Code-Signing Tool

User's Guide

Rev. 3.1.0
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About This Book

This manual, the *Code-Signing Tool User's Guide*, provides the details necessary to install, configure, and run the code-signing tool (CST).

Audience

This document provides installation instructions and describes the use of the code signing tools for administrators and engineers performing codes signing for the NXP High Assurance Boot (HAB) and Advanced High Assurance Boot (AHAB) feature.

Scope

This document focuses on the use of the CST to generate keys, certificates, HAB4/AHAB SRK tables, HAB3 SRK hash values and generating data which include digital signatures. The use of the NXP Manufacturing tool to load images and to burn e-fuses are beyond the scope of this document.

Organization

The remainder of this manual is divided into sections according to the main HAB Code Signing Tool user tasks:

- Section 1, "Introduction," describes the background of the code-signing tool and the goals of the procedures in later sections.
- Section 2, "Installation," describes the steps to install the Code-Signing Tool (CST) program files.
- Section 3, "Key and Certificate Generation," details the steps to generate signing keys and certificates for the HAB Version 3, HAB Version 4 and AHAB.
- Section 4, "CST Usage," describes how to use the CST client command line interface.
- Section 5, "CSF Description Language," provides CST description language details required to create a CSF description file.

Two appendices also included:

- Appendix A, "HAB Library Version 3 Details," presents details about CST Certificates, Signature Verification, and a description of the HAB Version 3 constants.
- Appendix B, "Replacing the CST Backend Implementation," presents details about other possible solutions for the CST Backend such as a Hardware Security Module (HSM)

Revision History

Version	Date	Change Description
1.0	11/15/2011	Initial Version
2.0	11/09/2012	Bug fixes and other updates
2.1	4/15/2013	Add Support for HAB4 fast authentication
2.2	10/14//2014	Add note on Linux RNG dependency Add Appendix B containing details on replacing the CST Back End Corrected CA flag documentation
2.3	3/30/2015	Bug fixes related to encrypted images
2.3.1	7/1/2015	Fix for 64-bit version of srktable
2.3.2	3/15/2016	Added support for manufacturing protection Changed input from STDIN to command line argument Made RNG unlock automatic only for CAAM
2.3.3	11/14/2017	Added support for MS Windows Removed support for several commands: Write Data Clear Mask Set Mask Check Clear/Set Set MID
3.0.0	04/04/2018	Added support for AHAB
3.0.1	05/11/2018	Bug fixes related to Windows support
3.1.0	08/2018	Added OpenSSL 1.1.0 support Added ECDSA support for HAB4

		Fix encrypted boot issue

Conventions

Use this section to name, describe, and define any conventions used in the book. This document uses the following notational conventions:

- `Courier monospaced type` indicates commands, command parameters, code examples, expressions, datatypes, and directives.
- *Italic type* indicates replaceable command parameters.
- All source code examples are in C.

Definitions, Acronyms, and Abbreviations

The following list defines the acronyms and abbreviations used in this document.

AES	Advanced Encryption Standard
API	Application Programming Interface
ASN.1	Abstract Syntax Notation One
CA	Certificate Authority
CCM	Counter with CBC-MAC
CSF	Command Sequence File
CMS	Cryptographic Message Syntax
CST	Code-Signing Tool
DEK	Data Encryption Key
DER	ASN.1 Distinguished Encoding Rules
HAB	High Assurance Boot
HAB3	High Assurance Boot Version 3
HAB4	High Assurance Boot Version 4
AHAB	Advanced High Assurance Boot
HSM	Hardware Security Module
MMU	Memory Management Unit
OS	Operating System
PEM	Privacy Enhanced Mail
PKI	Public Key Infrastructure
PKCS	Public Key Cryptography Standards

RVT	ROM Vector Table
RSA	Public key encryption algorithm created by Rivest, Shamir and Adleman
SA	Signature Authority
SHA	Secure Hash Algorithm
SoC	System on Chip
SRK	Super Root Key
SW	Software
UID	Unique ID — a field in the processor and CSF identifying a device or group of devices
WTLS	Wireless Transport Layer Security

References

The following sources were referenced to produce this book:

1. *Open Secure Socket Layer (OpenSSL)*, http://www.openssl.org.
2. *RFC 3369: Cryptographic Message Syntax (CMS),* http://www.ietf.org/rfc/rfc3852.txt
3. *RFC 5280: Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile*, http://www.ietf.org/rfc/rfc5280.txt
4. *RSA Private-Key Cryptography Standard #8 (PKCS #8) - Private-Key Information Syntax Standard*, version 1.2, RSA Laboratories, http://www.rsa.com/rsalabs.
5. *WAP Certificate and CRL Profiles (WAP-211-WAPCert)*, 22-May-2001, http://www.openmobilealliance.org
6. *RFC 3610: Counter with CBC-MAC (CCM)*, http://www.ietf.org/rfc/rfc3610.txt
7. *AES and Combined Encryption/Authentication Modes*, Brian Gladman, http://www.gladman.me.uk/

Additional Documents

The following documents provide additional information on secure boot with NXP processors

8. *High Assurance Boot Version 4 Application Programming Interface Reference Manual*. Included as part of the NXP Reference CST release.
9. *AN4547: Secure Boot on i.MX25, i.MX35, and i.MX51 using HABv3,* http://www.nxp.com
10. *AN4555: Secure Boot with i.MX28 HAB v4,* http://www.nxp.com
11. *AN4581: Secure Boot on i.MX50, i.MX53, and i.MX 6 Series using HABv4,* http://www.nxp.com
12. *i.MX 8 QXP/QM SRM* http://www.nxp.com

1 Introduction

This section introduces code signing for HAB and AHAB using the Code-Signing Tool (CST). The CST allows manufacturers to sign or encrypt the software for their products incorporating NXP processors. Coupled with the HAB or AHAB feature included in NXP processors, the CST can be used to ensure that only genuine or authentic software is allowed to run on the end product. At the moment, AHAB is only used by i.MX 8 QXP/QM families only.

1.1 Code Signing Components

The secure boot feature using HAB or AHAB included in many NXP processors is based on Public Key Infrastructure. The secure systems consist of two main components:

- The HAB library sub-component of NXP Processor Boot ROMs or the AHAB secure sub-system including a dedicated ARM core, ROM and FW.
- The CST

1.1.1 Secure components

The HAB library is a sub-component of the boot ROM and the AHAB component is a complete sub-system on select NXP processors. They are responsible for verifying the digital signatures included as part of the product software and ensures that, when the processor is configured as a secure device, no unauthenticated code is allowed to run. On NXP processors supporting the feature, encrypted boot may also be used to provide image cloning protection and, depending on the use case, image confidentiality. The secure components cannot only be used to authenticate the first stage of the boot chain, but the other components of the boot chain as well. The use of HAB or AHAB is bootloader and OS agnostic. An example is shown in Figure 1 and 2 for a generic boot chain.

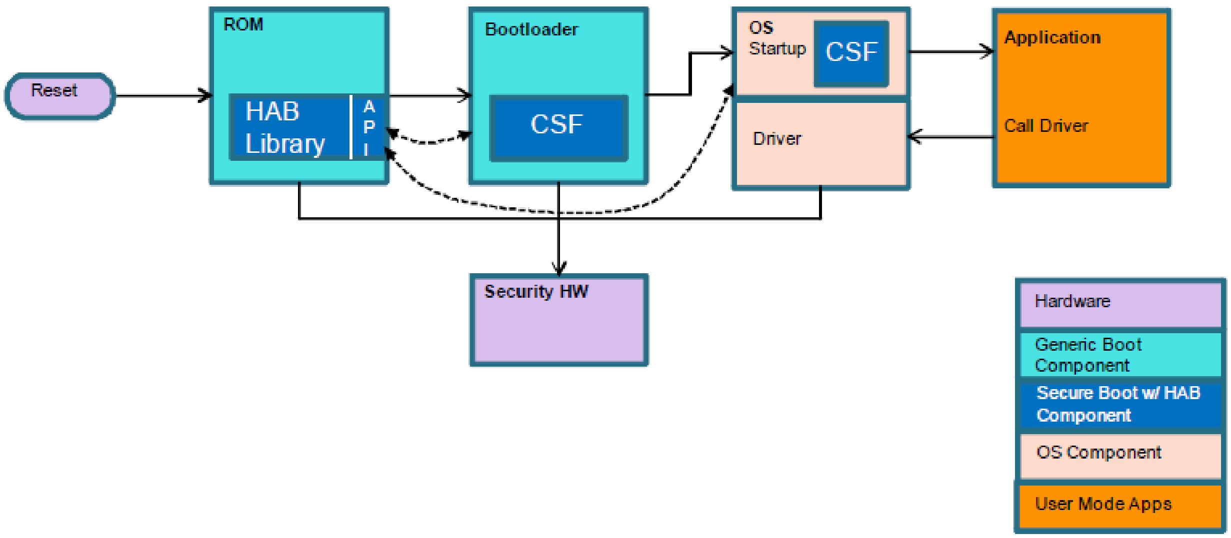


Figure 1. Generic Boot Flow using HAB

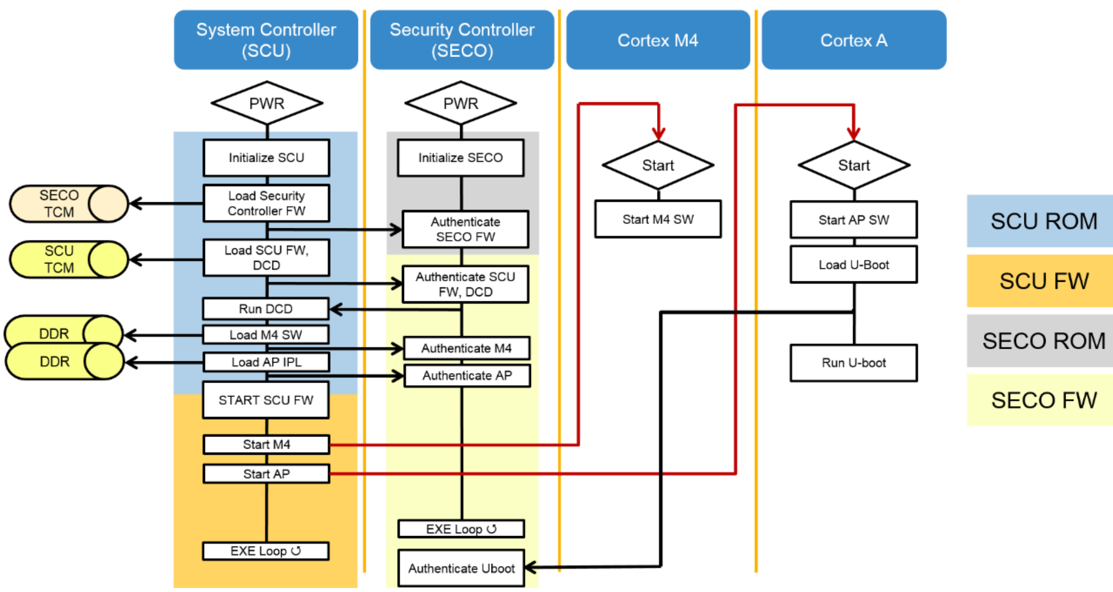


Figure 2. Generic Boot Flow using AHAB (SECO ROM & FW)

The secure boot process starts with the ROM reading eFuses to determine the security configuration of the SoC and the type of the boot device. The ROM then loads the images to memory. For HAB, the bootloader image contains both the bootloader itself in addition to: commands that the HAB uses to verify the image, digital signature data and public key certificate data which are collectively called Command Sequence File (CSF) data. The CSF data is generated off-line using the Code-Signing Tool (CST) which is introduced in the next section. For AHAB, the boot image contains the user-provided images (for the user programmable cores) in addition to a container header and a signature block that the AHAB uses to verify the images, the digital signatures and public key certificate data. The container header is generated off-line, using the mkimage tool that is not described as part of this document. The signature block is generated off-line by the Code Signing Tool (CST) which is introduced in the next section. Once ROM has completed loading the images, execution is then passed to the secure components which will verify the signatures. If signature verification fails, execution is not allowed to leave the ROM for securely configured SoCs. The exact behavior on signature verification failure at the ROM stage is SoC dependent. If all signatures, including image decryption, are successful then execution is passed to the next images which can perform similar steps to verify the next boot stage by calling back into the secure API.

NOTE

> The ROM, HAB and AHAB cannot be changed so they can be considered as trusted software components. This allows the use of ROM, HAB and AHAB to establish a secure boot chain.

HAB and AHAB require the use of physical addresses, so if an MMU and a Level 2 cache are enabled within the bootloader stage then the address translation must be idempotent. This ensures that all boot components provide HAB or AHAB with physical addresses. Once all boot components have been verified, HAB and AHAB are no longer needed and the MMU and Layer 2 cache may be re-configured as required by the Operating System (OS).

The ROM/HAB/AHAB library integration also provides access to the APIs that boot components outside the ROM may call for image verification. The exact implementation of API is SoC dependent so please refer to the Reference Manual for the NXP processor you are using for specific details.

There are three major versions of the secure components that exist on NXP processors: HAB Version 3 (HAB3), HAB Version 4 (HAB4) and AHAB version. Both HAB versions support the flow shown in Figure 1. AHAB version supports the flow shown in Figure 2. HAB3, HAB4 and AHAB use public key signature verification to ensure that product code is authentic. There some differences between these versions which are highlighted in Table 1 below. Please see the reference manual for the NXP processor you are using to determine which version of HAB or AHAB is supported.

Table 1. HAB3 - HAB4 - AHAB Differences

Feature	HAB3	HAB4	AHAB
Image Authentication	Yes	Yes	Yes
Super Root Key	Single, fused hash	Multiple, revocable, fused hash	Multiple, revocable, fused hash
Public Key Type	RSA-2048 (Max)	RSA-4096 (Max)	ECC-P256, ECC-P384, ECC-P521, RSA-2048, RSA-3072, RSA-4096
Certificate Format	WTLS	X.509	NXP proprietary
Signature Format	Proprietary (PKCS#1)	CMS (PKCS#1) CMS (ECDSA) (HAB 4.5 and later)	ECDSA (raw format, no DER encoding), PKCS#1
Hash Algorithm	SHA-1, SHA-256	SHA-256	SHA-256, SHA-384, SHA-512
Image Decryption	No	Yes (HAB4.1 and later)	Not supported yet
Image Decryption Algorithm	N/A	AES-CCM	AES-CCM
Image Decryption Key Blob Algorithm	N/A	NXP proprietary	NXP proprietary
Wrapped Key Format	None	CAAM Blob - Secret keys stored in CAAM secure RAM partition	CAAM Blob – Secret keys stored in CAAM secure RAM partition
Secret Key Type	None	AES-128/192/256	AES-128/192/256
Decryption Algorithm	None	AES-CCM - authenticated decryption	AES-CCM – authenticated decryption
Device Configuration Commands	Write value	Write value Set/Clear bitmask Wait on bitmask	Not applicable
Unlock Commands	None	Field Return Fuse Revocation Fuses Secure JTAG etc.	Not applicable

1.1.1.1 Secure components API

In order to allow boot components outside the ROM to continue the secure boot chain it must be possible for these components to call back into the HAB or AHAB. There are three versions of the API, one for HAB3, one for HAB4 and one for AHAB.

HAB3 API information can be found in System Boot Chapter of either the Reference Manual or Security Reference Manual for the following NXP processors: i.MX25, i.MX35 and i.MX51. This also includes the jump table and vector table location details for each of the API calls.

Information on the HAB4 API can be found in the HAB4 API Reference Manual.

Information on the AHAB API can be found in the i.MX8 QXP/QM SRM.

1.1.2 CST

There are several participants involved when performing cryptographic signatures as illustrated in Figure 2. These include:

- A Certificate Authority (CA). The CA is responsible for protecting the top-level CA key and for certifying lower level code signing keys.
- A Signature Authority (SA). The SA is responsible for performing the act of code signing.
- A Manufacturer. The Manufacturer is responsible for requesting digital signatures across product software

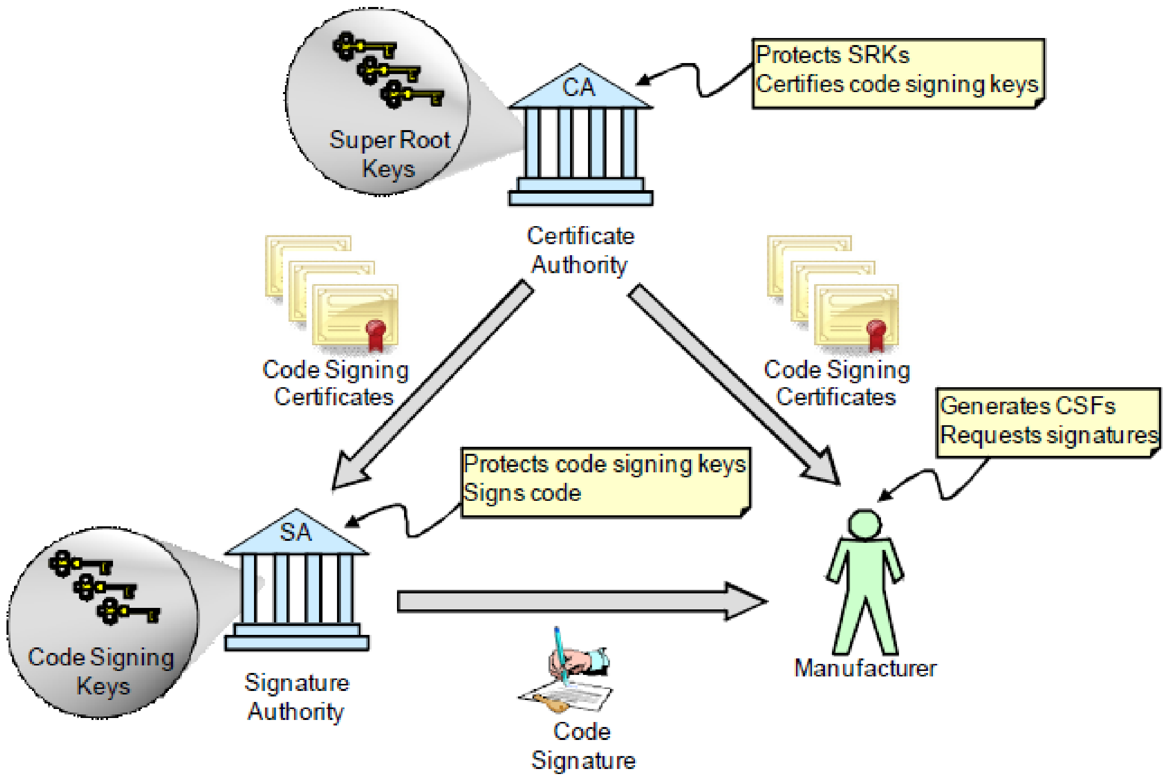


Figure 2. Generic Code Signing Participants

The CST is a set of command line tools residing on a host computer which serves as both the Certificate Authority (CA) and Signature Authority (SA) allowing manufacturers to control all aspects of the signing process.

The CST can establish a PKI tree of keys and certificates (CA function) needed for code signing in addition to generating digital signatures across data provided by a user (SA Function). The signatures generated by the CST can then be included as part of the end-product software image. The signatures are then verified by the secure components on the NXP processor at boot time.

Figure 3 shows how the CST is used to generate data which includes signatures, certificates and CSF commands (HAB only) the secure components in ROM will use to validate the product software. The CST takes two main inputs:

- A binary image or image(s) of the product software to be signed.
- A Command Sequence File (CSF). The CSF description file provides the instructions to the CST on what areas of the binary image need to be signed, which keys to sign the image with, etc.

The CST takes these inputs and generates binary data, which includes signatures, certificates and CSF commands (HAB only) that can then be attached to the product software to create a signed image. This User Guide focuses on the details of how to generate the key, certificates, CSF description files and how to run the CST executable.

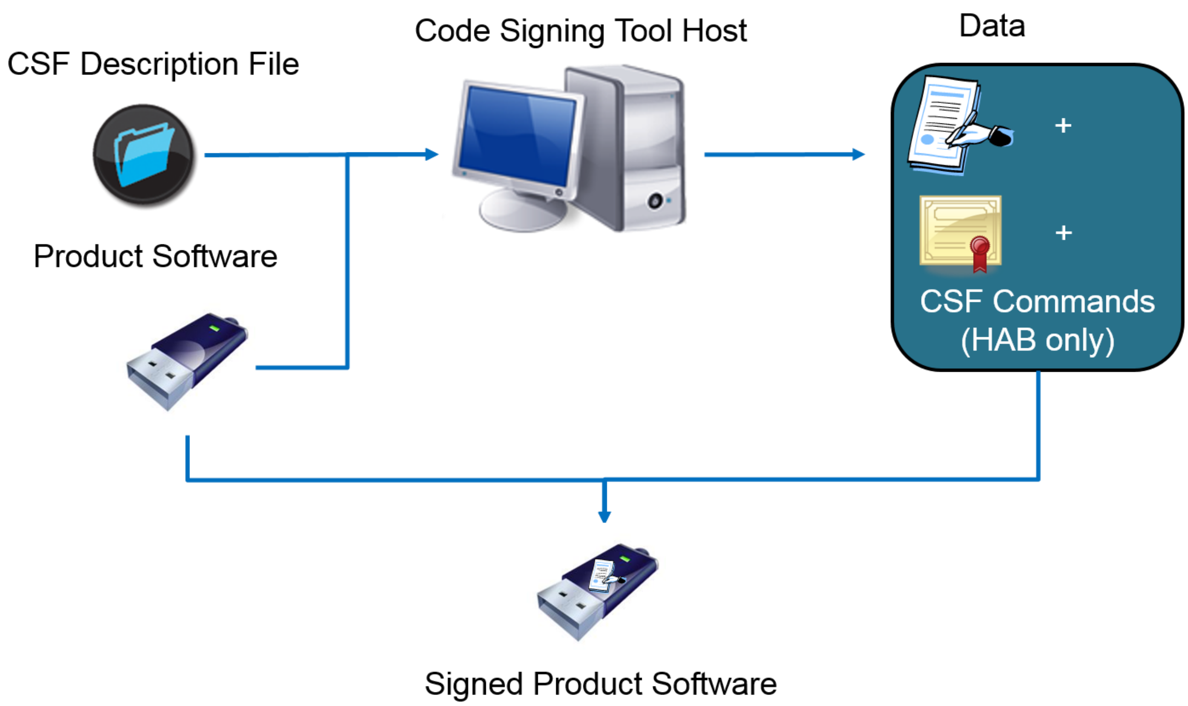


Figure 3. Code-Signing Tool - Digital Signatures

On certain NXP processors supporting HAB4, encrypted boot may also be used. Figure 4 shows the encrypted boot process with the CST. The encrypted boot case is very similar to generating signed images, but there are two main differences. The first is that the binary image is both decrypted and authenticated using a symmetric key rather than signed using a private asymmetric key. The second is the CST generates a one-time AES Data Encryption Key (DEK) which is used to encrypt the image. Note that when performing an encrypted boot digital signatures are still required, see Section 5.3.4 for an example CSF description file. The DEK is independent of the public keys used for code signing. The DEK output from the CST is protected but is not in the final form required for an encrypted boot on NXP processors.

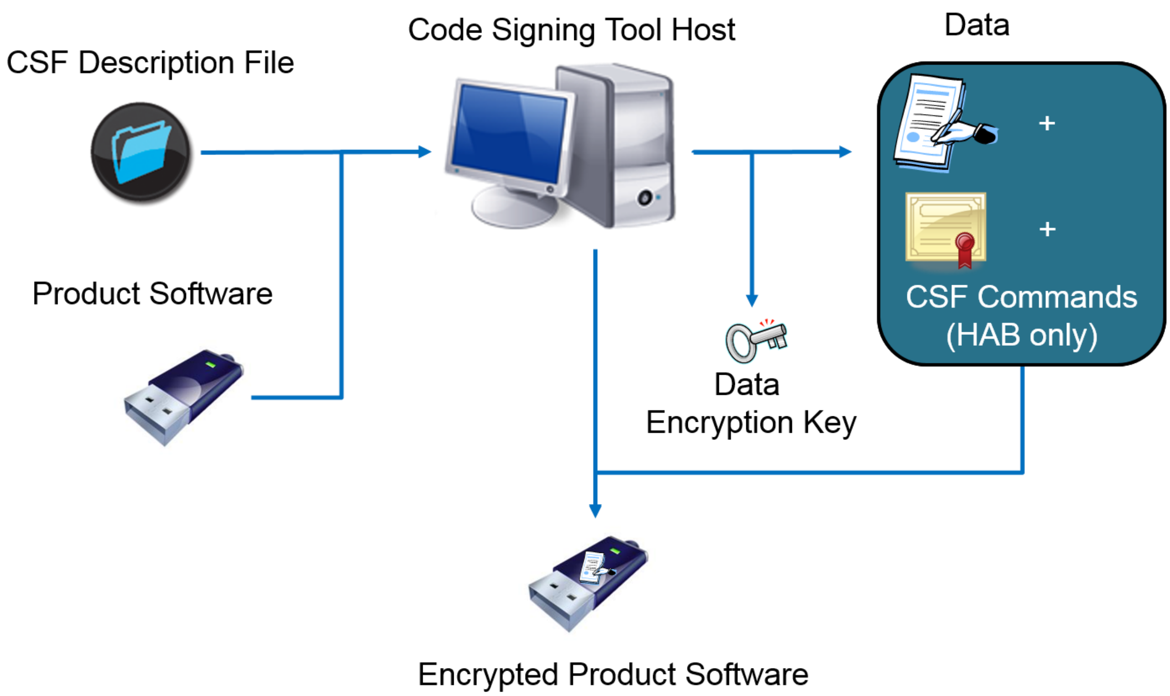


Figure 4. Code Signing Tool - Encrypted Boot

A cryptographic blob of the DEK must be created during the OEM manufacturing stages on each processor and then attached to the image on the boot device. The reason for this is the DEK blob is created using the device unique key embedded into the NXP processor which is only readable by the on-chip encryption engine. The DEK is common to all ICs using the same encrypted image but the DEK blob is unique per IC. Figure 5 provides an overview of DEK blob creation. The remaining details on DEK blob creation are beyond the scope of the CST and this document.

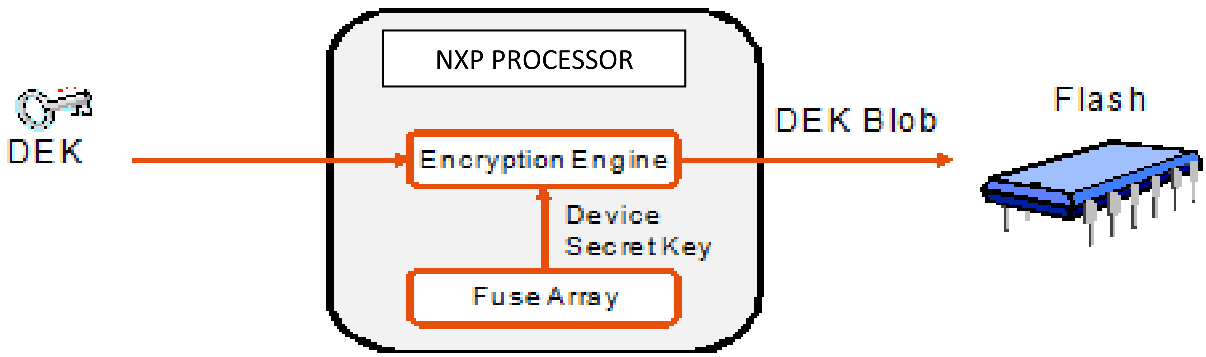


Figure 5. DEK Blob Creation

2 Installation

This section describes the installation of the CST code-signing client files.

2.1 CST Package Contents and Installation

The CST is delivered in an archive file, which contains a version for Linux and a version for Windows. The archive contains a contents.txt file that lists the entire contents of the archive.

2.1.1 Linux System Requirements

The following checklist can be used to ensure appropriate software is available for the Linux CST. Check with your system administrator if any components are missing.

Table 2.a. Linux — CST System Requirements Checklist

Required Component	
❑	A Linux distribution: Ubuntu 14.04 and 16.04 known to work although other distributions should also work but have not been formally tested. • Check by viewing information shown on Linux login screen
❑	GNU objcopy 2.15 or later • Check by running "`objcopy -V`" • Available at http://directory.fsf.org/wiki/Binutils
❑	Even if OpenSSL 1.0.2 is known to work, OpenSSL 1.1.0 or later is recommended for generating signing private keys and public key certificates. • Check by running "`openssl version`" • Available at http://www.openssl.org/

NOTE

The NXP Reference CST uses the Linux OS to generate random numbers for use as keys for encrypted boot. Given this, the Linux host on which the reference CST is installed MUST have good sources of entropy. Generally, this requires multiple entropy sources such as keyboard input, mouse input, network packet arrival times etc. Running the CST without these sources of entropy will cause lengthy delays in seeding the Linux random number generator.

2.1.2 Windows System Requirements

The following checklist can be used to ensure appropriate software is available for the MS Windows CST. Check with your system administrator if any components are missing.

Table 2.b. Windows — CST System Requirements Checklist

	Required Component
❑	Windows 7 32bit and Windows 10 64bit are known to work. • Check by viewing information shown on system panel
❑	Even if OpenSSL 1.0.2 is known to work, OpenSSL 1.1.0 or later is recommended for generating signing private keys and public key certificates. • Check by running "`openssl version`" • Available at http://www.openssl.org/ Note: OpenSSL 1.0.2 can be used with the restriction to convert the password file ("key_pass.txt") to Unix format. The small tool `convlb.exe` that can be found within the keys directory does this conversion when using the script for generating the keys. Note: it may happen that the OpenSSL Windows installer does not set the PATH environment variable. Please make sure this variable is set to the OpenSSL bin directory.

NOTE

The NXP Reference CST uses the Windows OS to generate random numbers for use as keys for encrypted boot. Given this, the Windows host on which the reference CST is installed MUST have good sources of entropy. Generally, this requires multiple entropy sources such as keyboard input, mouse input, network packet arrival times etc. Running the CST without these sources of entropy will cause lengthy delays in seeding the Windows random number generator.

2.1.3 Unpacking the Files

Unpack the CST archive to the desired installation point. The following is an example for Linux and assumes that the client archive was saved in a directory named /home/<*username*>/cst:

```
%cd /home/<username>/cst/
%tar -zxvf <release package name>.tgz
```

This creates the following directories:

ca/

Contains the OpenSSL configuration files. These configuration files are used when generating signing keys and certificates with the OpenSSL command line tool.

code/

The `/backend` directory contains the source and headers necessary for replacing the open source cryptographic libraries with a different implementation.

The `/back_end-hsm` directory contains the sources and headers necessary for replacing the open source cryptographic libraries with an implementation that can interact directly with an Hardware Security Module (HSM) by using the PKCS#11 interface definition. More detailed information can be found in the README file located in the directory.The `/hab_csf_parser` directory contains the sources and headers necessary to build a parser of the HAB CSF binaries generated by CST. More detailed information can be found in the README file located in the directory.

The `/hab_srktool_scripts` directory contains scripts that mimic the SRKTOOL executable behavior. More detailed information can be found in the README file located in the directory.

The `/hab3` directory contains the header defining the data structure for the Super Root Key required when building signed images for NXP processors containing HAB version 3.

crts/

Contains the public key certificates used for signing. Initially this directory is empty.

docs/

Contains the CST release notes and this user guide.

linux32/

Contains the CST executables for 32-bit Linux OS:

`bin/cst` — The CST executable used to sign code

`bin/srktool`— Generate SRK table and e-fuse files for HAB4 or AHAB. Generates SRK e-fuse information for HAB3.

`bin/x5092wtls` — Converts X.509 certificates to equivalent WTLS certificates required for HAB3.

`bin/hab_log_parser` — Parse HAB persistent memory dumps and print out the HAB events.

`/lib` — Contains library files needed for replacing the CST backend implementation.

linux64/

Contains the CST executables for 64-bit Linux OS:

`bin/cst` — The CST executable used to sign code

`bin/srktool`— Generate SRK table and e-fuse files for HAB4 or AHAB. Generates SRK e-fuse information for HAB3.

`bin/x5092wtls` — Converts X.509 certificates to equivalent WTLS certificates required for HAB3.

`bin/hab_log_parser` — Parse HAB persistent memory dumps and print out the HAB events.

`/lib` — Contains library files needed for replacing the CST backend implementation.

keys/

Contains the private key files used for signing. Initially this directory contains scripts to generate the PKI tree:

`hab3_pki_tree.sh` — Use to generate a series of keys and certificates on a Linux machine for use with a NXP processor supporting HAB3.

`hab3_pki_tree.bat` — Use to generate a series of keys and certificates on a Windows machine for use with a NXP processor supporting HAB3.

`hab4_pki_tree.sh` — Use to generate a series of keys and certificates on a Linux machine for use with a NXP processor supporting HAB4.

`hab4_pki_tree.bat` — Use to generate a series of keys and certificates on a Windows machine for use with a NXP processor supporting HAB4.

`ahab_pki_tree.sh` — Use to generate a series of keys and certificates on a Linux machine for use with a NXP processor supporting AHAB.

`ahab_pki_tree.bat` — Use to generate a series of keys and certificates on a Windows machine for use with a NXP processor supporting AHAB.`add_key.sh` — Use to add new keys to an existing HAB3 or HAB4 PKI tree.

`convlb.exe` — Use to convert the line breaks of Windows text files to Unix format. Use to workaround OpenSSL 1.0.2 limitations with file handling.

mingw32/

Contains the CST executables for MS Windows:

`bin/cst.exe` — The CST executable used to sign code

`bin/srktool.exe`— Generate SRK table and e-fuse files for HAB4 or AHAB. Generates SRK e-fuse information for HAB3.

`bin/x5092wtls.exe` — Converts X.509 certificates to equivalent WTLS certificates required for HAB3.

`/lib` — Contains library files needed for replacing the CST backend implementation.

Once the archive is unpacked, there are no additional installation steps required in order to use the CST.

3 Key and Certificate Generation

Once the CST installation is complete. The first step in signing code is generating private keys and certificates. The CST is not delivered with keys or certificates since these will be different for each manufacturer and perhaps even each product line.

The NXP reference CST generates keys by making use of the OpenSSL command line tool and a set of shell scripts for Linux. This makes OpenSSL the CA component shown in Figure 2. The provided scripts illustrate how to generate a PKI tree of keys and certificates. There are three sets of scripts generating an initial PKI tree. One for HAB3, one for HAB4 and one for AHAB. The reason for this is that the PKI tree structure is different for each version as well as the final public key certificate format. HAB3 requires public key certificates to be in WTLS [5] format where HAB4 and AHAB requires X.509 [3] format certificates. The provided key and certificate generation scripts are for reference to illustrate how they should be generated with OpenSSL. Users may update these scripts or replace these scripts with something equivalent if required.

CAUTION

The NXP reference CST requires a one-to-one correspondence between the key names in the /keys directory and the certificates in /crts directory. The convention is <keyname>_key.<ext> for keys and <keyname>_crt.<ext> for certificates. For example, a key named keys/SRK1_sha256_2048_65537_v3_ca_key.der must have a corresponding certificate crts/SRK1_sha256_2048_65537_v3_ca_crt.der.

3.1 Generating HAB3 Keys and Certificates

This section covers key and certificate generation for HAB3.

3.1.1 HAB3 PKI Tree

The tree structure for HAB3 generated by the `hab3_pki_tree.sh` script for Linux. This script will generate a HAB3 PKI tree as shown in Figure 6 and is in the /keys directory of the

NXP Reference CST.

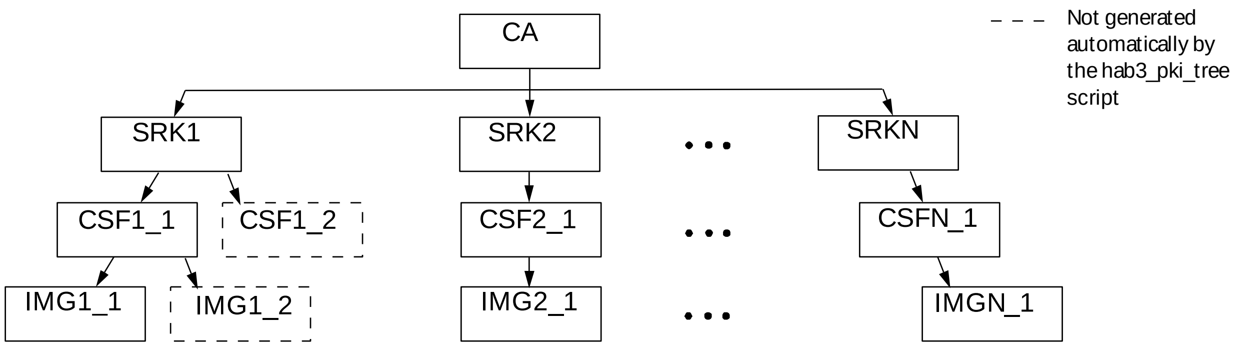


Figure 6. HAB3 PKI Tree

A HAB3 PKI tree consists of the following keys and certificates:

- CA key: is the top most key and is only used for signing SRK certificates.
- SRK: is the root key for HAB code signing keys. The cryptographic hash of this key is burned to one-time programmable efuses to establish a root of trust. The SRK must not be used for signing image code. Since the hash of the SRK is blown to efuses on the NXP processor only one SRK may be used for a product or product line.
- CSF: is a subordinate key of the SRK and is used to verify the signature across CSF commands and to verify signatures of image key certificates.
- IMG: is a subordinate key of the CSF key. Image keys are used to verify signatures across product software.

The hab3_pki_tree script generates a basic tree in which up to a maximum of four SRKs may be generated. For each SRK a single CSF key and IMG key are also generated. Additional keys may be added to the tree later. It is also possible to replace the OpenSSL and the hab3_pki_tree script with an alternative key generation solution, but this is beyond the scope of this document. If the key generation scheme described here is replaced a new scheme must follow these constraints:

- Keys must be in PKCS#8 format
- Certificates must be in WTLS format
- Keys and Certificates must follow the file naming convention specified in the caution message found in Section 3, "HAB Key and Certificate Generation".

3.1.2 Running the hab3_pki_tree script Example

The following are the steps to generate a HAB3 PKI tree for Linux.

1. `cd <CST Installation Path>/keys`
2. Using your favorite text editor create a file called 'serial' in the /keys directory with contents 12345678. OpenSSL uses the contents of this file for the certificate serial numbers. You may choose to use another number for the initial certificate serial number.

3. Using your favorite text editor create a file called 'key_pass.txt' in the /keys directory. This file contains your pass phrase that will protect the HAB code signing private keys. The format of this file is the pass phase repeated on the first and second lines of the file. For example:

   my_pass_phrase

   my_pass_phrase

   NOTE

   Failure to generate the serial and key_pass.txt files prior to running the hab3_pki_tree script will result in OpenSSL errors and the script will fail to generate the requested tree.

   CAUTION

   It is up to the user how best to protect the pass phrase for the private keys. Loss of the pass phrase will result in not being able to sign code with the affected keys.

   NOTE

   Note that OpenSSL enforces that the pass phrase must be at least four characters long.

4. Prior to running the `hab3_pki_tree.sh` ensure that OpenSSL is included in your search path by running:

   ```
   > openssl version
   ```

5. Run the `hab3_pki_tree.sh` script. The script will ask a series of questions:

   — Do you want to use an existing CA key (y/n)?
     – Choose no here unless you already have an existing CA key.
     – If you choose yes, the script will ask you to provide the filenames (including path information) to the location of the CA key and corresponding CA public key certificate.

   — Enter key length in bits for PKI tree:
     – This is the length in bit for the keys in the tree. For HAB3 1024 and 2048-bit RSA keys are supported. All keys in the tree are generated with the same length.

   — Enter PKI tree duration (years):
     – This defines the validity period of the corresponding certificates.

   — How many Super Root Keys should be generated?
     – Up to four SRKs may be generated by this script. This allows for different SRKs to be used for different product lines for example.

   At this point the script will generate the SRK, CSF and IMG keys and certificates in the /keys and /crts directory. The generated keys will exist in PKCS#8 [4] format in both PEM and DER forms. The CST will accept key files in either form. Although the script generates the public key certificates in the /crts in both X.509 [3]and WTLS [5] formats, the CST uses the WTLS certificates only for HAB3. The WTLS certificates exist only in binary format.

NOTE

> You may notice that there are a number of pem files such as 12345678.pem, serial.old, index.txt.attr and so on. These files are left over from the OpenSSL key and certificate generation process.

Figure 7 below illustrates the use of the hab3_pki_tree script.

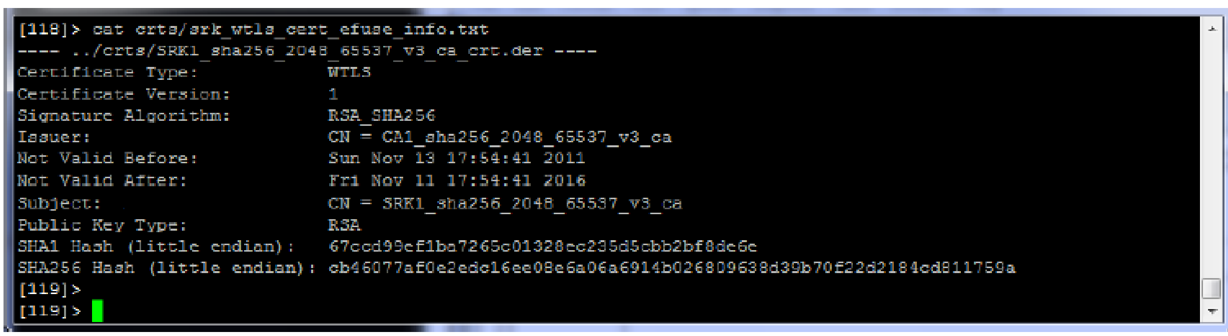
```
[94]> ./hab3_pki_tree.sh

    +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    This script is a part of the Code signing tools for Freescale's
    High Assurance Boot.  It generates a basic HAB3 PKI tree.
    The PKI tree consists of one or more Super Root Keys (SRK),
    with each SRK having a one subordinate Command Sequence File
    (CSF) key.  Each CSF key Image key then has one subordinate.
    Image key.  Additional keys can be added to the PKI tree but a
    separate script is available for this.  This script
    assumes openssl is installed on your system and is included in
    your search path.  Note that this script automatically generates
    the WTLS certificates required for HAB3.
    Finally, the private keys generated are password
    protected with the password provided by the file key_pass.txt.
    The format of the file is the password repeated twice:
        my_password
        my_password
    All private keys in the PKI tree will be protected by the same
    password.

    +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Do you want to use an existing CA key (y/n)?: n
Enter key length in bits for PKI tree: 2048
Enter PKI tree duration (years): 5
How many Super Root Keys should be generated? 1

+++++++++++++++++++++++++++++++++++++
+ Generating CA key and certificate +
+++++++++++++++++++++++++++++++++++++

Generating a 2048 bit RSA private key
................................+++
................................................................................
............+++
writing new private key to './temp_ca.pem'
-----

++++++++++++++++++++++++++++++++++++++++
+ Generating SRK key and certificate 1 +
++++++++++++++++++++++++++++++++++++++++

Generating RSA private key, 2048 bit long modulus
................................................................................
................................................+++
.................+++
e is 65537 (0x10001)
Using configuration from ../ca/openssl.cnf
Check that the request matches the signature
```

Figure 7. Example Usage of the hab3_pki_tree Script

In addition to the keys and certificates there are additional files created which are required for generating signed images for HAB3. These include:

— SRK C files: The script generates a C data structure containing the RSA public key exponent and modulus data. For the example above the file /crts/SRK1_sha256_2048_65537_v3_ca_crt.der.c is generated. This file in addition to the `/hdr/hab_super_root.h` file can be included as part of a signed image. This data structure is pointed to by the super root pointer of the ROM application header. Please see the System Boot chapter of the NXP processor that you are using for further details.

— srk_wtls_cert_efuse_info.txt: This file contains the certificate information in addition to a SHA-1 and SHA-256 hash value of the modulus and exponent for each SRK generated. This is the hash value that must be burned to the SRK_HASH fuse field. The results are displayed in little endian meaning the first byte of the hash listed is to be burned to the lowest SRK_HASH address which corresponds to SRK_HASH[255:248] and the last byte of the hash corresponds to SRK_HASH[7:0]. See Section 3.1.3, “Programming the SRK Hash Value to Efuses” for further details.



```
[118]> cat crts/srk_wtls_cert_efuse_info.txt
---- ../crts/SRK1_sha256_2048_65537_v3_ca_crt.der ----
Certificate Type:             WTLS
Certificate Version:          1
Signature Algorithm:          RSA_SHA256
Issuer:                       CN = CA1_sha256_2048_65537_v3_ca
Not Valid Before:             Sun Nov 13 17:54:41 2011
Not Valid After:              Fri Nov 11 17:54:41 2016
Subject:                      CN = SRK1_sha256_2048_65537_v3_ca
Public Key Type:              RSA
SHA1 Hash (little endian):    67ccd99cf1ba7265c01328cc235d5cbb2bf8dc6c
SHA256 Hash (little endian):  cb46077af0e2edc16ee08e6a06a6914b026809638d39b70f22d2184cd811759a
[119]>
[119]>
```

Figure 8. Example Output for srk_wtls_cert_efuse_info.txt

At this point all key and certificate information required for signing an image for HAB3 is now available.

3.1.3 Programming the SRK Hash Value to Efuses

The previous section provided the details on how to generate keys and certificated for HAB3 code signing. Included as part of the certificate generation process is the computation of the hash value for each SRK. This hash value is intended to be burned to the SRK_HASH Efuse field on the SoC supporting HAB3 and is computed automatically by the hab3_pki_tree script using the `x5092wtls` tool.

The hash value as shown in Figure 8 must be burned to the SoC Efuses in the following order:

```
SRK_HASH[255:248] = 0xcb
SRK_HASH[247:240] = 0x46
SRK_HASH[239:232] = 0x07
...
SRK_HASH[15:8] = 0x75
SRK_HASH[7:0] = 0x9a
```

Figure 9. SRK Hash Value Assignment to SoC SRK_HASH Efuse Field for HAB3

Please refer to the fuse map for the NXP processor you are using for location details of the SRK_HASH field.

3.1.4 Adding a Key to a HAB3 PKI Tree

Adding to an existing HAB3 PKI tree can be done using the add_key script. The following steps are used to add a new key:

1. Run the `add_key.sh` script for Linux. The script will prompt you with several questions:
   - Which version of HAB/AHAB do you want to generate the key for (3/4/a)?
   - Enter 3 here for HAB3
   - Enter new key name (e.g. SRK5):
     - This the name of the new key, such as SRK2, CSF1_2, etc.
   - Enter new key length in bits:
     - This is the length of the new key in bits. This should match the key length of the signing key.
   - Enter certificate duration (years):
     - This defines the validity period for the corresponding certificate generated
   - Which version of HAB do you want to generate the key for (3/4)?
     - Enter 3 here for HAB3
   - Is this an SRK key?
     - If you are generating a new SRK enter ‘y’, otherwise enter ‘n’
     - If you enter no you will be prompted with “Is this a CSF key?”. Like the SRK enter ‘y’ if you are generating a CSF key and ‘n’ if you are generating an IMG key.
     - Note that if you are generating a new SRK the `./crts/srk_wtls_cert_efuse_info.txt` is automatically updated with the certificate information including the SRK hash value.
   - Enter <key type> signing key name:
     - If you are generating an new SRK <key type> is CA. Enter the path and filename of the CA key in the /keys directory.

- If you are generating a new CSF key <key type> is SRK. Enter the path and filename of the SRK in the /keys directory you wish to use to generate the CSF key.
- If you are generating a new IMG key <key type> is CSF. Enter the path and filename of the CSF key in the /keys directory you with to use to generate the IMG key.

— Enter <cert type> signing certificate name:

- If you are generating a new SRK certificate the <cert type> is CA. Enter the path and filename of the CA certificate in the /crts directory.
- If you are generating a new CSF certificate <cert type> is SRK. Enter the path and filename of the SRK certificate in the /certs directory you wish to use to generate the CSF certificate. Note this ***must*** be the filename of the SRK X.509 certificate not the SRK WTLS certificate.
- If you are generating a new IMG certificate <cert type> is CSF. Enter the path and filename of the CSF certificate in the /certs directory you wish to use to generate the IMG certificate. Note this ***must*** be the filename of the CSF X.509 certificate not the CSF WTLS certificate.

Using the example from the previous section Figure 10 below shows how to add a new SRK key to the PKI tree.

```
[125]> ./add_key.sh
Enter new key name (e.g. SRK5): SRK2
Enter new key length in bits: 2048
Enter certificate duration (years): 5
Which version of HAB do you want to generate the key for (3/4)?: 3
Is this an SRK key?: y
Enter CA signing key name: CA1_sha256_2048_65537_v3_ca_key.pem
Enter CA signing certificate name: ../crts/CA1_sha256_2048_65537_v3_ca_crt.pem
Generating RSA private key, 2048 bit long modulus
.........................+++
.............................................+++
e is 65537 (0x10001)
Using configuration from ../ca/openssl.cnf
Check that the request matches the signature
Signature ok
The Subject's Distinguished Name is as follows
commonName            :ASN.1 12:'SRK2_sha256_2048_65537_v3_ca'
Certificate is to be certified until Nov 12 01:54:22 2016 GMT (1825 days)

Write out database with 1 new entries
Data Base Updated
[126]>
```

Figure 10. Adding a New SRK to a HAB3 PKI Tree Example

CAUTION

Do not run this script without first generating a HAB3 PKI tree. Failure to do so will result in errors.

3.2 Generating HAB4 Keys and Certificates

This section covers only key and certificate generation for HAB4. Note that when using making use of the encrypted boot feature digital signatures are still required. Data structures required by ROM and HAB cannot be encrypted but still must be covered by a valid digital signature. Also, a new symmetric key is dynamically generated by the CST for each Install Secret Key/Decrypt Data command pair. These symmetric keys are an output of the CST and encrypted with a supplied public key. See Section 5.3.4 for an example encrypted boot CSF file.

3.2.1 HAB4 PKI Tree

The tree structure for HAB4 generated by the `hab4_pki_tree.sh` script for Linux. This script will generate a HAB4 PKI tree as shown in Figure 11 and is located in the /keys directory of the NXP Reference CST.

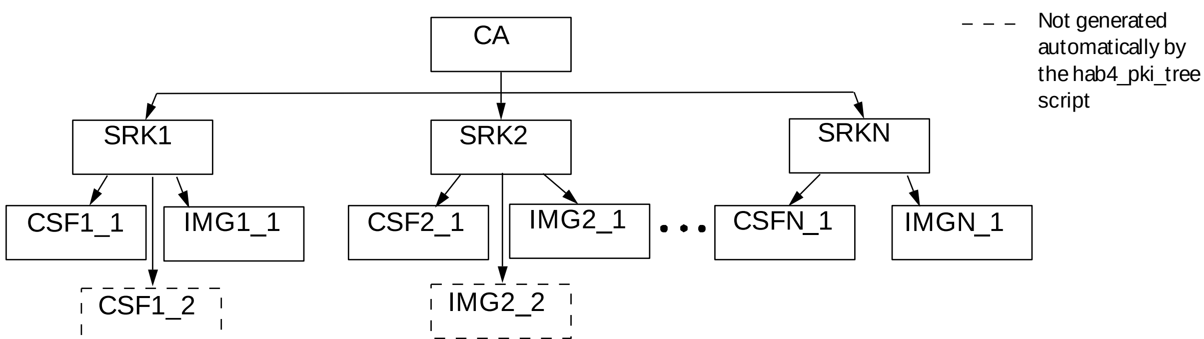


Figure 11. HAB4 PKI Tree

A HAB4 PKI tree consists of the following keys and certificates:

- CA key: is the top most key and is only used for signing SRK certificates.
- SRK: is the root key for HAB code signing keys. The cryptographic hash of a table of SRK is burned to one-time programmable efuses to establish a root of trust. Only one of the SRKs in the table may be selected for use on the NXP processor per reset cycle. The selection of which SRK to use is a parameter within the Install Key CSF command (see Section 5.2.2, "Install SRK"). The SRK may only be used for signing certificate data of subordinate keys.
- CSF: is a subordinate key of the SRK and is used to verify the signature across CSF commands.
- IMG: is a subordinate key of the SRK key and is used to verify signatures across product software.

- NOTE: The CSF and IMG keys are not generated for a fast authentication PKI tree

The hab4_pki_tree script generates a basic tree in which up to a maximum of four SRKs may be generated. For each SRK a single CSF key and IMG key are also generated. Additional keys may be added to the tree later using a separate script. It is also possible to replace the OpenSSL and the hab4_pki_tree script with an alternative key generation solution, but this is beyond the scope of this document. If the key generation scheme described here is replaced a new scheme must follow these constraints:

- Keys must be in PKCS#8 format
- Certificates must be in X.509 format following the certificate profile specified by HAB4. Keys and Certificates must follow the file naming convention specified in Section 3, “HAB Key and Certificate Generation”.

3.2.2 Running the hab4_pki_tree script Example

The following are the steps to generate a HAB4 PKI tree for Linux.

2. `cd <CST Installation Path>/keys`
3. Using your favorite text editor create a file called ‘serial’ in the /keys directory with contents 12345678. OpenSSL uses the contents of this file for the certificate serial numbers. You may choose to use another number for the initial certificate serial number.
4. Using your favorite text editor create a file called ‘key_pass.txt’ in the /keys directory. This file contains your pass phrase that will protect the HAB code signing private keys. The format of this file is the pass phase repeated on the first and second lines of the file. For example:

   my_pass_phrase

   my_pass_phrase

NOTE

Failure to generate the serial and key_pass.txt files prior to running the hab4_pki_tree script will result in OpenSSL errors and the script will fail to generate the requested tree.

CAUTION

It is up to the user how best to protect the pass phrase for the private keys. Loss of the pass phrase will result in not being able to sign code with the affected keys.

NOTE

Note that OpenSSL enforces that the pass phrase must be at least four characters long.

5. Prior to running the `hab4_pki_tree.sh` ensure that OpenSSL is included in your search path by running:
   `> openssl version`
6. Run the `hab4_pki_tree.sh` script. The script will ask a series of questions:
   - Do you want to use an existing CA key (y/n)?
     - Choose no here unless you already have an existing CA key.
     - If you choose yes, the script will ask you to provide the filenames (including path information) to the location of the CA key and corresponding CA public key certificate.
   - Do you want to use Elliptic Curve Cryptography (y/n)?:
     - If "n", Enter key length in bits for PKI tree:
       - This is the length in bit for the keys in the tree. For HAB4 1024, 2048, 3072 and 4096-bit RSA keys are supported. All keys in the tree are generated with the same length.
     - If "y", Enter length for elliptic curve to be used for PKI tree: Possible values p256, p384, p521:
       - This is the length in bit for the keys in the tree. For HAB4 P256, P384 and P521 EC keys are supported. All keys in the tree are generated with the same length.
   - Enter PKI tree duration (years):
     - This defines the validity period of the corresponding certificates.
   - How many Super Root Keys should be generated?
     - Up to four SRKs may be generated by this script. This allows for up to four SRKs to be included in a HAB4 SRK table. See Section 4.2, "SRK Tool" for further details.
   - Do you want the SRK certificates to have the CA Flag set?
     - Answer 'y' for a standard tree, 'n' for fast authentication tree.

   At this point the script will generate the SRK, CSF and IMG keys and certificates in the /keys and /crts directory. The generated keys will exist in PKCS#8 [4] format in both PEM and DER forms. Certificates are located in the /crts directory X.509 [3] format in both PEM and DER format. The `cst` will accept key and certificate files in either PEM or DER form.

NOTE

> You may notice that there are a number of pem files such as 12345678.pem, serial.old, index.txt.attr and so on. These files are left over from the OpenSSL key and certificate generation process.

Figure 12 below illustrates the use of the hab4_pki_tree script.

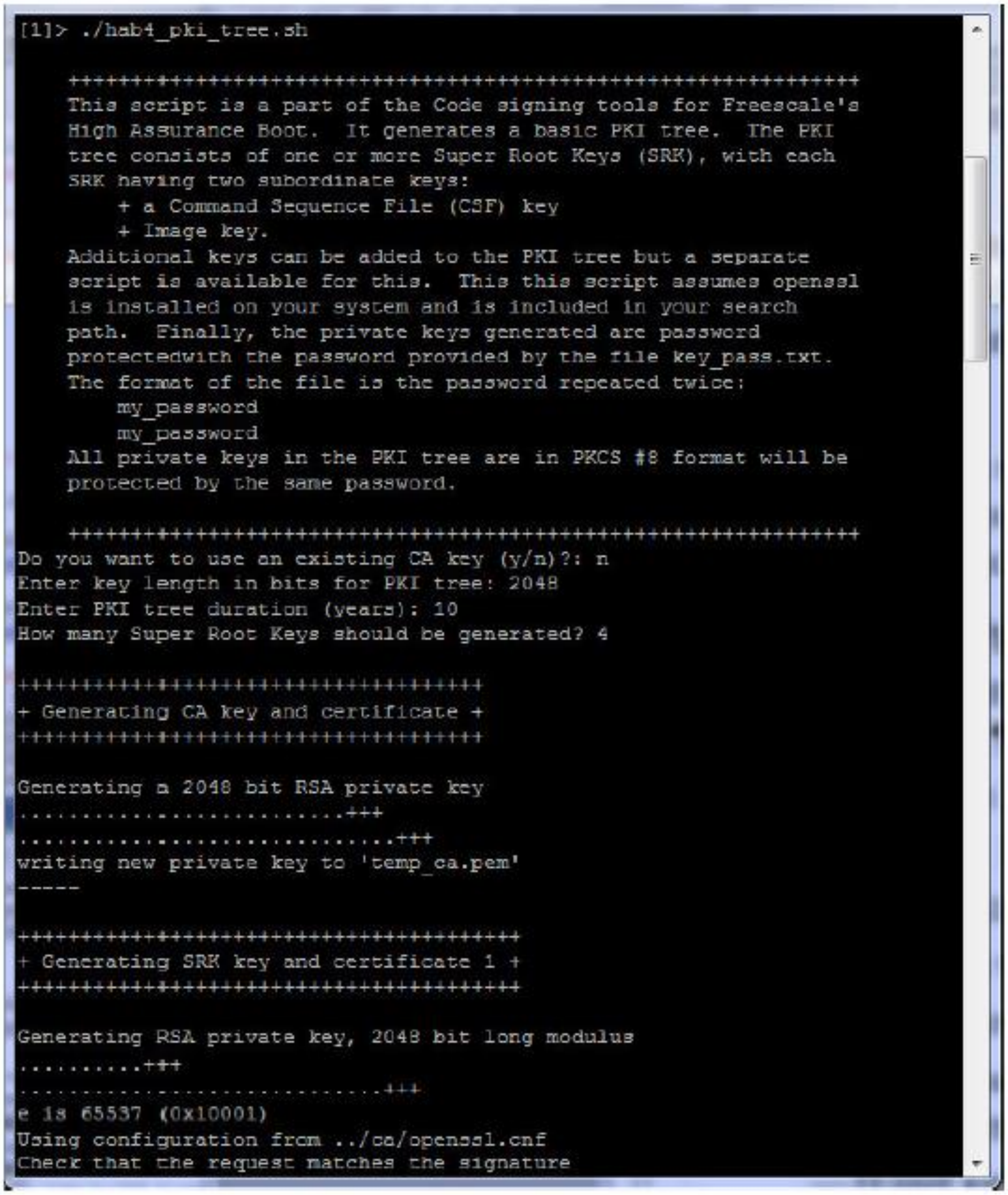


Figure 12. Example Usage of the hab4_pki_tree Script

At this point all key and certificate information required for signing an image for HAB4 is now available.

3.2.3 Generating HAB4 SRK tables and Efuse Hash

The previous section discussed the steps to generate the keys and certificates for a HAB4 PKI tree. Now that they have been generated, the next step is to generate a HAB4 SRK table and corresponding hash value for burning to efuses on the SoC. Unlike HAB3, in HAB4 it is possible to include up to four SRKs in a signed image, although only one may be used per reset cycle. By collecting SRKs in a table it is possible to select one of the SRKs at boot time. The Install SRK CSF command (see Section 5.2.2, "Install SRK") selects which SRK to use from the table to establish the root of trust. Any of the SRKs in the table may be selected without having to change the SRK_HASH value burned to efuses on the SoC.

This is useful on NXP processors where additional fuses are available for SRK revocation. That is, in the event one or more of the SRKs in the table are compromised, efuses corresponding to the compromised keys can be burned preventing those SRKs from ever being used again. This is enforced by the HAB library. The next SRK in the table can be used to sign new images. A minimum of one and maximum of four SRKs can be placed in an SRK table.

NOTE

Only the first three SRKs in a table can be revoked, so it recommended to use an SRK table with four keys in order to have one SRK to fall back on which cannot be revoked.

SRK tables are generated using the `srktool`. The following illustrates the generation of an SRK table from the /crts directory using the four SRKs created in the previous section.

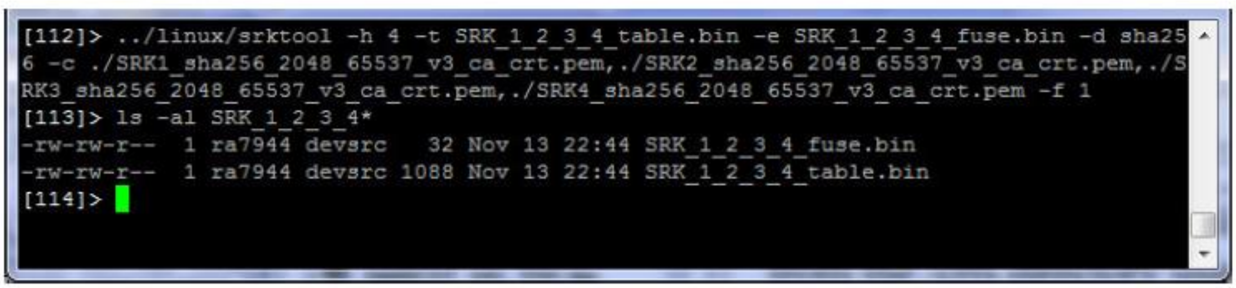


Figure 13. SRK Table and Efuse Generation Example

In this example:

- All four SRKs are included in the table
- The SHA-256 hash value is generated with 32 bit of fuse data per word. Some NXP processors require the hash value to be generated with 8 bits of fuse data per word. In that case use the '-f 0' option.
- The hash result in the resulting `SRK_1_2_3_4_fuse.bin` file is in little endian format. This means that the first byte in the file corresponds to SRK_HASH[255:248] and the last byte corresponds to SRK_HASH[7:0] in the efuse map. Similarly when using the '-f 0' option the first non-zero byte in the file corresponds to SRK_HASH[255:248] and the last non-zero byte corresponds to SRK_HASH[7:0].

CAUTION

Do not enter spaces between the ',' when specifying the SRKs in the -c or --certs option. Doing so will cause all certificates specified after the first space ***not*** to be included in the table and resulting efuse hash.

3.2.4 Programming the SRK Hash Value to Efuses

The previous section provided the details on how to SRK tables and the corresponding efuse data. In this section the hash value is of interest. The value located in the efuse file is intended to be burned to the SRK_HASH efuse field on the SoC supporting HAB4 and is computed automatically by the hab4_pki_tree script using the `srktool`. The `SRK1_2_3_4_fuse.bin` file from the example in the previous section has the following contents:

93ea61d0bd30ffb62aba0b9d5e144d082dd7faeb39223d9e3f9a22a06429895a

This hash value must be burned to the SoC efuses in the following order:

```
SRK_HASH[255:248] = 0x93
SRK_HASH[247:240] = 0xea
SRK_HASH[239:232] = 0x61
...
SRK_HASH[15:8] = 0x89
SRK_HASH[7:0] = 0x5a
```

Figure 14. SRK Hash Value Assignment to SoC SRK_HASH Efuse Field for HAB4

Please refer to the fuse map for the NXP processor you are using for location details of the SRK_HASH field.

3.2.5 Adding a Key to a HAB4 PKI Tree

Adding to an existing HAB4 PKI tree can be done using the add_key script. The following steps are used to add a new key:

1. Run the `add_key.sh` script for Linux. The script will prompt you with several questions:
   - Which version of HAB/AHAB do you want to generate the key for (3/4/a)?
     - Enter 4 here for HAB4
   - Enter new key name (e.g. SRK5):
     - This the name of the new key, such as SRK2, CSF1_2, etc.
   - Enter new key length in bits:
     - This is the length of the new key in bits. This should match the key length of the signing key.
   - Enter certificate duration (years):
     - This defines the validity period for the corresponding certificate generated
   - Which version of HAB do you want to generate the key for (3/4)?

- Enter 4 here for HAB4

- Is this an SRK key?
  - If you are generating a new SRK enter ‘y’, otherwise enter ‘n’
  - If you enter no you will be prompted with “Is this a CSF key?”. Like the SRK enter ‘y’ if you are generating a CSF key and ‘n’ if you are generating an IMG key.
- Enter <key type> signing key name:
  - If you are generating a new SRK <key type> is CA. Enter the path and filename of the CA key in the /keys directory.
  - If you are generating a new CSF key <key type> is SRK. Enter the path and filename of the SRK in the /keys directory you wish to use to generate the CSF key.
  - If you are generating a new IMG key <key type> is CSF. Enter the path and filename of the CSF key in the /keys directory you with to use to generate the IMG key.
- Enter <cert type> signing certificate name:
  - If you are generating a new SRK certificate the <cert type> is CA. Enter the path and filename of the CA certificate in the /crts directory.
  - If you are generating a new CSF certificate <cert type> is SRK. Enter the path and filename of the SRK certificate in the /certs directory you wish to use to generate the CSF certificate.
  - If you are generating a new IMG certificate <cert type> is CSF. Enter the path and filename of the CSF certificate in the /certs directory you wish to use to generate the IMG certificate.

Using the keys generated in Section 3.2.2, “Running the hab4_pki _tree script Example”, Figure 15 below shows how to add a new SRK key to the PKI tree.

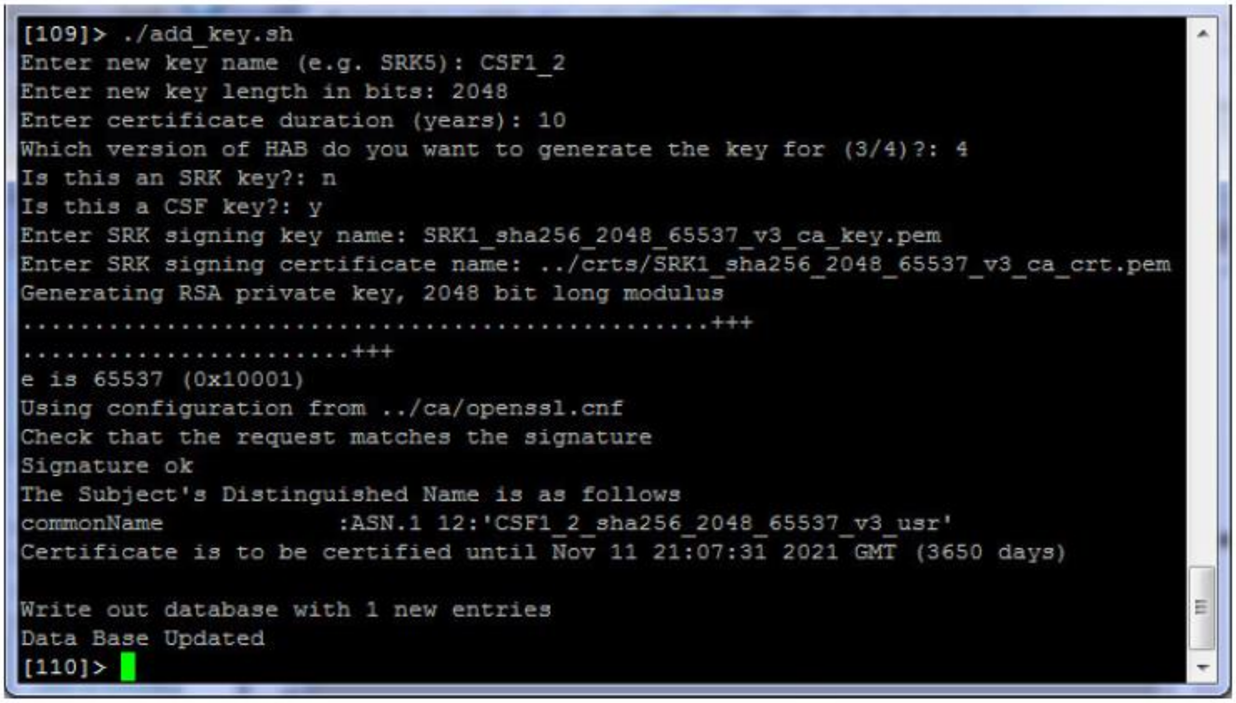


Figure 15. Adding a New SRK to a HAB4 PKI Tree Example

CAUTION

Do no run this script without first generating a HAB4 PKI tree. Failure to do so will result in errors.

3.3 Generating AHAB Keys and Certificates

This section covers only key and certificate generation for AHAB. Note that when making use of the encrypted boot feature digital signatures are still required. Data structures required by ROM and AHAB cannot be encrypted but still must be covered by a valid digital signature.

3.3.1 AHAB PKI Tree

The tree structure for AHAB generated by the `ahab_pki_tree.sh` script for Linux. This script will generate a AHAB PKI tree as shown in Figure 11 and is located in the /keys directory of the NXP Reference CST.

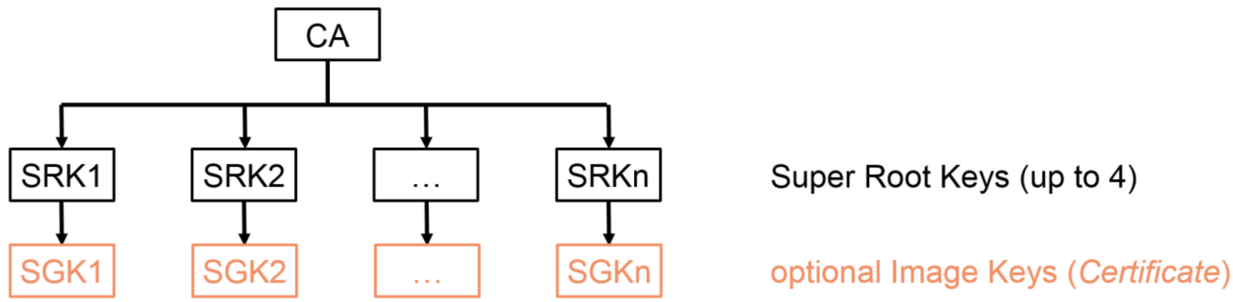


Figure 11. AHAB PKI Tree

A AHAB PKI tree consists of the following keys and certificates:

- CA key: is the top most key and is only used for signing SRK certificates.
- SRK: is the root key for AHAB code signing keys. The cryptographic hash of a table of SRK is burned to one-time programmable efuses to establish a root of trust. Only one of the SRKs in the table may be selected for use on the NXP processor. The selection of which SRK to use is a parameter within the Install SRK CSF command (see Section 5.2.2, "Install SRK"). The SRK may only be used for signing certificate data of subordinate keys.
- SGK: is a subordinate key of the SRK key and is used to verify signatures across product software.
- NOTE: The SGK keys are not generated if the SRK keys do not have the CA flag set

The ahab_pki_tree script generates a basic tree in which four SRKs may be generated. For each SRK a single SGK key is also generated. Additional keys may be added to the tree later using a separate script. It is also possible to replace the OpenSSL and the ahab_pki_tree script with an alternative key generation solution, but this is beyond the scope of this document. If the key generation scheme described here is replaced a new scheme must follow these constraints:

- Keys must be in PKCS#8 format
- Certificates must be in X.509 format following the certificate profile specified by AHAB. Keys and Certificates must follow the file naming convention specified in Section 3, "Key and Certificate Generation".

3.3.2 Running the ahab_pki_tree script Example

The following are the steps to generate a AHAB PKI tree.

1. `cd <CST Installation Path>/keys`
2. Using your favorite text editor create a file called 'serial' in the /keys directory with contents 12345678. OpenSSL uses the contents of this file for the certificate serial numbers. You may choose to use another number for the initial certificate serial number.
3. Using your favorite text editor create a file called 'key_pass.txt' in the /keys directory. This file contains your pass phrase that will protect the AHAB code signing private keys.

The format of this file is the pass phase repeated on the first and second lines of the file. For example:

my_pass_phrase
my_pass_phrase

NOTE

Failure to generate the serial and key_pass.txt files prior to running the ahab_pki_tree script will result in OpenSSL errors and the script will fail to generate the requested tree.

CAUTION

It is up to the user how best to protect the pass phrase for the private keys. Loss of the pass phrase will result in not being able to sign code with the affected keys.

NOTE

Note that OpenSSL enforces that the pass phrase must be at least four characters long.

4. Prior to running the `ahab_pki_tree` script ensure that OpenSSL is included in your path by running:

```
> openssl version
```

5. Run the `ahab_pki_tree` script. The script will ask a series of questions:
   - Do you want to use an existing CA key (y/n)?
     - Choose no here unless you already have an existing CA key.
     - If you choose yes, the script will ask you to provide the filenames (including path information) to the location of the CA key and corresponding CA public key certificate.
   - Do you want to use Elliptic Curve Cryptography (y/n)?
     - This is the type of the keys in the tree.
     - If you choose yes, the script will ask you to provide the Elliptic Curve to be used. For AHAB, P-256, P-384 and P-521curves are supported.
     - If you choose no, the script will ask you to enter the length in bit for the RSA keys in the tree. For AHAB 2048, 3072 and 4096-bit RSA keys are supported.
     - All keys in the tree are generated with the same length.
   - Enter PKI tree duration (years):
     - This defines the validity period of the corresponding certificates.
   - Do you want the SRK certificates to have the CA Flag set?
     - Answer ‘y’ for a tree with *Certificates* as defined by the AHAB architecture.

At this point the script will generate the SRK and SGK keys and certificates in the /keys and /crts directory. The generated keys will exist in PKCS#8 [4] format in both PEM and DER forms. Certificates are located in the /crts directory X.509 [3] format in both PEM and DER format. The `cst` will accept key and certificate files in either PEM or DER form.

NOTE

> You may notice that there are a number of pem files such as 12345678.pem, serial.old, index.txt.attr and so on. These files are left over from the OpenSSL key and certificate generation process.

Figure 12 below illustrates the use of the ahab_pki_tree script.

```
    ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    This script is a part of the Code signing tools for NXP's
    Advanced High Assurance Boot.  It generates a basic PKI tree. The
    PKI tree consists of one or more Super Root Keys (SRK), with each
    SRK having one subordinate keys:
        + a Signing key (SGK)
    Additional keys can be added to the PKI tree but a separate
    script is available for this.  This this script assumes openssl
    is installed on your system and is included in your search
    path.  Finally, the private keys generated are password
    protectedwith the password provided by the file key_pass.txt.
    The format of the file is the password repeated twice:
        my_password
        my_password
    All private keys in the PKI tree are in PKCS #8 format will be
    protected by the same password.

    ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Do you want to use an existing CA key (y/n)?: n
Do you want to use Elliptic Curve Cryptography (y/n)?: y
Enter length for elliptic curve to be used for PKI tree:
Possible values p256, p384, p521:  p384
Enter the digest algorithm to use: sha384
Enter PKI tree duration (years): 10
Do you want the SRK certificates to have the CA flag set? (y/n)?: n

+++++++++++++++++++++++++++++++++++++
+ Generating CA key and certificate +
+++++++++++++++++++++++++++++++++++++

Generating a 384 bit EC private key
writing new private key to 'temp_ca.pem'
-----

++++++++++++++++++++++++++++++++++++++++
+ Generating SRK key and certificate 1 +
++++++++++++++++++++++++++++++++++++++++

read EC key
writing EC key
Using configuration from ../ca/openssl.cnf
Check that the request matches the signature
Signature ok
The Subject's Distinguished Name is as follows
commonName            :ASN.1 12:'SRK1_sha384_secp384r1_v3_usr'
Certificate is to be certified until Mar 24 08:27:48 2028 GMT (3650 days)

Write out database with 1 new entries
Data Base Updated
```

Figure 12. Example Usage of the AHAB_pki_tree Script

At this point all key and certificate information required for signing an image for AHAB is now available.

3.3.3 Generating AHAB SRK tables and Efuse Hash

The previous section discussed the steps to generate the keys and certificates for a AHAB PKI tree. Now that they have been generated, the next step is to generate a AHAB SRK table and corresponding hash value for burning to efuses on the SoC. In AHAB four SRKs are included in a signed image, although only one may be used. By collecting SRKs in a table it is possible to select one of the SRKs at boot time. The Install SRK CSF command (see Section 5.2.2, “Install SRK”) selects which SRK to use from the table to establish the root of trust. Any of the SRKs in the table may be selected without having to change the SRK_HASH value burned to efuses on the SoC.

This is useful on NXP processors where additional fuses are available for SRK revocation. That is, in the event one or more of the SRKs in the table are compromised, efuses corresponding to the compromised keys can be burned preventing those SRKs from ever being used again. This is enforced by the AHAB code. The next SRK in the table can be used to sign new images. Four SRKs can be placed in an SRK table.

NOTE

The four SRKs in a table can be revoked.

SRK tables are generated using the `srktool`. The following illustrates the generation of an SRK table from the /crts directory using the four SRKs created in the previous section.

```
nxf41842@nxf41842-vm-11:/srv/dev/repo-cst/cst/release.demo/crts$ ../linux64/bin/
srktool -a -s sha384 -t SRK1234table.bin -e SRK1234fuse.bin -f 1 -c SRK1_sha384_
secp384r1_v3_usr_crt.pem,SRK2_sha384_secp384r1_v3_usr_crt.pem,SRK3_sha384_secp38
4r1_v3_usr_crt.pem,SRK4_sha384_secp384r1_v3_usr_crt.pem
nxf41842@nxf41842-vm-11:/srv/dev/repo-cst/cst/release.demo/crts$ ll SRK1234*
-rw-rw-r-- 1 nxf41842 nxf41842  64 mars  20 10:49 SRK1234fuse.bin
-rw-rw-r-- 1 nxf41842 nxf41842 436 mars  20 10:49 SRK1234table.bin
```

Figure 13. SRK Table and Efuse Generation Example

In this example:

- All four SRKs are included in the table
- The signature hash algorithm that will be used for signing is SHA-384 (option “-s”)
- The SHA-512 hash value to be fused is generated with 32 bit of fuse data per word. Some NXP processors require the hash value to be generated with 8 bits of fuse data per word. In that case use the ‘-f 0’ option.
- The hash result is in the resulting `SRK1234fuse.bin` file.

CAUTION

Do not enter spaces between the ‘,’ when specifying the SRKs in the -c or --certs option. Doing so will cause all certificates specified after the first space ***not*** to be included in the table and causing an execution error of `srktool`.

3.3.4 Programming the SRK Hash Value to Efuses

The previous section provided the details on how to SRK tables and the corresponding efuse data. In this section the hash value is of interest. The value located in the efuse file is intended to be burned to the SRK_HASH efuse field on the SoC supporting AHAB and is computed automatically by the AHAB_pki_tree script using the `srktool`. The `SRK1234fuse.bin` file from the example in the previous section has the following contents:

```
988a35b6073c42120ebaf31be8324d817331adb386d7b8933574eaa27264ec5eba63147fff99717d450efd
2ec28de640b2daff23f9ffb15f42402a7d00fa7d4e
```

Here is the corresponding hexadecimal dump of the fuse file.

```
$ hexdump -C SRK1234fuse.bin
00000000  98 8a 35 b6 07 3c 42 12  0e ba f3 1b e8 32 4d 81  |..5..<B......2M.|
00000010  73 31 ad b3 86 d7 b8 93  35 74 ea a2 72 64 ec 5e  |s1......5t..rd.^|
00000020  ba 63 14 7f ff 99 71 7d  45 0e fd 2e c2 8d e6 40  |.c....q}E......@|
00000030  b2 da ff 23 f9 ff b1 5f  42 40 2a 7d 00 fa 7d 4e  |...#..._B@*}..}N|
```

This hash value must be burned to the SoC efuses in the following order (the first word to the first fuse row index):

```
$ hexdump -e '/4 "0x"' -e '/4 "%X""\n"' ../crts/SRKfuse.bin
0xB6358A98
0x12423C07
0x1BF3BA0E
0x814D32E8
0xB3AD3173
0x93B8D786
0xA2EA7435
0x5EEC6472
0x7F1463BA
0x7D7199FF
0x2EFD0E45
0x40E68DC2
0x23FFDAB2
0x5FB1FFF9
0x7D2A4042
0x4E7DFA00
```

Please refer to the fuse map for the NXP processor you are using for location details of the SRK_HASH field.

3.3.5 Adding a Key to a AHAB PKI Tree

Adding to an existing AHAB PKI tree can be done using the add_key script. The following steps are used to add a new key:

1. Run the `add_key.sh` script for Linux. The script will prompt you with several questions:
   - Which version of HAB/AHAB do you want to generate the key for (3/4/a)?

  - Enter a here for AHAB
- Enter new key name (e.g. SRK5):
  - This is the name of the new key, such as SRK2, SGK3, etc.
- Enter new key type (ecc / rsa):
  - This is the type of the new key, either ECC or RSA.
- Enter new key length in bits:
  - This is the length of the new key in bits. This should match the key length of the signing key.
- Enter new message digest:
  - This is the digest of the key signature.
- Enter certificate duration (years):
  - This defines the validity period for the corresponding certificate generated
- Is this an SRK key?
  - If you are generating a new SRK enter 'y', otherwise enter 'n'
  - If you enter yes, you will be prompted with "Do you want the SRK to have the CA flag set?". Enter yes if you are generating a SRK with the CA flag set.
  - If you enter no, you are generating a new SGK key.
- Enter <key type> signing key name:
  - If you are generating a new SRK <key type> is CA. Enter the path and filename of the CA key in the /keys directory.
  - If you are generating a new SGK key <key type> is SRK. Enter the path and filename of the SRK in the /keys directory you wish to use to generate the SGK key.
- Enter <cert type> signing certificate name:
  - If you are generating a new SRK certificate the <cert type> is CA. Enter the path and filename of the CA certificate in the /crts directory.
  - If you are generating a new SGK certificate <cert type> is SRK. Enter the path and filename of the SRK certificate in the /certs directory you wish to use to generate the SGK certificate.

Using the keys generated in Section 3.2.2, "Running the AHAB_pki _tree script Example", Figure 15 below shows how to add a new SRK key to the PKI tree.

```
Which version of HAB do you want to generate the key for (3 = HAB3 / 4 = HAB4 / a = AHAB)?: a
Enter new key name (e.g. SRK5): SRK5
Enter new key type (ecc / rsa): ecc
Enter new key length (p256 / p384 / p521): p384
Enter new message digest (sha256, sha384, sha512): sha384
Enter certificate duration (years): 10
Is this an SRK key? y
Do you want the SRK to have the CA flag set (y/n)?: n
Enter CA signing key name: .\CA1_sha384_secp384r1_v3_ca_key.pem
Enter CA signing certificate name: ..\crts\CA1_sha384_secp384r1_v3_ca_crt.pem
read EC key
writing EC key
Using configuration from ..\ca\openssl.cnf
Check that the request matches the signature
Signature ok
The Subject's Distinguished Name is as follows
commonName            :T61STRING:'SRK5_sha384_secp384r1_v3_usr'
Certificate is to be certified until Mar 18 16:32:03 2028 GMT (3650 days)

Write out database with 1 new entries
Data Base Updated
```

Figure 15. Adding a New SRK to a AHAB PKI Tree Example

CAUTION

Do no run this script without first generating a AHAB PKI tree. Failure to do so will result in errors.

4 CST Usage

This section describes how to use the CST and other tools in the release package.

4.1 CST (Code Signing Tool)

The `cst` tool in the release package is the main application used to generate binary CSF data using input CSF description files passed as standard input. The CST can be executed from any location provided the correct absolute or relative path is provided. The paths to certificate and image files inside CSF can be either relative to the current working directory location or as absolute paths.

CAUTION

Due to limitation in current cst implementation the cst must be run from a directory at the same level as <Installation path>/keys. For example, <Installation path>/product_code where the product code to be signed is located.

Usage:

cst --output <*binary*> [--cert <cert_file>] --input <input_csf>

[--license] [--help]

Description:

```
-o, --output <binary>:

   For HAB, output binary CSF filename. For AHAB, output signed binary
   filename. Required when generating binary output. An input CSF passed as
   standard input is required when this option is given.

-l, --license:

   Optional, displays program license information. No additional arguments are
required

-h, --help:

   Optional, displays usage information. No additional arguments are required

-i, --input <input_csf>:

   Text file with CSF language commands.
--cert <cert_file>:

   Valid only for HAB. Public key certificate filename.  Required when input
CSF contains Install Secret Key command(s).  Symmetric key(s) are encrypted
using the public key and saved to a filename specified in the CSF command
```

Command line arguments that specify a file or directory can contain spaces if they are quoted. File names with leading and trailing spaces are not supported.

If an error occurs during the operation of `cst`, an error message will be printed to the standard output stream and the executable will exit with a non-zero status.

Exit Status:

0 if the executable succeeded, or

>0 otherwise.

Cautions:

None.

Pre Conditions/Assumptions:

Input CSF must be present at specified path.

Certificates must be in a directory called `crts`.

Keys must be in a directory called `keys`. The `keys` directory must be located at the same level as the `crts` directory.

Filenames for the keys and certificates must use the following convention <filename>_<type>.pem or <filename>_<type>.der

where: <filename> is the root of the key/certificate filename

<type> is key for keys and crt for certificates.

Example: keys/SRK1_sha256_2048_65537_v3_ca_key.der must have a corresponding certificate crts/SRK1_sha256_2048_65537_v3_ca_crt.der

Post Conditions:

None.

Examples:

1. To generate out.bin file from input example.csf, use

```
cst -o out.bin -i example.csf
```

2. To print program license information, use

```
cst --license
```

3. To print usage information, use

```
cst --help
```

4. To generate out.bin from input hab4.csf and public key certificate to encrypt symmetric key(s)

```
cst -o out.bin --cert dek_protection_crt.pem -i example.csf
```

4.2 SRK Tool

For HAB4 or AHAB the SRK tool is used to generate super root key table data and its hash (for efuses) and for HAB3 it is used to generate efuse information for given keys.

4.2.1 SRK Tool Usage for HAB3

This section describes usage of SRK tool for HAB3.

Usage:

srktool --hab_ver <version> --certs <srk>,<srk>,... [--output]

Description:

```
-h, --hab_ver <version>:
      HAB Version - set to 3 to generate HAB3 SRK data/files
-c, --certs <srk1>,<srk2>,...,<srk8>:
      WTLS certificate filenames.
        - WTLS certificates are always in binary format
        - Certificate filenames must be separated by a ',' with no spaces
        - A maximum of 8 certificate filenames may be provided. Additional
          certificate names are ignored
-o, --output:
```

```
      Optional, generate file containing the C structures of the
              public keys from the given WTLS certificates. C files use
              certificate filename appending a .c suffix
-l, --license:
      Optional, displays program license information. No additional
      arguments are required.
```

Command line arguments that specify a file or directory can contain spaces if they are quoted. File names with leading and trailing spaces are not supported.

If an error occurs during the operation of `srktool`, an error message will be printed to the standard error stream and the executable will exit with a non-zero status.

Exit Status:

0 if the executable succeeded, or

>0 otherwise.

Cautions:

None.

Pre-Conditions/Assumptions:

None.

Post Conditions:

None.

Examples:

1. To display information for two WTLS certificates

   srktool --hab_ver 3 --certs SRK.CA1.FSL.wtls.crt,SRK.CA2.FSL.wtls.crt

2. To display information for two WTLS certificates and generate corresponding C data output files

   srktool --hab_ver 3 --certs SRK.CA1.FSL.wtls.crt,SRK.CA2.FSL.wtls.crt –o

4.2.2 SRK Tool Usage for HAB4

This section describes usage of SRK tool for HAB4.

Usage:

srktool --hab_ver <version> --table <tablefile> --efuses <efusefile>

--digest <digestalg> --certs <srk>,%<srk>,...

[--fuse_format <format>] [--license]

Description:

```
-h, --hab_ver <version>:
      HAB Version - set to 4 for HAB4 SRK table generation
-t, --table <tablefile>:
      Filename for output SRK table binary file
-e, --efuses <efusefile>:
      Filename for the output SRK efuse binary file containing the SRK table
hash
-d, --digest <digestalg>:
      Message Digest algorithm. Only sha256 is supported
-c, --certs <srk1>,<srk2>,...,<srk4>:
      X.509v3 certificate filenames.
        - Certificates may be either DER or PEM encoded format
        - Certificate filenames must be separated by a ',' with no spaces
        - A maximum of 4 certificate filenames may be provided. Additional
          certificate names are ignored
        - Placing a % in front of a filename replaces the public
          key data in the SRK table with a corresponding hash digest
-f, --fuse_format <format>:
      Optional, Data format of the SRK efuse binary file. The
      format may be selected by setting <format> to either:
        - 0: 8 fuses per word, ex: 00 00 00 0a 00 00 00 01 ...
        - 1 (default): 32 fuses per word, ex: 0a 01 ff 8e
-l, --license:
      Optional, displays program license information. No additional
      arguments are required.
```

Command line arguments that specify a file or directory can contain spaces if they are quoted. File names with leading and trailing spaces are not supported.

If an error occurs during the operation of `srktool`, an error message will be printed to the standard output stream and the executable will exit with a non-zero status.

Exit Status:

0	if the executable succeeded, or
>0	otherwise.

NOTE

Using the % prefix in the -c option does not change the SRL fuse pattern generated but does reduce the overall size of the SRK Table. However, an SRK prefixed with % cannot be selected in the Install SRK command using that SRK Table.

Cautions:

None.

Pre-Conditions/Assumptions:

None.

Post Conditions:

None.

Examples:

1. To generate an SRK table and corresponding fuse pattern from 3 certificates
   - using PEM encoded certificate files
   - using full key for first two certificates and hash digest for the third
   - using the default 32 fuse bits per word for the efuse file

```
srktool --hab_ver 4 --table table.bin --efuses fuses.bin \
        --digest sha256 \
        --certs srk1_crt.pem,srk2_crt.pem,%srk3_crt.pem
```

2. To generate an alternative SRK Table with the same fuse pattern as in example 1 and with SRK3 selectable:

```
srktool --hab_ver 4 --table table.bin  --efuses fuses.bin \
        --digest sha256 \
        --certs %srk1_crt.pem,%srk2_crt.pem,srk3_crt.pem
```

3. To generate an SRK table and corresponding fuse pattern from 2 certificates
   - using DER encoded certificate files
   - using the optional 8 fuse bits per word for the efuse file

```
srktool --hab_ver 4 --table table.bin  --efuses fuses.bin \
        --digest sha256 \
        --certs srk1_crt.der,srk2_crt.der\
```

--fuse_format 1

4.2.3 SRK Tool Usage for AHAB

This section describes usage of SRK tool for AHAB.

Usage:

```
srktool --ahab_ver --table <tablefile> --efuses <efusefile>
             --digest <digestalg> --certs <srk>,%<srk>,...
             [--fuse_format <format>] [--license]
```

Description:

```
-a, --ahab_ver:
      AHAB Version - set for AHAB SRK table generation
-t, --table <tablefile>:
      Filename for output SRK table binary file
-e, --efuses <efusefile>:
      Filename for the output SRK efuse binary file containing the SRK table
hash
-s, --sign_digest <digestalg>:
      Signature Digest algorithm that will be used later on for the digital
signatures. Either sha256, sha384 or sha512
-c, --certs <srk1>,<srk2>,...,<srk4>:
      X.509v3 certificate filenames.
        - Certificates may be either DER or PEM encoded format
        - Certificate filenames must be separated by a ',' with no spaces
        - 4 certificate filenames may be provided. Additional
          certificate names are ignored
-f, --fuse_format <format>:
      Optional, Data format of the SRK efuse binary file. The
      format may be selected by setting <format> to either:
        - 0: 8 fuses per word, ex: 00 00 00 0a 00 00 00 01 ...
        - 1 (default): 32 fuses per word, ex: 0a 01 ff 8e
-l, --license:
      Optional, displays program license information. No additional
      arguments are required.
```

Command line arguments that specify a file or directory can contain spaces if they are quoted. File names with leading and trailing spaces are not supported.

If an error occurs during the operation of `srktool`, an error message will be printed to the standard output stream and the executable will exit with a non-zero status.

Exit Status:

0 if the executable succeeded, or

>0 otherwise.

Cautions:

None.

Pre-Conditions/Assumptions:

None.

Post Conditions:

None.

Examples:

1. To generate an SRK table and corresponding fuse pattern
   - using PEM encoded certificate files
   - using the default 32 fuse bits per word for the efuse file

```
srktool --ahab_ver --table table.bin --efuses fuses.bin \
                  --sign_digest sha384 \
                  --certs
      srk1_crt.pem,srk2_crt.pem,srk3_crt.pem,srk4_crt.pem
```

2. To generate an SRK table and corresponding fuse pattern
   - using DER encoded certificate files
   - using the optional 8 fuse bits per word for the efuse file

```
srktool --ahab_ver --table table.bin --efuses fuses.bin \
            --sign_digest sha256 \
            --certs
srk1_crt.der,srk2_crt.der,srk3_crt.der,srk4_crt.der \
                 --fuse_format 1
```

4.3 X5092WTLS Tool

The x5092wtls tool is used to convert certificates in X509 format to WTLS required for HAB3.

Usage:

x5092wtls --cert <certfile> --key <keyfile>

--wtls <wtlsfile> [--passin <password file>] [--license]

Description:

```
-c, --cert <certfile>:
      X509 certificate file. May be either a PEM or DER encoded file
-k, --key <keyfile>:
      PKCS #8 private key used to sign the input X.509 certificate. May be
      either a PEM or DER encoded file
-w, --wtls <wtlsfile>:
      Output WTLS file in binary format
-p, --passin <passfile>:
      Optional password file. Max. supported password length is 20 characters
-l, --license:
      Optional, displays program license information. No additional
      arguments are required.
```

Command line arguments that specify a file or directory can contain spaces if they are quoted. File names with leading and trailing spaces are not supported.

PEM files must have a pem extension. All other extensions are considered to be binary DER encoded files.

If an error occurs during the operation of `x5092wtls`, an error message will be printed to the standard output stream and the executable will exit with a non-zero status.

Exit Status:

0 if the executable succeeded, or

>0 otherwise.

Cautions:

None.

Pre-Conditions/Assumptions:

None.

Post Conditions:

None.

Examples:

1. To generate a WTLS certificate (wtls.der) from a given x509 certificate (x509_cert.pem) by the given key (key.pem):

```
x5092wtls.exe --cert x509_cert.pem --key key.pem --wtls wtls.der
```

2. To generate a WTLS certificate (wtls.der) from a given x509 certificate (x509_cert.pem) by the given encrypted key (key.pem):

```
x5092wtls.exe -c x509_cert.pem -k key.pem -w wtls.der -p key_pass.txt
```

where key_pass.txt is a file containing the password for the encrypted key.

5 CSF Description Language

This section describes the CSF description language. A CSF description file is written in the CSF description language, which is parsed and processed by the CST application and generates a binary file containing the CSF commands (valid only for HAB), certificates, and signatures, which are interpreted by the secure element on the end-product device.

5.1 Overview

The following are the general properties of CSF description files:

- The CSF description file is a text file containing statements, one per line.
- A backslash character '\' at the end of a line (ignoring white space or comments) continues the statement to the next line.
- Blank lines are ignored.
- Comments beginning with the # character on any line are ignored.
- Multiple white space characters are equivalent to a single space. Except where noted, keywords and parameters are separated by white space. White space at the beginning or end of a line is ignored.
- Except for file names, all keywords and parameters are case-insensitive.
- All certificate file parameters are relative to current folder from where CST application is being executed.
- All byte parameters are specified as integers in the range 0...255. They can be specified in hexadecimal or decimal.
- All parameters that specify a file name must be double quoted. A quoted file name can contain spaces. The following file names are not supported:
  - File name with leading or trailing spaces.

- File name that contains a double quote (") as part of the file name.

- Ordering of commands within the CSF description is significant only to the following extent:
  - The Header command must precede any other command. Valid for HAB and AHAB. The next statements are valid only for HAB.
  - The Install SRK command must precede the Install CSFK command.
  - The Install CSFK must precede the Authenticate CSF command.
  - Install SRK, Install CSFK and Authenticate CSF commands must appear exactly once in a CSF description file.
  - A verification index in an Authenticate Data command must appear as the target index in a previous Install Key command.
  - Commands in the binary CSF follow the order in which they appear in the CSF description.

5.2 CSF Commands

This section describes each CSF command in detail.

5.2.1 Header

The Header command contains data used in the CSF header as well as default values used by the CST for other commands throughout the remaining CSF.

There must be exactly one Header command and it must appear first in the CSF.

Table 3 below lists the Header command arguments.

Table 3. Header arguments

Argument name	Description	Valid values	HAB3	HAB4	AHAB
Target	Targeted secure element. If not specified, HAB will be assumed.	HAB, AHAB	O	O	M
Version	Version of HAB	3, 3.5, 4.x, where x=0,1,...	M	M	M
Mode	Mode of CST execution (to be specified only for HSM handling)	HSM	O	O	O
Security Configuration	Fused security configuration	Engineering, Production	M	X	X

UID	Value expected in UID fuses	Generic (matches any value) U0, U1,... Un where each Ui=0..255 and n<255	M	X	X
CODE	Value expected in “customer code” fuses	0..255	M	X	X
Hash Algorithm	Default hash algorithm	SHA1, SHA256 (HAB3) SHA256 (HAB4)	O	O	X
Engine	Default engine.	ANY, SAHARA, RTIC, DCP, CAAM and SW	O	O	X
Engine Configuration	Default engine configuration	See Table 4	O	O	X
Certificate Format	Default certificate format)	WTLS, X509	O	O	X
Signature Format	Default signature format	PKCS1, CMS	O	O	X

M = mandatory, O = optional, D = use default from Header if absent and X = not present

Table 4 below lists valid engine configuration values for each engine type

Table 4. Valid Engine configuration values

Engine name	Valid engine configuration values
ANY	0
SAHARA	One or more of these, separated by ‘|’: 0 IN SWAP8 IN SWAP16 DSC BE816 DSC BE832
DCP	One or more of these, separated by ‘|’: 0 IN SWAP8 IN SWAP32 OUT SWAP8 OUT SWAP32
CAAM	One or more of these, separated by ‘|’: 0 IN SWAP8 IN SWAP16 OUT SWAP8 OUT SWAP16 DSC SWAP8 DSC SWAP16

RTIC	One or more of these, separated by '|': 0 IN SWAP8 IN SWAP16 OUT SWAP8 KEEP
SW	0

5.2.1.1 Header Examples

```
[Header]
    Version = 3.5 # HAB3 example
    Security Configuration = Engineering
    UID = Generic
    Hash Algorithm = SHA256
    Certificate Format = WTLS
    Signature Format = PKCS1


[Header]
    Version = 4.1 # HAB4 example
    Hash Algorithm = SHA256
    Engine = Any
    Engine Configuration = 0
    Certificate Format = X509
    Signature Format = CMS

[Header]
    Target = AHAB # AHAB example
    Version = 1.0
```

5.2.2 Install SRK

The Install SRK command authenticates and installs the root public key for use in subsequent Install CSFK (HAB only) or Install Key (HAB4 only) commands.

HAB or AHAB authenticates the SRK using the SRK hash (SRK_HASH) fuses. HAB4 or AHAB allows revocation of individual keys within the SRK table using the SRK revocation (SRK_REVOKE) fuses.

HAB installs the SRK in slot 0 of its internal public key store.

There must be exactly one Install SRK command in a CSF, and it must occur before the Install CSFK (HAB only) command. Table 5 lists the Install SRK command arguments.

Table 5. Install SRK arguments

Argument name	Description	Valid values	HAB3	HAB4	AHAB
File	SRK certificate (HAB3) SRK table (HAB4, AHAB)	Valid file path	M	M	M
Source Index	SRK index within SRK table. Installation fails if the SRK revocation fuse with this index is burned.	0..3	X	M	M
Source	SRK certificate corresponding to the specified SRK index	Valid file path	X	X	M
Source Set	Origin of the SRK table	NXP, OEM (NXP is reserved for NXP deliverables)	X	X	M
Revocations	Revoked SRKs (Note that this field may trigger a fusing procedure)	4-bit bitmask	X	X	M
Hash Algorithm	SRK table hash algorithm	SHA256 (HAB4)	X	D	X

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.2.1 Install SRK Examples

```
[Install SRK] # HAB3 example
    File = "../crts/srk.der"


[Install SRK] # HAB4 example
    File = "../crts/srk_table.bin"
    Source Index = 0
    Hash Algorithm = sha256


[Install SRK] # AHAB example
    File = "../crts/srk_table.bin"
    Source = "../crts/srk3_crt.pem
    Source index = 2
    Source set = OEM
    Revocations = 0x0
```

5.2.3 Install CSFK (HAB only)

The Install CSFK command authenticates and installs a public key for use in subsequent Install Key (HAB3 only) or Authenticate CSF commands.

HAB authenticates the CSFK from the CSFK certificate using the SRK.

HAB installs the CSFK in slot 1 of its internal public key store.

There must be exactly one Install CSFK command in a CSF, and it must occur before the Authenticate CSF command. Table 6 lists the Install CSFK command arguments.

Table 6. Install CSFK arguments

Argument name	Description	Valid values	HAB3	HAB4
File	CSFK certificate	Valid file path	M	M
Certificate Format	CSFK certificate format	WTLS, X509	D	D

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.3.1 Install CSFK Examples

```
[Install CSFK] # HAB3 example
    File = "../crts/csf.der"
    Certificate Format = WTLS

[Install CSFK] # HAB4 example
    File = "../crts/csf.pem"
    Certificate Format = X509
```

5.2.4 Install NOCAK (HAB4 only)

The Install NOCAK command authenticates and installs a public key for use with the fast authentication mechanism (HAB 4.1.2 and later only). With this mechanism, one key is used for all signatures.

HAB installs the no-CA key in slot 1 of its internal public key store.

There must be exactly one Install NOCAK command in a CSF, and it must occur before the Authenticate CSF command and there must be no Install Key commands. Table 7 lists the install NOCAK command arguments.

Table 7. Install CSFK arguments

Argument name	Description	Valid values	HAB3	HAB4
File	CSFK certificate	Valid file path	M	M
Certificate Format	CSFK certificate format	WTLS, X509	D	D

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.4.1 Install NOCAK Examples

```
[Install NOCAK] # HAB4 example
    File = "../crts/csf.pem"
    Certificate Format = X509
```

5.2.5 Authenticate CSF (HAB only)

The Authenticate CSF command authenticates the CSF from which it is executed.

HAB authenticates the CSF using the CSFK public key, from a digital signature generated automatically by the CST.

There must be exactly one Authenticate CSF command in a CSF file, and it must occur after the Install CSFK command. Most other CSF commands are allowed only after the Authenticate CSF command. Table 8 lists the Authenticate CSF command arguments.

Table 8. Authenticate CSF arguments

Argument name	Description	Valid values	HAB3	HAB4
Engine	CSF signature hash engine	ANY, SAHARA, RTIC, DCP, CAAM and SW	X	D
Engine Configuration	Configuration flags for the hash engine. Note that the hash is computed over an internal RAM copy of the CSF.	see Table 4	X	D
Signature Format	CSF signature format	PKCS1, CMS	D	D

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.5.1 Authenticate CSF Examples

```
[Authenticate CSF] # HAB3/HAB4 example using all default arguments


[Authenticate CSF] # HAB4 example
```

```
Engine = DCP
Engine Configuration = 0
Signature Format = CMS
```

5.2.6 Install Key (HAB only)

The Install Key command authenticates and installs a public key for use in subsequent Install Key or Authenticate Data commands.

HAB authenticates a public key from a public key certificate using a previously installed verifying key and a hash of the public key certificate.

HAB installs the authenticated public key in an internal public key store with a zero-based array of key slots.

The CSF author is responsible for managing the key slots in the internal public key store to establish the desired public key hierarchy and determine the keys used in authentication operations. Overwriting occupied key slots is not allowed, although a repeat command to re-install the same public key occupying the target slot will be skipped and not generate an error.

Multiple Install Key commands are allowed in a CSF. An Install Key command must precede any command which uses the installed key, and all Install Key commands must come after the Authenticate CSF command. Table 9 lists the Install Key command arguments.

Table 9. Install Key arguments

Argument name	Description	Valid values	HAB3	HAB4
File	Public key certificate	Valid file path	M	M
Verification Index	Verification key index in key store.	1, ..., 4 (HAB3) 0, 2, ..., 4 (HAB4) SRK (HAB3), CSFK (HAB4) not supported	M	M
Target Index	Target key index in key store.	2, ..., 4 (HAB3) 2, ..., 4 (HAB4) SRK, CSFK slots reserved.	M	M
Certificate Format	Public key certificate format.	WTLS, X509	D	D
Hash Algorithm	Hash algorithm for certificate binding. If present, a hash of the certificate specified in the File argument is included in the command to prevent installation from other sharing the same verification key.	SHA1, SHA256 (HAB3) SHA256 (HAB4)	D	O

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.6.1 Install Key Examples

```
[Install Key] # HAB3 example
    Key = "../crts/imgk.der"
    Verification Index = 1
    Target Index = 2
    Certificate Format = WTLS
    Hash Algorithm = SHA1

[Install Key] # HAB4 example
    Key = "../crts/imgk.pem"
    Verification Index = 0
    Target Index = 2
    Certificate Format = X509
```

5.2.7 Authenticate Data

The Authenticate Data command verifies the authenticity of pre-loaded data in memory. The data may include executable SW instructions and may be spread across multiple non-contiguous address ranges drawn from multiple object files.

HAB authenticates the pre-loaded data using a previously installed public key from a digital signature generated automatically by the CST. For HAB3, authentication may be restricted to a single chip and security configuration.

The security configuration is taken from the Header command. Table 10 lists the Authenticate Data command arguments.

Table 10. Authenticate Data arguments

Argument name	Description	Valid values	HAB3	HAB4	AHAB
Blocks	List of one or more data blocks. Each block is specified by four parameters: • source file (must be ***binary***), • starting load address in memory • starting offset within the source file • length (in bytes)	file address offset length with file: valid pathname address: 32-bit unsigned integer offset: 0, ..., size of file length: 0, ..., size of file - offset Block parameters separated by spaces. Multiple blocks separated by commas.	M	M	X
Verification Index	Verification key index in key store.	2, ..., 4 (HAB3) 2, ..., 4 (HAB4) SRK, CSFK not supported NOTE: For HAB4 Fast Authentication, this must be 0	M	M	X

Engine	Data signature hash engine.	ANY, SAHARA, RTIC, DCP, CAAM and SW	D	D	X
Engine Configuration	Configuration flags for the engine.	See Table 4	D	D	X
Signature Format	Data signature format	PKCS1, CMS	D	D	X
Binding	64-bit unique ID (UID) for binding. If present, authentication succeeds only if the UID fuse value matches this argument, and the TYPE fuse value matches the Security Configuration argument from the Header command.	`U0,U1,…U7` with `Ui` 0, ..., 255. UID bytes separated by commas.	O	X	X
File	Binary to be signed	Valid file path	X	X	M

Offsets	List of 2 offsets. Meaningful information for CST into the binary to be signed (this information is printed out by mkimage)	`container_header_offset`
		`signature_block_offset`
		
		Offset parameters separated by spaces
		Unsigned integers
			X	X	M

Signature	Binary file containing the signature of the container. This field has been added for the HSM support.	Valid file path	X	X	O

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.7.1 Authenticate Data Examples

```
[Authenticate Data] # HAB3 example
    Blocks = 0xf8000000 0x0 0x10000 "flash.bin", \
               0xf8010000 0x0 0x1000 "xyz.bin"
    Verification Index = 2

[Authenticate Data] # HAB3 example
```

```
    Blocks = 0xf8000000 0x0 0x10000 "flash.bin", \
               0xf8010000 0x0 0x1000 "xyz.bin", \
               0xf8012000 0x2000 0x4000 "xyz.bin", \
               0xf8018000 0x8000 0x1000 "xyz.bin"
    Verification Index = 3
    Engine = SAHARA
    Binding = 0x01, 0x23, 0x45, 0x67, 0x89, 0xab, 0xcd, 0xef

[Authenticate Data] # HAB4 example
    Blocks = 0xf8000000 0x0 0x10000 "flash.bin", \
               0xf801000 0x0 0x1000 "xyz.bin"
    Verification Index = 2
    Engine = DCP
    Engine Configuration = 0
    Signature Format = CMS

[Authenticate Data] # AHAB example
    File = "flash.bin"
    Offsets = 0x400 0x610
```

5.2.8 Install Secret Key (HAB only)

This command is applicable from HAB 4.1 onwards and only on processors which include CAAM and SNVS. Each instance of this command generates a CSF command to install a secret key in CAAM's secret key store. A key blob as described in Section 1.1.2 is unwrapped using a master key encryption key (KEK) supplied by SNVS. A random key is generated and protected by the CST back end and encrypted using a public key passed with --cert command line option to CST and saved in a file under the name passed in the Key argument. This file is intended for later use by provisioning software to create the blob. Table 11 lists the Install Secret Key command arguments. Each execution of the CST will generate a different secret key, overwriting any previous secret key in the given file.

Table 11. Install Secret Key arguments

Argument name	Description	Valid values	HAB (> 4.0)
Key	Output filename for CST to create the cms encrypted data encryption key	Valid pathname	M
Key length	Key length in bits	128, 192 and 256	M
Verification Index	Master KEK index	0 or 1: OTPMK from fuses 2: ZMK from SNVS 3: CMK from SNVS	D
Target Index	Target secret key store index	0, 1, 2 or 3 of secret key store	M

Blob Address	Absolute memory address where blob will be loaded	Internal or external DDR address	M

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.8.1 Install Secret Key Examples

```
[Install Secret Key] # Example using OPTMK (Default)
    Key = "data_encryption.key"
    Target Index = 0 /* Secret key store index */
    Blob Address = 0x0090a000 /* internal ram address */


[Install Secret Key] # Example using ZMK
    Key = "data_encryption.key"
    Verification Index = 2 /* ZMK */
    Target Index = 0 /* Secret key store index */
    Blob Address = 0x0090a000 /* internal ram address */
```

5.2.9 Decrypt Data (HAB only)

This command is applicable from HAB4.1 onwards. Each instance generates a CSF command to decrypt and authenticate a list of code/data blocks using secret key stored in the secret key store. CST will generate a corresponding AUT_DAT command. CST will encrypt the data blocks in-place in the given files using a secret key and generate MAC data which is appended to the CSF. Table 12 lists the Decrypt Data command arguments. The secret key index must have been the target key index in a preceding Install Secret Key command. The same secret key must never be used more than once. The secret key used is removed from the secret key store by the Decrypt Data command. A separate Install Secret Key command (which generates a fresh secret key) is required for another Decrypt Data command.

Table 12. Decrypt Data arguments

Argument name	Description	Valid values	HAB (> 4.0)
Blocks	List of one or more data blocks. Each block is specified by four parameters: • source file (must be ***binary***), • starting load address in memory • starting offset within the source file • length (in bytes)	file address offset length with file: valid pathname address: 32-bit unsigned integer offset 0, ..., size of file length: 0, ..., size of file - offset Block parameters separated by spaces. Multiple blocks separated by commas.	M

Verification Index	Secret key index in Secret key store	0, 1, 2 or 3 from secret key store	M
Engine	MAC engine	CAAM (Default)	D
Engine Configuration	Configuration flags for the engine.	See Table 4 Default from header command	D
MAC Bytes	Size of MAC in bytes.	Even value between 4 and 16 (Default 16)	D

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.9.1 Decrypt Data Examples

```
[Decrypt Data]
    Blocks = 0xf8000000 0x0 0x10000 "flash.bin", \
    0xf8010000 0x0 0x1000 "xyz.bin"
    Verification Index = 0

[Decrypt Data]
Blocks = 0xf8000000 0x0 0x10000 "flash.bin", \
               0xf8010000 0x0 0x1000 "xyz.bin", \
               0xf8012000 0x2000 0x4000 "xyz.bin", \
               0xf8018000 0x8000 0x1000 "xyz.bin"
    Verification Index = 3
    Engine = CAAM
    Engine Configuration = 0
```

5.2.10 NOP (HAB only)

The NOP command has no effect.

Multiple NOP commands may appear in a CSF after the Authenticate CSF command. For HAB4, NOP commands may also appear between the Header and Authenticate CSF commands.

The NOP command has no arguments.

5.2.10.1 NOP Example

```
[NOP]
```

5.2.11 Set Engine (HAB only)

The Set Engine command selects the default engine and engine configuration for a given algorithm. HAB3 does not support the Set Engine command.

Some CSF commands allow the CSF author to select the engine used for an algorithm by specifying an argument other than ANY. However, if the engine argument is ANY, then HAB selects the engine to use based on internal criteria. The Set Engine command overrides the HAB internal criteria and selects the engine and configuration to use when ANY is specified.

Some algorithm types do not have an associated engine argument in the CSF commands (e.g. the signature algorithm in Authenticate Data commands). By default, HAB selects the engine to use for such algorithms based on internal criteria. The Set Engine command overrides the HAB internal criteria in such cases as well.

Multiple Set Engine commands may appear anywhere in a CSF after the Header command. Subsequent commands use the engine selected by the most recent Set Engine command. Table 21 lists the Set Engine command arguments.

Table 21. Set Engine arguments

Argument name	Description	Valid values	HAB3	HAB4
Hash Algorithm	Hash algorithm	SHA256 (HAB4)	X	M
Engine	Engine Use ANY to restore the HAB internal criteria.	ANY, SAHARA, RTIC, DCP, CAAM and SW	X	M
Engine Configuration	Configuration flags for the engine.	See Table 4	X	O

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.11.1 Set Engine Example

```
[Set Engine]
    Hash Algorithm = SHA256
    Engine = DCP
    Engine Configuration = 0
```

5.2.12 Init (HAB only)

The Init command initializes specified engine features when exiting the internal boot ROM. HAB3 does not support the Init command.

Multiple Init commands may appear after the Authenticate CSF command. A feature will be initialized if specified in one or more Init commands. Table 22 lists the Init command arguments.

Table 22. Init arguments

Argument name	Description	Valid values	HAB3	HAB4
Engine	Engine to initialize	SRTC	X	M
Features	Comma-separated list of features to initialize	See Table 24	X	O

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.12.1 Init Example

```
[Init]
    Engine = SRTC
```

5.2.13 Unlock (HAB only)

The Unlock command prevents specified engine features from being locked when exiting the internal boot ROM. HAB3 does not support the Unlock command.

Multiple Unlock commands may appear after the Authenticate CSF command. A feature will be unlocked if specified in one or more Unlock commands. Table 23 lists the Unlock command arguments.

Table 23. Unlock arguments

Argument name	Description	Valid values	HAB3	HAB4
Engine	Engine to unlock	SRTC, CAAM, SNVS and OCOTP	X	M
Features	Comma-separated list of features to unlock	See Table 24	X	O
UID	Device specific 64-bit UID Required to unlock certain features, must be absent for others (see Table 24).	U0,U1,…U7 with Ui=0..255 UID bytes separated by commas	X	M/X

M = mandatory, O = optional, D = use default from Header if absent and X = not present

Table 24 shows valid Features values available in Init/Unlock commands for each Engine argument.

Table 24. Valid feature values

Engine	Features	UID	Init/Unlock command effect
SRTC		X	The Init command clears any failure status flags and clears the low-power counters and timers if the SRTC is in Init state. The Unlock command prevents the secure timer and monotonic counter being locked if the SRTC is in Valid state
CAAM	MID	X	Leaves Job Ring and DECO master ID registers unlocked.

	RNG	X	Leaves RNG state handle 0 uninstantiated, does not generate descriptor keys, does not set the AES DPA mask, and does not block state handle 0 test instantiation.
	MFG	X	Keep manufacturing protection private key in CAAM internal memory.
SNVS	LP SWR	X	Leaves LP SW reset unlocked.
	ZMK WRITE	X	Leaves Zeroisable Master Key write unlocked.
OCOTP	FIELD RETURN	M	Leave Field Return activation unlocked.
	SRK REVOKE	X	Leave SRK revocation unlocked.
	SCS	M	Leave SCS register unlocked.
	JTAG	M	Unlock JTAG using SCS HAB_JDE bit.

M = mandatory, O = optional, D = use default from Header if absent and X = not present

5.2.13.1 Unlock Examples

```
[Unlock]
    Engine = SRTC

[Unlock]
    Engine = CAAM
    Features = RNG

[Unlock]
    Engine = OCOTP
    Features = JTAG, SRK REVOKE
    UID = 0x01, 0x23, 0x45, 0x67, 0x89, 0xab, 0xcd, 0xef
```

5.2.14 Install Certificate (AHAB only)

The Install Certificate command is optional.

The Install Certificate command converts a public key into the NXP format.

AHAB authenticates a Certificate from a previously installed verifying SRK and a hash of the public key certificate.

There must be up to one Install Certificate command in a CSF. Table 9 lists the Install Certificate command arguments.

Table 9. Install Key arguments

Argument name	Description	Valid values	AHAB
File	Public key certificate	Valid file path	M
Permissions	Please refer to the AHAB architecture specification for setting this value correctly	8-bit bitmask	M
Signature	Binary file containing the signature of the NXP-format public key certificate. This field has been added for the HSM support.	Valid file path	O

M = mandatory, O = optional

5.2.14.1 Install Key Examples

```
[Install Certificate]
    File = "../crts/sgk1_crt.pem"
    Permissions = 0x1
```

5.3 CSF Examples

This section provides some examples for HAB3, HAB4 and AHAB CSF.

5.3.1 HAB3 CSF Example

Figure 16 is an example of HAB3 CSF description. This example CSF description:

- Defines a version 3 CSF description.
- Uses a generic UID for a processor with the HAB_TYPE fuses burned to Engineering
- Covers three blocks of memory loaded from two different files with a single signature verification.

```
# Illustrative Command Sequence File Description (generic UID)

[Header]
    Version = 3.0
    Security Configuration = Engineering
    Hash Algorithm = sha256
    Engine = ANY
    Engine Configuration = 0
    Certificate Format = WTLS
    Signature Format = PKCS1
    UID = Generic
    Code = 0x0F

[Install SRK]
    File = "../crts/SRK1_sha256_2048_65537_v3_ca_crt.der"

[Install CSFK]
    File = "../crts/CSF1_1_sha256_2048_65537_v3_ca_crt.der"

[Authenticate CSF]

[Install Key]
    Verification index = 1
    Target index = 2
    File = "../crts/IMG1_1_sha256_2048_65537_v3_usr_crt.der"

# whole line comment

[Authenticate Data]   # part line comment
    Verification index = 2
    Blocks = 0x80000000 0 0x00001000 "image.bin" \
             0x80004000 0x4000 0x00001000 "image.bin" \
             0x8000a000 0 0x00002000 "image2.bin"
```

Figure 16. Example Development CSF Description File

5.3.2 HAB3 Binding CSF Example

Figure 17 is an example of HAB3 CSF description. This example CSF description:

- Defines a version 3.5 CSF description.
- Uses a generic UID for the CSF of a processor with HAB_TYPE fuses set for Production.

- Uses a bound signature for the software load. The bound signature is specified by using the Binding argument in Authenticate Data command. This binds the signature to the device by including the UID in the signature process.
- Uses the RTIC hash engine and keeps the calculated hash value to allow activating RTIC run-time monitoring later in the boot flow.

```
# Illustrative Command Sequence File Description (generic UID)

[Header]
    Version = 3.5
    Security Configuration = Production
    Hash Algorithm = sha256
    Certificate Format = WTLS
    Signature Format = PKCS1
    UID = Generic
    Code = 0x0F

[Install SRK]
    File = "../crts/SRK1_sha256_2048_65537_v3_ca_crt.der"

[Install CSFK]
    File = "../crts/CSF1_1_sha256_2048_65537_v3_ca_crt.der"

[Authenticate CSF]

[Install Key]
    Verification index = 1
    Engine = RTIC
    Engine Configuration = KEEP
    Target index = 2
    File = "../crts/IMG1_1_sha256_2048_65537_v3_usr_crt.der"

# whole line comment

[Authenticate Data]   # part line comment
    Verification index = 2
    Binding = 0x01, 0x23, 0x45, 0x67, 0x89, 0xab, 0xcd, 0xef
    Blocks = 0x80000000 0 0x00001000 "image.bin" \
             0x80004000 0x4000 0x00001000 "image.bin" \
             0x8000a000 0 0x00002000 "image2.bin"
```

Figure 17. Example Production CSF Description File

5.3.3 HAB4 CSF Example

Figure 18 is an example of a HAB4 CSF description. This example CSF description:

- Defines a version 4 CSF description.

- Overrides default engine ANY with DCP in Authenticate Data command
- Lists three blocks from image for signing.

```
# Illustrative Command Sequence File Description

[Header]
    Version = 4.0
    Hash Algorithm = sha256
    Engine = ANY
    Engine Configuration = 0
    Certificate Format = X509
    Signature Format = CMS

[Install SRK]
    File = "../crts/TBL_1_sha256_tbl.bin"
    Source index = 0

[Install CSFK]
    File = "../crts/CSF1_1_sha256_2048_65537_v3_usr_crt.pem"

[Authenticate CSF]

[Install Key]
    Verification index = 0
    Target index = 2
    File = "../crts/IMG1_1_sha256_2048_65537_v3_usr_crt.pem"

# whole line comment

[Authenticate Data]   # part line comment
    Verification index = 2
    Engine = DCP
    Blocks = 0xf8009400 0x400 0x40 "MCUROM-OCRAM-ENG_img.bin", \
             0xf8009440 0x440 0x40 "MCUROM-OCRAM-ENG_img.bin", \
             0xf800a000 0x1000 0x8000 "MCUROM-OCRAM-ENG_img.bin"
```

Figure 18. Example HAB4 CSF Description File

5.3.4 HAB4 CSF Fast Authentication Example

Figure 19 is an example of a HAB4 CSF description for fast authentication. This example CSF description:

- Defines a version 4 CSF description.
- Tells HAB to use fast authentication mechanism
- Lists single block from image for signing

```
#Illustrative Command Sequence File Description
[Header]
    Version = 4.1
    Hash Algorithm = sha256
    Engine = ANY
    Engine Configuration = 0
    Certificate Format = X509
    Signature Format = CMS

[Install SRK]
    File = "../crts/TBL_1_sha256+tbl.bin"
    Source index = 0

[Install NOCAK]
    File = "../crts/SRK1_sha256_2048_65537_v3_usr_crt.pem"

[Authenticate CSF]
#whole line comment

[Authenticate Data]    # part line comment
    Verification index = 0
    Blocks = 0x877fb000 0x000 0x48000 "signed-uboot.bin"
```

Figure 19. Example HAB4 CSF Description File

5.3.5 HAB4 CSF Example for Encrypted Boot

Figure 20 is an example of a HAB version 4.1 CSF description demonstrating on how to use Install Secret Key and Decrypt Data commands. This example CSF description:

- Defines a version 4.1 CSF description.
- Necessary blocks from image for signing.
- Install Secret Key command
- Blocks for encryption by CST and decryption by ROM/HAB

```
# Illustrative Command Sequence File Description

[Header]
    Version = 4.1
    Hash Algorithm = SHA256
    Engine Configuration = 0
    Certificate Format = X509
    Signature Format = CMS
    Engine = CAAM
    Engine Configuration = 0

[Install SRK]
    File = "../crts/SRK_1_2_3_4_table.bin"
    Source index = 0

[Install CSFK]
    File = "../crts/CSF1_1_sha256_4096_65537_v3_usr_crt.der"

[Authenticate CSF]

[Install Key]
    Verification index = 0
    Target index = 2
    File = "../crts/IMG1_1_sha256_4096_65537_v3_usr_crt.der"

[Authenticate data]
    Verification index = 2
    Blocks = 0x27800400 0x400 800 "u-boot-mx6q-arm2_padded.bin"

[Install Secret Key]
    Verification index = 0
    Target index = 0
    Key = "dek.bin"
    Key Length = 128
    Blob address = 0x27831000

[Decrypt Data]
    Verification index = 0
    Mac Bytes = 16
    Blocks = 0x27800720 0x720 0x2E8E0 "u-boot-mx6q-arm2_padded.bin"
```

Figure 20. Example HAB4 CSF Description File with Decrypt Data Command

5.3.6 AHAB CSF Example

Figure 18 is an example of a AHAB CSF description. This example CSF description:

```
[Header]
       Target = AHAB
       Version = 1.0

[Install SRK]
       # Output of srktool
       File = "…/crts/srk_table.bin"
       # Public key certificate in PEM or DER format
       Source = "…/crts/srk1_crt.pem"
       # Index of SRK in SRK table
       Source index = 0
       # Origin of SRK table
       Source set = OEM
       # Revoked SRKs
       Revocations = 0x0

[Authenticate Data]
       # Output of mkimage
       File = "flash.bin"
       # Offsets = Container header  Signature block (printed out by mkimage)
       Offsets   = 0x400             0x490
```

Figure 18. Example AHAB CSF Description File

5.3.7 AHAB CSF with Certificate Example

Figure 19 is an example of a AHAB CSF description with the Certificate. This example CSF description:

```
[Header]
       Target = AHAB
       Version = 1.0

[Install SRK]
       # Output of srktool
       File = "…/crts/srk_table.bin"
       # Public key certificate in PEM or DER format
       Source = "…/crts/srk3_crt.pem"
       # Index of SRK in SRK table
       Source index = 2
       # Origin of SRK table
       Source set = OEM
       # Revoked SRKs
       Revocations = 0x1
[Install Certificate]
       # Public key certificate in PEM or DER format
       File = "…/crts/sgk3_crt.pem"
       Permissions = 0x1
```

```
[Authenticate Data]
       # Output of mkimage
       File = "flash.bin"
       # Offsets = Container header  Signature block (printed out by mkimage)
       Offsets   = 0x400             0x710
```

Figure 19. Example AHAB CSF Description File

Appendix A HAB Library Version 3 Details

This section provides additional details on the Certificate and Signature formats supported by SoCs including the HAB library Version 3.

A.1 HAB CST Certificate Details

The HAB CST supports public key certificates in WTLS version 1 format using the RSA/SHA-256 signature format. This format is a proprietary extension to the RSA/SHA-1 algorithm specified in [5].

The RSA/SHA-1 signature format in [5] and the RSA/SHA-256 signature format both use PKCS#1 v1.5 Block Type 1 padding, but it is unclear whether the Signature scheme or Encryption scheme (which differs in the use of ASN.1 encoding) is intended. The HAB supports either choice (see Section A.2, "HAB Signature Verification Details"). Note that the Block Type 1 Encryption scheme is not supported in PKCS#1 v2.0.

A.2 HAB Signature Verification Details

HAB Version 3 signature verification is the authentication of digital signature(s) on a chain of data blocks, which can be optionally bound to other data. Signature Verification supports RSA PKCS#1 v1.5 Block Type 1 encoding with SHA-1, SHA-256, or MD5 as the hash algorithm. Either the Signature scheme or Encryption scheme is accepted as valid. MD5 support is disabled by default in HAB ROM code. For SoCs using SHA-256 as the default hash algorithm, both MD-5 and SHA-1 are disabled in the HAB ROM.

Signature lengths are equal to the modulus length of the verifying RSA key.

Signature verification in the HAB ROM component performs the following operations given a signature algorithm, chain of data blocks, an optional rehash chain, a signature, and a public key:

- Verifies that the signature algorithm is supported.
- Computes a hash on the data block chain with the hash algorithm appropriate to the signature algorithm.
- Computes an optional hash on the rehash chain if required as part of a bound signature.
- Recovers the padded hash digest from the signature using RSA computation and the public key.
- Verifies that the recovered padded hash conforms to the PKCS #1 v1.5 Block Type 1 padding format for either the Signature scheme or the Encryption scheme.
- Verifies that the hash within the recovered padded hash matches the computed hash (if the optional rehash chain is present, the hash on the rehash chain is used).

The hash algorithm to use is embedded in the padding recovered in the PKCS#1 v1.5 Signature scheme.

A.3 HAB3 SRK Structure Information

On SoCs supporting HAB3 the ROM expects an Application Header (also known as the Flash Header) to be included as part of the product code which is usually a bootloader. The SoC boot ROM expects the Application Header to be located at a fixed offset from the beginning of the product code image. Note that one of the fields in the Application Header is the pointer to the SRK data structure which is defined as:

```
typedef struct
{
 /* RSA public exponent */
 unsigned char rsa_exponent[HAB_MAX_EXPONENT_BYTES];
 unsigned char *rsa_modulus;              /* RSA modulus pointer */
 unsigned short int exponent_bytes;       /* Exponent size in bytes */
 unsigned short int modulus_bytes;        /* Modulus size in bytes */
 unsigned char init_flag;                 /* Indicates if key initialized */
} hab_rsa_public_key;
```

This data structure is defined in the file hab_super_root.h included in the `/code/hab3/hdr` directory of the CST release. Further details on the Application Header are available in the System Boot chapter of the Reference Manual for the NXP Processor that you are using.

A C file containing the static data for each SRK public key is generated by the hab3_pki_tree script (See Section 3.1.2, "Running the hab3_pki_tree script Example"). The data generated in the C files is the public key exponent and modulus data the HAB library on the SoC requires and follows the structure given above. To include the SRK public key data in your product code add the selected SRK C file in your product code build process, being sure to include hab_super_root.h to the include search path. Then be sure that the SRK field of the Application Header points to this data.

Appendix B Replacing the CST Backend Implementation

The NXP CST is a reference implementation and is sufficient for most use cases. However, there may be instances where a higher level of security is required. In such cases the level of protection required for signing keys needs to be much higher than what the CST reference implementation provides. To accommodate this NXP has architected the CST in two parts a Front End and a Back End. The Front End contains all the NXP proprietary operations of the CST with the Back End containing all standard cryptographic operations.

The CST Back End make use of standard cryptographic protocols allowing the use of common cryptographic library implementations. The CST makes use of the OpenSSL library [1] for performing basic cryptographic operations related to digital signature generation. For encrypted boot operations using AES in CCM mode the reference CST makes use of the AES library from Brian Gladman [7].

The remainder of this appendix describes how the reference Back End can be replaced with a different solution such as a Hardware Security Module (HSM). The replacement of the Back End with another solution is completely optional.

B.1 CST Architecture

Figure B-1 provides an overview of the CST components. To replace the Back End of the CST not only do you need to replace the OpenSSL commands, OpenSSL library and AES library but you must develop new Adaptation Layer software. The Adaptation Layer must be written to provide the equivalent functionality to the Front End as the reference Back End.

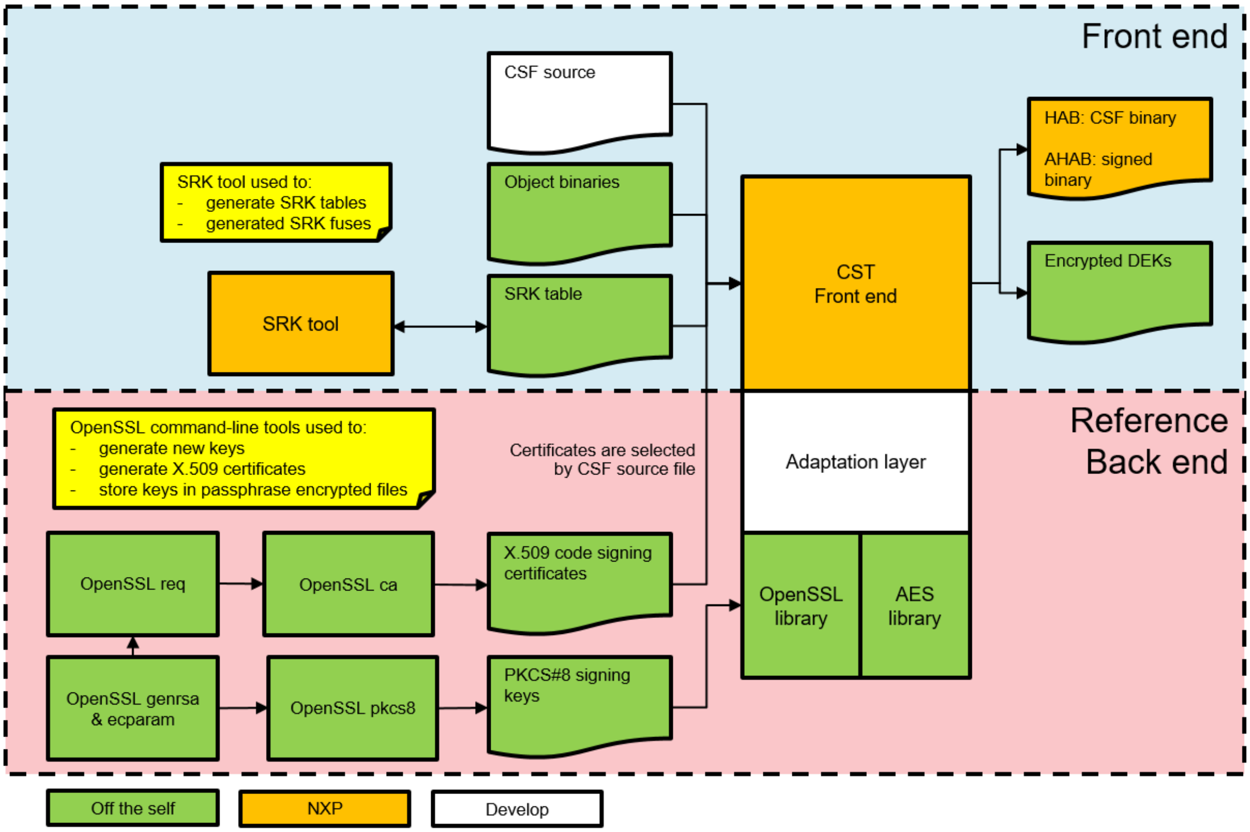


Figure B-1. Overview of Reference CST components

B.2 Back End Components

The section provides a brief overview of each of the components that make up the CST Back End. Note that the CST depends on OpenSSL in two ways. The first is by using the command line interface for generating code signing keys. The second is programmatically via the cryptographic library for generating signatures and making use of cryptographic algorithms. The reference implementation of the CST acts as both an CA through the use of OpenSSL command and an SA through the use of the OpenSSL library:

- **OpenSSL genrsa**: OpenSSL command line option the CST key generation scripts use to create code signing RSA key pairs.
- **OpenSSL ecparam**: OpenSSL command line option the CST key generation scripts use to create code signing EC key pairs.
- **OpenSSL pkcs8**: OpenSSL command line option the CST key generation scripts use to protect the confidentiality of the private keys. Keys stored in PKCS#8 format encrypted with a pass phrase.
- **OpenSSL req**: OpenSSL command line option used to generate a PKCS#10 certificate requests.
- **OpenSSL ca**: OpenSSL command line option used to generate X.509 certificates for use with code signing. The High Assurance Boot Version 4 Application Programming

Interface Reference Manual [8] provides details on the X.509 certificate profile supported by HAB.

- **OpenSSL Library**: Provides support for the PKCS standards and the underlying cryptographic algorithms. The exception is AES CCM mode which at the time of CST development OpenSSL did not include support.
- **AES Library**: This library includes Brian Gladman's reference AES implementation [7] together with CCM mode [6]. This is to encrypt images for HAB encrypted boot.
- **CST Adaptation Layer**: The adaptation layer provides the interface linking the CST Front End to the Back-End services provided by the OpenSSL and AES libraries. To replace the Back-End services provided open source libraries requires a new implementation of the adaptation layer based on the new Back-End services. The implementation will be specific to the Back-End Service implementation you have chosen. For example, if OpenSSL and the AES libraries are replaced with and HSM, then the adaptation layer must be re-written to interface with the HSM APIs.

B.3 Back End Replacement for Linux

In addition to the reference CST executables the CST is delivered with the following additional components:

- `./linux/lib/libfrontend.a`: This is the Front End library containing the NXP proprietary features of the CST as shown in Figure B-1. This is a 32-bit library built with GCC 3.4.3 using the -m32 compiler option.
- `./code/back_end/hdr/adapt_layer.h`: Is the main header file for the adaptation layer and includes the documentation for the APIs used by the Front End. There are two APIs used by the Front End:
  - `gen_sig_data`: The CST Front End uses this API to generate HAB signatures.
  - `gen_auth_encrypted_data`: The CST Front End uses this API to generate encrypted data using AES-CCM.
- Any new Back End implementation must follow implement these two APIs in an equivalent adaptation layer corresponding to the new cryptographic services replacing OpenSSL and the AES libraries.
- For reference the source code and header files for the NXP reference implementation are included in `./code/back_end.`
- To use a new method for public key generation, replace the key generation scripts with the new implementation.

These components will assist you in developing a new Adaptation Layer component.

NOTE

Although the Back End may replace OpenSSL for code signing, SA and CA support, the CST Front End still makes use of OpenSSL for some non-code signing operations. This means that when linking library components together to generate a CST executable an OpenSSL library must also be included. NXP recommends using OpenSSL 1.1.0 or later which is available at [1].

B.4 Front End References to Code Signing Keys

When replacing the CST Back-End it is important to keep in mind that he CST Front End refers to code signing keys and certificates using file names. These are the key filenames that correspond to the RSA public key certificate and private key files generated by the CST. However, filenames may not be the native method for referencing keys in a new replacement Back End service. If this is the case, then the new Adaptation Layer is responsible for converting to and from file name references.

This is also true for Data Encryption Keys that the CST generates for encrypting images.

B.5 Back End alternative

An alternative Back-End replacement is proposed under the directory `/code/back_end-hsm`. This alternative provides the support to interact with an Hardware Security Module (HSM) by using the PKCS#11 interface definition.

More detailed information can be found in the documentation located in the directory `/code/back_end-hsm/doc`.

Here is an overview of the proposed solution.

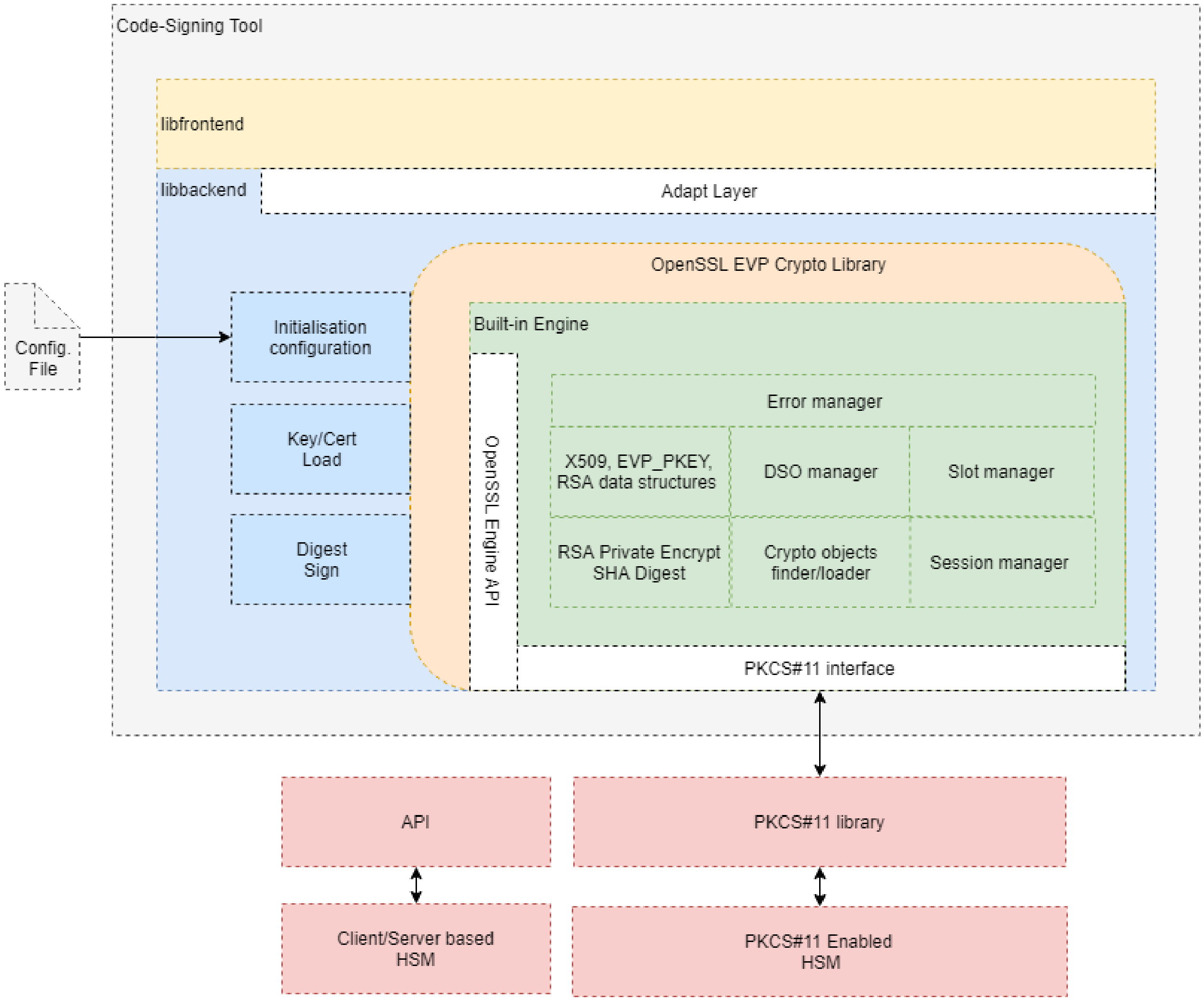


Figure B-2. Overview of the Back-End HSM alternative replacement