required by the PKCS #11 standard, the
* operator must log in as the PKCS #11 Security Officer (SO),
* with the predefined empty string password, to set the
* operator's initial password.
*/
rv = pFunctionList->C_Login(hSession, CKU_SO, NULL, 0);
assert(rv == CKR_OK);
rv = pFunctionList->C_InitPIN(hSession,
password, strlen(password));
assert(rv == CKR_OK);
/* log out as the PKCS #11 SO */
rv = pFunctionList->C_Logout(hSession);
assert(rv == CKR_OK);
}
/* the module is now ready for use */
/* authenticate the operator using a password */

rv = pFunctionList->C_Login(hSession, CKU_USER,
password, strlen(password));
assert(rv == CKR_OK);
/* use the module's services ... */
rv = pFunctionList->C_CloseSession(hSession);
assert(rv == CKR_OK);
rv = pFunctionList->C_Finalize(NULL);
assert(rv == CKR_OK);
status = PR_UnloadLibrary(lib);
assert(status == PR_SUCCESS);
return 0;
}
```

The mode of operation of the FCM is determined by the second argument passed to the `PR_FindFunctionSymbol` function.

- For the non-FIPS Approved mode of operation, look up the standard PKCS #11 function `C_GetFunctionList`.
- For the FIPS Approved mode of operation, look up the alternative function `FC_GetFunctionList`.

Acknowledgments

The contents of this security policy are directly inherited from the original NSS Cryptographic Module version 3.11.4, FIPS 140-2 Non-Proprietary Security Policy Level 1 and 2 Validation, Document version 1.19.

References

[1] RSA Laboratories, “PKCS #11 v2.20: Cryptographic Token Interface Standard”, 2004. (http://www.rsasecurity.com/rsalabs/node.asp?id=2133)

[2] P. Kocher, "Timing Attacks on Implementations of Diffie-Hellman, RSA, DSS, and Other Systems," CRYPTO '96, Lecture Notes In Computer Science, Vol. 1109, pp. 104-113, Springer-Verlag, 1996. (http://www.cryptography.com/timingattack/)

[3] D. Boneh and D. Brumley, "Remote Timing Attacks are Practical," http://crypto.stanford.edu/~dabo/abstracts/ssl-timing.html.

[4] C. Percival, "Cache Missing for Fun and Profit," http://www.daemonology.net/papers/htt.pdf

[5] N. Ferguson and B. Schneier, Practical Cryptography, Sec. 16.1.4 "Checking RSA Signatures", p. 286, Wiley Publishing, Inc., 2003.