Microsoft Windows

FIPS 140 Validation

Microsoft Windows 10 (Creators Update)
Microsoft Windows 10 Mobile (Creators Update)

Non-Proprietary

Security Policy Document

<table>
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<th>Version Number</th>
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<tr>
<td>Updated On</td>
<td>May 24, 2018</td>
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<td>May 24, 2018</td>
<td>Updated Bounded Module</td>
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13.1 HOW TO VERIFY WINDOWS VERSIONS

13.2 HOW TO VERIFY WINDOWS DIGITAL SIGNATURES
1 Introduction
Code Integrity (CI) verifies the integrity of Windows executable files as they are loaded into memory from storage. Code Integrity is implemented in a Dynamic Link Library (DLL) file, CI.DLL.

The Secure Kernel Code Integrity cryptographic module is closely related to Code Integrity, and, depending on the hardware and Windows configuration, will also validate system and application binaries.

Two Windows configuration options dictate whether Code Integrity or Secure Kernel Code Integrity are used to verify a binary image:

- Virtual Secure Mode (VSM) – Windows can use the Hypervisor to start an execution environment, called the Secure Kernel, that can enforce additional security rules. When VSM is configured, Secure Kernel Code Integrity verifies the integrity of critical user-mode modules such as BCRYPTPRIMITIVES.DLL instead of the Code Integrity module.
- Hypervisor Code Integrity (HVCI) – This feature depends on VSM. When enabled, all drivers loaded into the Windows kernel are integrity verified by Secure Kernel Code Integrity.

Code Integrity is not a general-purpose cryptographic module. It is validated under FIPS 140-2 because it implements cryptographic algorithms and provides the integrity checks for the Windows general-purpose cryptographic modules.

This Security Policy Document assumes that the following prerequisites are available:

- UEFI Secure Boot is available and enabled

1.1 List of Cryptographic Module Binary Executables
Code Integrity cryptographic module contains the following binaries:

- ci.dll

The Windows builds covered by this validation are:

- Version 10.0.15063
- Version 10.0.15063.728

1.2 Validated Platforms
The Windows editions covered by this validation are:

- Microsoft Windows 10 Home Edition (32-bit version)
- Microsoft Windows 10 Pro Edition (64-bit version)
- Microsoft Windows 10 Enterprise Edition (64-bit version)
- Microsoft Windows 10 Education Edition (64-bit version)
- Microsoft Windows 10 S Edition (64-bit version)
• Microsoft Windows 10 Mobile
• Microsoft Surface Hub

Code Integrity was validated using the combination of computers and Windows operating system editions specified in the following table:

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<th>Windows 10 Home</th>
<th>Windows 10 Pro</th>
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2 Cryptographic Module Specification

Code Integrity is a multi-chip standalone module that operates in FIPS-approved mode during normal operation of the computer and Windows operating system.

\(^1\) Host OS: Windows Server 2016, hardware platform: Surface Pro 4
The following configurations and modes of operation will cause Code Integrity to operate in a non-approved mode of operation:

- Boot Windows in Debug mode
- Boot Windows with Driver Signing disabled

2.1 Cryptographic Boundary
The software binary that comprises the cryptographic boundary for Code Integrity is CI.DLL.

2.2 FIPS 140-2 Approved Algorithms
Code Integrity implements the following FIPS 140-2 Approved algorithms:\(^2\)

- FIPS 186-4 RSA PKCS#1 (v1.5) digital signature verification with 1024, 2048, and 3072 moduli; supporting SHA-1, SHA-256, SHA-384, and SHA-512 (Cert. #2522 for version 10.0.15063) (Cert. #2844 for version 10.0.15063.728)
- FIPS 180-4 SHS SHA-1, SHA-256, SHA-384, and SHA-512 (Cert. #3790 for version 10.0.15063)(Cert. #4253 for version 10.0.15063.728)

2.3 Non-Approved Algorithms
Code Integrity only implements approved algorithms.

2.4 FIPS 140-2 Approved Algorithms from Bounded Modules
A bounded module is a FIPS 140 module which provides cryptographic functionality that is relied on by a downstream module. As described in the Integrity Chain of Trust section, Code Integrity depends on the following modules and algorithms:

Implemented in the Windows OS Loader (module certificate #3090):

- CAVP certificate #2523 for FIPS 186-4 RSA PKCS#1 (v1.5) digital signature verification with 2048 moduli; supporting SHA-256
- CAVP certificate #3790 for FIPS 180-4 SHS SHA-256
- CAVP certificate #2846 for FIPS 186-4 RSA PKCS#1 (v1.5) digital signature verification with 2048 moduli; supporting SHA-256
- CAVP certificate #4253 for FIPS 180-4 SHS SHA-256

Implemented in Windows Resume (module certificate #3091) to decrypt and restore the encrypted memory state during a boot from hibernation, which acts to preserve the module’s integrity (established by the Windows OS Loader) across hibernations:

- CAVP certificate #4624 for FIPS 197 AES CBC 128 and 256, SP 800-38E AES XTS 128 and 256
- CAVP certificate #5300 for FIPS 197 AES CBC 128 and 256, SP 800-38E AES XTS 128 and 256

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\(^2\) This module may not use some of the capabilities described in each CAVP certificate.
2.5 Cryptographic Bypass
Cryptographic bypass is not supported by Code Integrity.

2.6 Hardware Components of the Cryptographic Module
The physical boundary of the module is the physical boundary of the computer that contains the module. The following diagram illustrates the hardware components used by the Code Integrity module:

3 Cryptographic Module Ports and Interfaces
3.1 Code Integrity Export Functions
All the functions exported by Code Integrity to kernel-mode callers are listed below. Code Integrity is not callable outside the kernel. The exported functions are explained further in the subsequent subsections.

- CiInitialize
- CiGetPEInformation
- CiVerifyHashInCatalog
- CiCheckSignedFile
- CiFindPageHashesInCatalog
- CiFindPageHashesInSignedFile
- CiFreePolicyInfo
- CiSetTrustedOriginClaimId
- CiValidateFileObject
3.1.1 CiInitialize

CiInitialize is the function exported by Code Integrity for initializing the image file integrity validation capability of Code Integrity.

See Self-Tests for information regarding cryptographic self-tests.

If the self-tests succeed, CiInitialize() returns a callback structure consisting of the following binary executable file integrity validation functions.

- CiValidateImageHeader
- CiValidateImageData
- CiQueryInformation
- CiSetFileCache
- CiGetFileCache
- CiHashMemory
- KappxlsPackageFile
- CiCompareSigningLevels
- CiValidateFileAsImageType
- CiRegisterSigningInformation
- CiUnregisterSigningInformation
- CiInitializePolicy
- CipQueryPolicyInformation
- CiValidateDynamicCodePages
- SIPolicyQuerySecurityPolicy
- CiRevalidateImage
- CiSetUnlockInformation
- CiGetBuildExpiryTime

And if HVCI is enabled, also:

- CiGetStrongImageReference
- CiReleaseContext
- CiHvciSetImageBaseAddress

3.1.2 CiGetPEInformation

This function returns system configuration data which is related to the protected media subsystem.

3.1.3 CiVerifyHashInCatalog

For an input Authenticode file digest, validates that the digest is contained within a verified system catalog. It optionally returns information about the catalog.

3.1.4 CiCheckSignedFile

For an input Authenticode file digest and an Authenticode signature, verifies that the digest is in the signature and that the signature validates. It optionally returns information about the signature.
3.1.5 **CiFindPageHashesInCatalog**
For an input Authenticode digest of the first page of a PE image, validates that the digest is contained within a verified system catalog. It optionally returns information about the catalog.

3.1.6 **CiFindPageHashesInSignedFile**
For an input Authenticode digest of the first page of a PE image and an Authenticode signature, verifies that the digest is in the signature and that the signature validates. It optionally returns information about the signature.

3.1.7 **CiFreePolicyInfo**
Frees memory allocated by the CiVerifyHashInCatalog, CiCheckSignedFile, CiFindPageHashesInCatalog, and CiFindPageHashesInSignedFile functions.

3.1.8 **CiSetTrustedOriginClaimId**
This function is invoked by Appid.sys when an AppLocker policy is being processed.

3.1.9 **CiValidateFileObject**
Verifies the signature of a file object and returns the policy info along with the timestamp and signing time.

3.2 **Code Integrity Callback Functions**

The following functions are not exported, but are accessed via a callback structure provided by the CiInitialize function. These functions are also explained in subsequent subsections.

- CiValidateImageHeader
- CiValidateImageData
- CiQueryInformation
- CiSetFileCache
- CiGetFileCache
- CiHashMemory
- KappxIsPackageFile
- CiCompareSigningLevels
- CiValidateFileAsImageType
- CiRegisterSigningInformation
- CiUnregisterSigningInformation
- CiInitializePolicy
- CiQueryPolicyInformation
- CiValidateDynamicCodePages
- SIPolicyQuerySecurityPolicy
- CiRevalidateImage
- CiSetUnlockInformation
- CiGetBuildExpiryTime

And if HVCI is enabled, also:
3.2.1 CiValidateImageHeader
When a caller, such as the Memory Manager, wants to obtain the set of trusted per-page hashes of an image file, it calls CiValidateImageHeader(). Trusted per-page hashes can use the following algorithms:

- SHS (SHA-1)
- SHS (SHA-256)
- SHS (SHA-384)
- SHS (SHA-512)

If CiValidateImageHeader() does not find the set of trusted per-page hashes for the cryptographic module, then CiValidateImageHeader() verifies the full cryptographic module image by verifying a trusted file hash. The trusted file hash may be:

- SHS (SHA-1)
- SHS (SHA-256)
- SHS (SHA-384)
- SHS (SHA-512)

If this validation process fails, the module is not valid and the module is not loaded.

Both the trusted file image hash and trusted page hashes are signed using the RSA signature algorithm with PKCS#1 v1.5 padding.

3.2.2 CiValidateImageData
After calling CiValidateImageHeader to obtain the set of trusted per-page hashes of an image file, CiValidateImageData() is used to check the integrity of each page by computing the hash value of the page.

If the computed hash matches the identified trusted hash, then CiValidateImageData confirms the integrity of the page. Otherwise, CiValidateImageData returns STATUS_INVALID_IMAGE_HASH.

3.2.3 CiQueryInformation
Returns state data about the enforcement of Code Integrity. Whether CI is being enforced and whether test signing is enabled.

3.2.4 CiSetFileCache
For a verified file, saves the signature level and thumbprint of the signing certificate. If the file was not previously verified, it will verify the file against either its embedded signature or a system catalog.
3.2.1 Code Integrity

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3.2.5 CiGetFileCache
For an input file, returns the previously validated signature level and the thumbprint of the signing certificate. This check was done during a previous validation, and this function is just returning a cached result.

3.2.6 CiHashMemory()
Passes supplied data to MinCrypK_HashMemory and returns the hash of that data.

3.2.7 KappxIsPackageFile
This routine takes an input file object and parses out the full package name associated with the corresponding package. Package association is established based on the normalized path corresponding to the file object.

3.2.8 CiCompareSigningLevels
This routine determines if the source signing level is applicable for the target. For example, a source of Microsoft is not valid for a target of Windows, but vice-versa is valid.

3.2.9 CiValidateFileAsImageType
This routine determines if a PE file is signed appropriately for the specified image type. The file must be mapped as a view to a data section or be a copy of that view.

3.2.10 CiRegisterSigningInformation
This routine sets a signer, in addition to those already configured, for a specified signing level. Only those levels that are enabled for runtime configuration will accept signers supplied to this routine.

3.2.11 CiUnregisterSigningInformation
This routine removes a previous registered runtime signing information. Once a registration handle has been unregistered, it must be discarded.

3.2.12 CiInitializePolicy
This routine is called to get the configuration of CI for this boot and return the list of address ranges to be protected by Patch Guard.

3.2.13 CipQueryPolicyInformation
This routine returns information about Code Integrity policy state.

3.2.14 CiValidateDynamicCodePages
This routine validates the contents of code pages generated dynamically.

3.2.15 SIPolicyQuerySecurityPolicy
This routine queries the secure setting for specific provider’s <Key,Value> pair.

3.2.16 CiRevalidateImage
This routine determines if previously validated images must be validated again.
3.2.17 **CiSetUnlockInformation**  
This function sets unlock information for Code Integrity.

3.2.18 **CiGetBuildExpiryTime**  
This routine determines the expiry time of the build. Zero time means the build never expires, which is true for production and test builds. Flight builds expire when the certificate that signs CI expires.

3.2.19 **CiGetStrongImageReference**  
This routine returns the handle to a secure image.

3.2.20 **CiReleaseContext**  
This routine closes a validation context.

3.2.21 **CiHvciSetImageBaseAddress**  
This routine changes the base address of an image that is using secure relocations.

3.3 **Control Input Interface**  
The SecureRequired parameter in CiValidateImageHeader() is the only control option provided by Code Integrity in the Control Input Interface.

3.4 **Status Output Interface**  
The Status Output Interface for Code Integrity consists of the exported and callable functions listed in Code Integrity export functions. For each function, the status information is returned to the caller as the return value (e.g. STATUS_SUCCESS, STATUS_UNSUCCESSFUL, STATUS_INVALID_IMAGE_HASH) from the function.

3.5 **Data Input Interface**  
The Data Input Interface for Code Integrity is the exported and callable functions listed in Code Integrity export functions with the exception of the initialization and status functions. Data and options are passed to the interface as input parameters to the CI export functions.

3.6 **Data Output Interface**  
The Data Output Interface for Code Integrity also consists of most of the exported and callable functions listed in Code Integrity export functions with the exception of the initialization and status functions. Data is returned to the function’s caller via output parameters.

4 **Roles, Services and Authentication**

4.1 **Roles**  
Code Integrity is a library used solely by the Windows kernel and does not interact with the user through any service. The module’s functions are fully automatic and not configurable. FIPS 140 validations define formal “User” and “Cryptographic Officer” roles. Both roles can use any Code Integrity service.
4.2 Services

Code Integrity’s services are:

1. **Verify the integrity of binary executable code** – This service is called by the Windows kernel to verify the integrity of digitally signed drivers and other binary components of the operating system.
2. **Show Status** – The module does not provide an explicit status interface. Operational status is indicated by successfully initializing the module using CiInitialize and success status messages using the binary integrity verification functions.
3. **Self-Tests** - The module provides a power-up self-tests service that is automatically executed when the module is loaded into memory.

The following table maps the services to their corresponding algorithms and critical security parameters (CSPs) as described in Cryptographic Key Management.

<table>
<thead>
<tr>
<th>Service / Function</th>
<th>Algorithms</th>
<th>CSPs</th>
<th>Invocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify the integrity of binary executable code</td>
<td>FIPS 186-4 RSA PKCS#1 (v1.5) verify with public key</td>
<td>RSA public key</td>
<td>This service is fully automatic. This service is executed whenever a binary executable is loaded.</td>
</tr>
<tr>
<td></td>
<td>FIPS 180-4 SHS: SHA-1 hash</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHA-256 hash</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHA-384 hash</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHA-512 hash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Show Status</td>
<td>None</td>
<td>None</td>
<td>This service is fully automatic. This service is executed upon completion of an integrity check function.</td>
</tr>
<tr>
<td>Self-Tests</td>
<td>FIPS 186-4 RSA PKCS#1 (v1.5) verify with public key and known signature</td>
<td>None</td>
<td>This service is fully automatic.</td>
</tr>
<tr>
<td></td>
<td>FIPS 180-4 SHS: SHA-1 KAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHA-256 KAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHA-512 KAT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following table maps services to the export functions listed in [Code Integrity export functions and Code Integrity Callback Functions](#).

<table>
<thead>
<tr>
<th>Service</th>
<th>Export Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify the integrity of binary executable code</td>
<td>CiGetPEInformation()</td>
</tr>
<tr>
<td></td>
<td>CiVerifyHashInCatalog()</td>
</tr>
<tr>
<td></td>
<td>CiCheckSignedFile()</td>
</tr>
<tr>
<td></td>
<td>CiFindPageHashesInCatalog()</td>
</tr>
<tr>
<td></td>
<td>CiFindPageHashesInSignedFile()</td>
</tr>
<tr>
<td></td>
<td>CiFreePolicyInfo()</td>
</tr>
</tbody>
</table>
4.3 Authentication
The module does not provide authentication. Roles are implicitly assumed based on the services that are executed.

5 Finite State Model

5.1 Specification
The following diagram shows the finite state model for Code Integrity:
6 Operational Environment
The operational environment for Code Integrity is the Windows 10 operating system running on a supported hardware platform.

6.1 Single Operator
Code Integrity is invoked by the Windows kernel as a fully automatic service with no user interaction.

6.2 Cryptographic Isolation
In the Windows operating system, all kernel-mode modules, including CI.DLL, are loaded into the Windows Kernel (ntoskrnl.exe) which executes as a single process. The Windows operating system environment enforces process isolation from user-mode processes including memory and processor scheduling between the kernel and user-mode processes.
6.3 Integrity Chain of Trust

Windows uses several mechanisms to provide integrity verification depending on the stage in the OS boot sequence and also on the hardware and OS configuration. The following diagram describes the Integrity Chain of trust for each supported configuration:

![Boot Sequence & Chain of Trust Diagram]
The integrity of the Code Integrity module is checked by the Windows Loader. The Code Integrity module is then, in certain configurations, responsible for checking integrity of every other user and kernel mode system binary as they are loaded.

Refer back to the introduction for information on the relationship between Code Integrity and Secure Kernel Code Integrity and the effect of configuration on module validation.

7 Cryptographic Key Management
Code Integrity does not generate or store any persistent cryptographic keys; and uses RSA public keys for validating file integrity.

8 Self-Tests
The Code Integrity module implements Known Answer Test (KAT) functions each time the module is loaded by the Windows kernel and CiInitialize is called.

The module performs the following power-on (startup) self-tests:

- SHS (SHA-1) Known Answer Test
- SHS (SHA-256) Known Answer Test
- SHS (SHA-512) Known Answer Test
- RSA verify using a verify test with a Known Signature of the PKCS#1 v1.5 format with both 1024-bit keys with SHA1 digest and 2048-bit keys with SHA-256 digest.

If any self-test fails, the module will not load and a failure status, STATUS_INVALID_IMAGE_HASH, is returned and the computer will fail to boot. Otherwise STATUS_SUCCESS is returned and the boot process completes.

9 Design Assurance
The secure installation, generation, and startup procedures of this cryptographic module are part of the overall operating system secure installation, configuration, and startup procedures for Windows 10 operating system.

The Windows 10 operating system must be pre-installed on a computer by an OEM, installed by the end-user, by an organization’s IT administrator, or updated from a previous Windows 10 version downloaded from Windows Update.

An inspection of authenticity of the physical medium can be made by following the guidance at this Microsoft web site: https://www.microsoft.com/en-us/howtotell/default.aspx

The installed version of Windows must be verified to match the version that was validated. See Appendix A for details on how to do this.
For Windows Updates, the client only accepts binaries signed by Microsoft certificates. The Windows Update client only accepts content whose SHA-2 hash matches the SHA-2 hash specified in the metadata. All metadata communication is done over a Secure Sockets Layer (SSL) port. Using SSL ensures that the client is communicating with the real server and so prevents a spoof server from sending the client harmful requests. The version and digital signature of new cryptographic module releases must be verified to match the version that was validated. See Appendix A for details on how to do this.
10 Mitigation of Other Attacks
The following table lists the mitigations of other attacks for this cryptographic module:

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Protected Against</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHA1</td>
<td>Timing Analysis Attack</td>
<td>Constant time implementation</td>
</tr>
<tr>
<td></td>
<td>Cache Attack</td>
<td>Memory access pattern is independent of any confidential data</td>
</tr>
<tr>
<td>SHA2</td>
<td>Timing Analysis Attack</td>
<td>Constant time implementation</td>
</tr>
<tr>
<td></td>
<td>Cache Attack</td>
<td>Memory access pattern is independent of any confidential data</td>
</tr>
</tbody>
</table>

11 Security Levels
The security level for each FIPS 140-2 security requirement is given in the following table.

<table>
<thead>
<tr>
<th>Security Requirement</th>
<th>Security Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryptographic Module Specification</td>
<td>1</td>
</tr>
<tr>
<td>Cryptographic Module Ports and Interfaces</td>
<td>1</td>
</tr>
<tr>
<td>Roles, Services, and Authentication</td>
<td>1</td>
</tr>
<tr>
<td>Finite State Model</td>
<td>1</td>
</tr>
<tr>
<td>Physical Security</td>
<td>NA</td>
</tr>
<tr>
<td>Operational Environment</td>
<td>1</td>
</tr>
<tr>
<td>Cryptographic Key Management</td>
<td>1</td>
</tr>
<tr>
<td>EMI/EMC</td>
<td>1</td>
</tr>
<tr>
<td>Self-Tests</td>
<td>1</td>
</tr>
<tr>
<td>Design Assurance</td>
<td>2</td>
</tr>
<tr>
<td>Mitigation of Other Attacks</td>
<td>1</td>
</tr>
</tbody>
</table>
12 Additional Details

For the latest information on Microsoft Windows, check out the Microsoft web site at:

https://www.microsoft.com/en-us/windows

For more information about FIPS 140 validations of Microsoft products, please see:

13 Appendix A – How to Verify Windows Versions and Digital Signatures

13.1 How to Verify Windows Versions
The installed version of Windows must be verified to match the version that was validated using the following method:

1. In the Search box type "cmd" and open the Command Prompt desktop app.
2. The command window will open.
3. At the prompt, enter "ver".
4. The version information will be displayed in a format like this:
   Microsoft Windows [Version 10.0.xxxxx]

If the version number reported by the utility matches the expected output, then the installed version has been validated to be correct.

13.2 How to Verify Windows Digital Signatures
After performing a Windows Update that includes changes to a cryptographic module, the digital signature and file version of the binary executable file must be verified. This is done like so:

1. Open a new window in Windows Explorer.
2. Type “C:\Windows\” in the file path field at the top of the window.
3. Type the cryptographic module binary executable file name (for example, “CNG.SYS”) in the search field at the top right of the window, then press the Enter key.
4. The file will appear in the window.
5. Right click on the file’s icon.
6. Select Properties from the menu and the Properties window opens.
7. Select the Details tab.
8. Note the File version Property and its value, which has a number in this format: xx.x.xxxxx.xxxx.
9. If the file version number matches one of the version numbers that appear at the start of this security policy document, then the version number has been verified.
10. Select the Digital Signatures tab.
11. In the Signature list, select the Microsoft Windows signer.
12. Click the Details button.
13. Under the Digital Signature Information, you should see: “This digital signature is OK.” If that condition is true, then the digital signature has been verified.