RX Family

Renesas Secure IP (RSIP) Module Protected Mode Firmware Integration Technology

Introduction

This document explains the usage of the software drivers for the Renesas Secure IP (RSIP) modules Protected Mode on RX Family microcontrollers (MCUs). These software drivers are referred to collectively as the RSIP Protected Mode (PM) driver.

The RSIP PM driver is provided as a Firmware Integration Technology (FIT) module. Refer to the webpage linked to below for an overview of FIT.

https://www.renesas.com/us/en/products/software-tools/software-os-middleware-driver/software-package/fit.html

The RSIP PM driver provides APIs for the cryptographic algorithms listed in Table 1 as well as for securely performing firmware updates.

Confirmed Devices

RX261 group

Table 1 RSIP-E11A Cryptographic Algorithms

Cipher Type		Algorithms
Asymmetric key cryptography	Signature generation/ verification	ECDSA (secp256r1, brainpoolP256r1, secp256k1): RFC6979
	Key generation	secp256r1, brainpoolP256r1, secp256k1
Symmetric key cryptography	AES	AES (128-/256-bit) ECB/CBC/CTR: FIPS 197, SP800-38A
Hashing	SHA	SHA-224, SHA-256: FIPS 180-4
Authenticated encryption with associated data (AEAD)		GCM/CCM: FIPS 197, SP800-38C, SP800-38D
Message authentication		CMAC (AES): FIPS 197, SP800-38B GMAC: RFC 4543 HMAC (SHA): RFC 2104
Pseudo-random bit generation		SP 800-90A
Random number generation		Tested with SP 800-90B.
Key wrapping		AES (128-/256-bit)

Note: RFC 2104: HMAC: Keyed-Hashing for Message Authentication (rfc-editor.org)
RFC 4543: The Use of Galois Message Authentication Code (GMAC) in IPsec ESP and AH (rfc-editor.org)
RFC 6979 - Deterministic Usage of the Digital Signature Algorithm (DSA) and Elliptic Curve Digital Signature Algorithm (ECDSA) (ietf.org)
NIST SP 800-38A, Recommendation for Block Cipher Modes of Operation Methods and Techniques
NIST SP 800-38-B Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication (nist.gov)
NIST SP 800-38D, Recommendationfor Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC
NIST SP800-56A: Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Lograrithm Cryptography (nist.gov)
NIST SP800-56C: Recommendation for Key-Derivation Methods in Key-Establishment Schemes (nist.gov)
NIST SP800-22: https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-22r1a.pdf
NIST SP800-90A: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-90Ar1.pdf
NIST SP800-90B: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-90B.pdf
FIPS 180-4: https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.180-4.pdf

Contents

1. Overview

1.1 Terminology

Terms used in this document are defined below.

Table 1-1 Descriptions of Terms

Term	Description
Key injection	Injecting a wrapped key into the device at the factory.
Key updating	Injecting a wraped key into the device in the field.
User key	An encryption key in plaintext used by the user. Not used on the device. For AES and HMAC, user keys are used as shared keys. For ECC, user keys are used as public keys and secret keys.
Encrypted key	Key information generated by adding a MAC value and encrypting a user key using a UFPK or update key. An encrypted key corresponding to the same user key is a shared value on each device.
Wrapped key	Data consisting of an encrypted key that has been converted into a form that is usable by the RSIP PM driver by key injection or key updating. The wrapped key has been wrapped using an HUK, so the wrapped key of the same encrypted key will be a unique value on each device.
UFPK	User Factory Programming Key A keyring set by the user and used to generate an encrypted key from a user key during key injection. Not used on the device.
W-UFPK	Wrapped UFPK Key information generated by wrapping a UFPK using an HRK on the DLM server. The UFPK is decrypted using the HRK internally by the TSIP.
Key update key (KUK)	A key set by the user and used to generate an encrypted key from a user key during key updating. Thewrapped KUK for the update key must be generated beforehand by key injection in order to perform key updating on the device.
Hardware root key (HRK)	A shared encryption key that exists only inside the TSIP and in secure rooms within Renesas.
Hardware unique key (HUK)	A device-specific encryption key that is derived internally by the TSIP and used to protect key data.
Device Lifecycle Management (DLM) server	A key management server operated by Renesas. It is used for wrapping UFPK.
Image Encryption Key	256-bit key used in firmware encryption for use with the firmware update API
Key Encryption Key	AES 128bit key used in Image Encryption Key wrap

1.2 RSIP Overview

The Renesas Secure IP (RSIP) block on RX Family MCUs creates a secure area inside the MCU by monitoring for unauthorized access attempts. This ensures that the RSIP can utilize the encryption engine and user key (encryption key) reliably and securely. The RSIP handles the encryption key in a format called a wrapped key that is secure and unreadable outside the RSIP block. This means that the encryption key, the most important element in reliable and secure encryption, can be stored in the flash memory.

The RSIP block has a safe area that contains the encryption engine and storage for the encryption key in plaintext format.

The RSIP restores from the wrapped key the encryption key used for cryptographic operations. The Wrapped Key is generated tied to the HUK, which is a device-specific value. This means that even if a wrapped key is copied from one device to a different device it cannot be used on the second device. To access the TSIP hardware an application must use the RSIP PM driver.

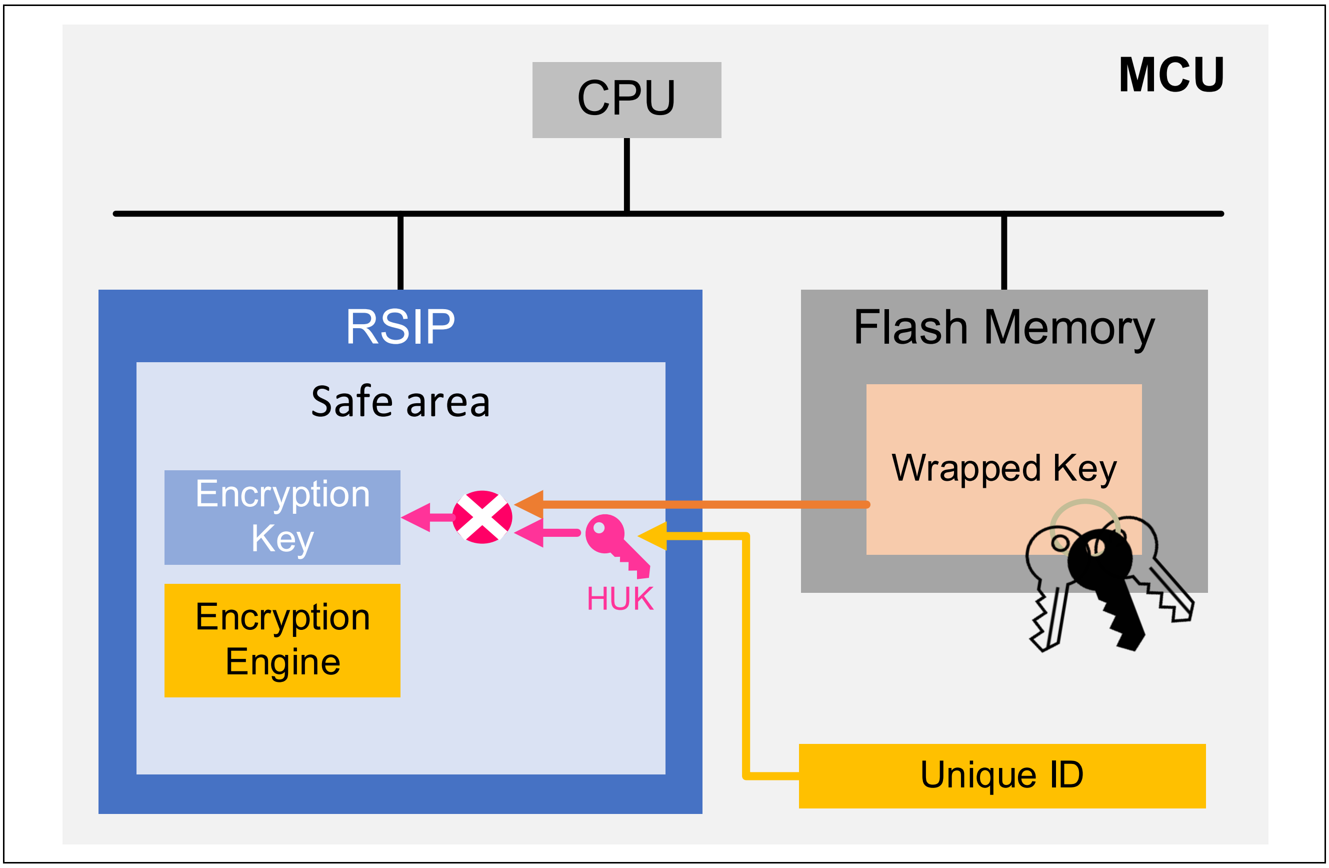


Figure 1.1 MCU Incorporating RSIP

1.3 Structure of Product Files

Table 1.2 below lists the files included in the product.

Table 1-2 Structure of Product Files

File/Directory (Bold) Name	Description
Readme.txt	Readme
RX_RSIP_SoftwareLicenseAgreement_JPN.pdf	Software License Agreement (Japanese)
RX_RSIP_SoftwareLicenseAgreement_ENG.pdf	Software License Agreement (English)
r20an0748jj0121-rx-rsip-security.pdf	RSIP PM driver application note (Japanese)
r20an0748ej0121-rx-rsip-security.pdf	RSIP PM driver application note (English)
reference_documents	Folder containing documentation of topics such as how to use the FIT module with various integrated development environments
ja	Folder containing documentation of topics such as how to use the FIT module with various integrated development environments (Japanese)
r01an1826jj0110-rx.pdf	How to add FIT modules to CS+ projects (Japanese)
r01an1723ju0121-rx.pdf	How to add FIT modules to e^2 studio projects (Japanese)
r20an0451js0140-e2studio-sc.pdf	Smart Configurator user’s guide (Japanese)
en	Folder containing documentation of topics such as how to use the FIT module with various integrated development environments (English)
r01an1826ej0110-rx.pdf	How to add FIT modules to CS+ projects (English)
r01an1723eu0121-rx.pdf	How to add FIT modules to e^2 studio projects (English)
r20an0451es0140-e2studio-sc.pdf	Smart Configurator user’s guide (English)
FITModules	FIT module folder
r_rsip_protected_rx_v1.00.zip	RSIP PM driver FIT module
r_rsip_protected_rx_v1.00.xml	RSIP PM driver FIT module e^2 studio FIT plug-in XML file
r_rsip_protected_rx_v1.00_extend.mdf	RSIP PM driver FIT module Smart Configurator configuration settings file
FITDemos	Demo project folder
rx261_ek_rsip_sample	Project showing how to write keys and use cryptographic APIs
rx261_ek_rsip_secure_boot*1*2	Secure boot/secure update implementation example
rx261_ek_rsip_secure_boot*1*2	Secure boot firmware
rx261_ek_rsip_user_program*1*2	User program following secure update

Table 1.3 lists the files and folders contained in the folder produced by unzipping r_rsip_protected_rx_v.1.00.zip.

Table 1-3 File Structure

File/Directory (Bold) Names	Description
r_config	RSIP PM driver config file folder
r_rsip_protected_rx_config.h	RSIP PM driver config file (default settings)
r_rsip_protected_rx	RSIP PM driver FIT module folder
primitive	RSIP PM driver source code folder
rx261	Folder containing program code dependent on specific MCU models
r_rsip_rx261_iodefine.h	RSIP access header file
r_rsip_primitive.h	Header files for RSIP access source code
r_rsip_rx_finction*xxx*.c	Source files for RSIP access source code *xxx* in the file name is a number.
r_rsip_rx_p*xx*.c	Source files for RSIP access source code *xxx* in the file name is a number.
s_flash.c	Key information file
private	Folder for storing program code of RSIP PM driver internal functions
common	Folder for storing program code for microcontroller model-independent portions
r_rsip_private.h	Header files for internal functions
rx261	Folder for storing program code for microcontroller model-dependent portions
r_rsip_private.c	Source code for RSIP PM driver internal functions
r_rsip_wrapper.c	Source code for RSIP PM driver wrapper APIs
r_rsip_ wrapper.h	Header files for RSIP PM driver wrapper APIs
public	Folder for storing programs for RSIP PM driver API
common	Folder for storing program code for microcontroller model-independent portions
r_rsip.c	Source code for RSIP PM driver common function API
r_rsip_aes.c	Source code for RSIP PM driver AES API
r_rsip_ecc.c	Source code for RSIP PM driver ECC API
r_rsip_sha.c	Source code for RSIP PM driver HASH API
r_rsip_public.h	Header file for RSIP PM driver function API
rx261	Folder for storing program code for microcontroller model-dependent portions
r_rsip_fwup.c	Source code for RSIP PM driver Firmware Update API
r_rsip_fwup.h	Header file for RSIP PM driver Firmware Update API
doc	
ja	RSIP PM driver source code (required)
r20an0748jj0100-rx-rsip-security.pdf	RSIP PM driver application note (Japanese)
en	RSIP PM driver source code (Can be turned on/off with an option.)
r20an0748ej0100-rx-rsip-security.pdf	RSIP PM driver application note (English)
r_rsip_protected_rx_if.h	RSIP PM driver header file
readme.txt	Readme

1.4 Development Environment

The RSIP PM driver was developed using the tools described below. When developing your own applications, use the versions of the software indicated below, or newer.

1. Integrated development environment
   Refer to the “Integrated development environment” item under 7.1, Confirmed Operation Environment.

2. C compiler
   Refer to the “C compiler” item under 7.1, Confirmed Operation Environment.

3. Emulator/debugger
   E2 Lite

4. Evaluation boards
   Refer to the “Board used” item under 7.1, Confirmed Operation Environment. All of the boards listed are special product versions with cryptographic functionality. Make sure to confirm the product model name before ordering. e^2 studio and CC-RX were used in combination for evaluation and to create the demo project.
   The project conversion function can be used to convert projects from e^2 studio to CS+. If you encounter errors such as compiler errors, please contact your Renesas representative.

1.5 Code Size

The table below lists the ROM and RAM sizes and the maximum stack usage associated with this module.

The actual ROM (code and constants) and RAM (global data) sizes are determined by the configuration options listed in 2.6, Configuration.

The values listed in the table below have been confirmed under the following conditions:

Module revision: r_rsip_protected_rx rev1.00

Compiler version: Renesas Electronics C/C++ Compiler Package for RX Family V3.06.00
(Optimization Level 2 with “-lang = c99” option added)

GCC for Renesas RX 8.3.0.202311
(Optimization Level -Os with “-std = gnu99” option added)

IAR C/C++ Compiler for Renesas RX version 5.10.01
(Optimization level high(balance）)

Configuration options:
Renesas Electronics C/C++ Compiler Package for RX Family: -isa=rxv3, Optimization Level 2

GCC for Renesas RX: RXv3, Optimization Level -Os

IAR C/C++ Compiler for Renesas RX: --core rxv3 -Oh, Optimization level high(balance）

Category	Memory Used		
	Renesas Compiler	GCC*	IAR Compiler
ROM	72,659 bytes	86,088 bytes	96,938 bytes
RAM	16 bytes	0 bytes	16 bytes
Stack	240 bytes	16 bytes	188 bytes

1.6 Sections

When using the secure boot functionality, the sections BSECURE_BOOT*, PSECURE_BOOT, PSECURE_BOOT_ERASE, CSECURE_BOOT*, DSECURE_BOOT*, and RSECURE_BOOT* can be used. Please set RSIP_SECURE_BOOT_SECTION_ENABLE to preprocessor macro definition in e^2 studio settings when these section are required.

1.7 Performance

Performance is measured in cycles of ICLK, the core clock. The operating clock (PCLKB) for RSIP is set to ICLK : PCLKB = 2 : 1. The drivers are built using CC-RX with optimization level 2. Refer to 7.1, Confirmed Operation Environment, for version information. The configuration options are left in their default settings.

1.7.1 RX231

Table 1-4 Performance of Common APIs

API	Performance (Unit: Cycle)
R_RSIP_Open	447,000
R_RSIP_Close	440
R_RSIP_GetVersion	20

Table 1-5 Performance of Key management APIs

API	Performance (Unit: Cycle)
R_RSIP_EncryptedKeyWrap	11,300
R_RSIP_KeyGenerate	5,660
R_RSIP_KeyPairGenerate	4,700,000
R_RSIP_PublicKeyExport	100
R_RSIP_InjectedKeyImport	100
R_RSIP_InitialKeyWrap	9,190
R_RSIP_InitialKeyUpdateKeyWrap	10,000

Table 1-6 Performance of Random Number Generate API

API	Performance (Unit: Cycle)
R_RSIP_RandomNumberGenerate	1,050

Table 1-7 Performance of AES APIs

Algorithm	API	Performance (Unit: Cycle)		
		48-Byte Processing	64-Byte Processing	80-Byte Processing
ECB Encryption	R_RSIP_AES_Cipher_Init	4,520	4,520	4,520
	R_RSIP_AES_Cipher_Update	840	950	1,050
	R_RSIP_AES_Cipher_Finish	470	470	470
ECB Decryption	R_RSIP_AES_Cipher_Init	4,530	4,530	4,530
	R_RSIP_AES_Cipher_Update	970	1,070	1,180
	R_RSIP_AES_Cipher_Finish	480	480	480
CBC Encryption	R_RSIP_AES_Cipher_Init	4,560	4,560	4,560
	R_RSIP_AES_Cipher_Update	880	990	1,100
	R_RSIP_AES_Cipher_Finish	500	500	500
CBC Decryption	R_RSIP_AES_Cipher_Init	4,570	4,570	4,570
	R_RSIP_AES_Cipher_Update	1,010	1,120	1,230
	R_RSIP_AES_Cipher_Finish	500	500	500
CTR	R_RSIP_AES_Cipher_Init	4,580	4,580	4,580
	R_RSIP_AES_Cipher_Update	930	1,040	1,140
	R_RSIP_AES_Cipher_Finish	510	510	510

Table 1-8 Performance of AES AEAD APIs

Algorithm	API	Performance (Unit: Cycle)		
		48-Byte Processing	64-Byte Processing	80-Byte Processing
GCM Encryption	R_RSIP_AES_AEAD_Init	4,720	4,720	4,720
	R_RSIP_AES_AEAD_AADUpdate	420	420	420
	R_RSIP_AES_AEAD_Update	1,630	1,830	2,020
	R_RSIP_AES_AEAD_Finish	1,280	1,280	1,280
GCM Decryption	R_RSIP_AES_AEAD_Init	4,720	4,720	4,720
	R_RSIP_AES_AEAD_AADUpdate	420	420	430
	R_RSIP_AES_AEAD_Update	1,730	1,930	2,120
	R_RSIP_AES_AEAD_Verify	1,700	1,700	1,700
CCM Encryption	R_RSIP_AES_AEAD_Init	260	260	260
	R_RSIP_AES_AEAD_LengthsSet	50	50	50
	R_RSIP_AES_AEAD_AADUpdate	4,870	4,870	4,870
	R_RSIP_AES_AEAD_Update	1,670	1,880	2,100
	R_RSIP_AES_AEAD_Finish	1,060	1,060	1,060
CCM Decryption	R_RSIP_AES_AEAD_Init	260	260	260
	R_RSIP_AES_AEAD_LengthsSet	50	50	50
	R_RSIP_AES_AEAD_AADUpdate	4,870	4,870	4,870
	R_RSIP_AES_AEAD_Update	1,560	1,780	1,990
	R_RSIP_AES_AEAD_Verify	1,640	1,640	1,640

Note: GCM performance was measured with parameters fixed as follows: ivec = 128 bits, AAD = 128 bits, and authentication tag = 128 bits.

CCM performance was measured with parameters fixed as follows: nonce = 56 bits, AAD = 64 bits, and MAC = 32 bits.

Table 1-9 Performance of AES MAC APIs

Algorithm	API	Performance (Unit: Cycle)		
		48-Byte Processing	64-Byte Processing	80-Byte Processing
Generate CMAC	R_RSIP_AES_MAC_Init	4,110	4,110	4,110
	R_RSIP_AES_MAC_Update	760	870	970
	R_RSIP_AES_MAC_SignFinish	1,000	1,000	1,000
Verify CMAC	R_RSIP_AES_MAC_Init	4,110	4,110	4,110
	R_RSIP_AES_MAC_Update	760	870	970
	R_RSIP_AES_MAC_VerifyFinish	1,520	1,520	1,520

Table 1-10 Performance of ECC APIs

Algorithm	API	Performance (Unit: Cycle)		
		48-Byte Processing	64-Byte Processing	80-Byte Processing
secp256r1	R_RSIP_ECDSA_Sign	4,900,000	4,900,000	4,900,000
	R_RSIP_ECDSA_Verify	4,900,000	4,900,000	4,900,000
secp256k1	R_RSIP_ECDSA_Sign	4,900,000	4,900,000	4,900,000
	R_RSIP_ECDSA_Verify	4,900,000	4,900,000	4,900,000
brainpoolP256r1	R_RSIP_ECDSA_Sign	4,900,000	4,900,000	4,900,000
	R_RSIP_ECDSA_Verify	4,900,000	4,900,000	4,900,000

Table 1-11 Performance of HASH APIs

Algorithm	API	Performance (Unit: Cycle)		
		48-Byte Processing	64-Byte Processing	80-Byte Processing
SHA224	R_RSIP_SHA_Init	120	120	120
	R_RSIP_SHA_Update	130	140	1,920
	R_RSIP_SHA_Finish	1,970	3,260	1,950
SHA256	R_RSIP_SHA_Init	120	120	120
	R_RSIP_SHA_Update	130	140	1,920
	R_RSIP_SHA_Finish	1,970	3,250	1,950

Table 1-12 Performance of HMAC APIs

Algorithm	API	Performance (Unit: Cycle)		
		48-Byte Processing	64-Byte Processing	80-Byte Processing
Generate HMAC-SHA224	R_RSIP_HMAC_Init	90	100	100
	R_RSIP_HMAC_Update	130	140	7,060
	R_RSIP_HMAC_SignFinish	10,500	11,800	5,090
Verify HMAC-SHA224	R_RSIP_HMAC_Init	100	100	100
	R_RSIP_HMAC_Update	130	140	7,060
	R_RSIP_HMAC_VerifyFinish	11,400	12,600	6,060
Generate HMAC-SHA256	R_RSIP_HMAC_Init	100	100	100
	R_RSIP_HMAC_Update	130	140	7,060
	R_RSIP_HMAC_SignFinish	10,500	11,700	5,050
Verify HMAC-SHA256	R_RSIP_HMAC_Init	100	100	100
	R_RSIP_HMAC_Update	130	140	7,070
	R_RSIP_HMAC_VerifyFinish	11,300	12,600	6,010

Table 1-13 Performance of Key Wrap APIs

API	Performance (Unit: Cycle)	
	Wrapping Key AES-128	Wrapping Key AES-256
R_RSIP_RFC3394_KeyWrap	15,900	22,900
R_RSIP_RFC3394_KeyUnwrap	17,900	24,900

Table 1-14 Performance of Secure Boot APIs

API	Performance (Unit: Cycle)		
	2K-Byte Processing	4K-Byte Processing	6K-Byte Processing
R_RSIP_SB_MAC_Verify_Init	2,140	2,140	2,140
R_RSIP_SB_MAC_Verify_Update	17,900	35,600	53,300
R_RSIP_SB_MAC_Verify_Finish	18,200	35,900	53,500

2. API Information

2.1 Hardware Requirements

RSIP PM drivers can only be used with devices provided with a RSIP. Check the product number of the device to ensure that it incorporates a RSIP.

2.2 Software Requirements

The RSIP PM drivers are dependent on the following module:

r_bsp Use rev. 7.51 or later. (BSP stands for “board support package.”)

Change the value in the following macro in r_bsp_config.h in the r_config folder to 0xB.

```
/* Chip version.
   Character(s) = Value for macro =
   A            = 0xA              = Chip version A
                                   = Encryption module not included, USB
included, CAN FD included (only CAN 2.0 protocol supported)
   B            = 0xB              = Chip version B
                                   = Encryption module and USB included, CAN FD
included
*/
#define BSP_CFG_MCU_PART_VERSION        (0xB)
```

2.3 Supported Toolchain

The operation of the RSIP PM driver has been confirmed with the toolchain indicated in 7.1, Confirmed Operation Environment.

2.4 Header File

All API calls and their supported interface definitions are contained in r_rsip_protected_rx_if.h.

2.5 Integer Types

The RSIP PM driver uses ANSI C99 integer types defined in stdint.h.

2.6 Configuration

By setting the values of the following macros to 1 or 0 in /r_config/r_rsip_protected_rx_config.h you can turn the corresponding functions on or off.

Table 2-1 Configration Options /r_rsip_protected_rx_config.h (1)

Definition	Default Value	Meanings
RSIP_CFG_PARAM_CHECKING_ENABLE	1	Enable parameter check 1 : enabled 0: disabled
RSIP_CFG_AES_128_ENABLE	1	Enable AES 128bit 1 : enabled 0: disabled
RSIP_CFG_AES_256_ENABLE	1	Enable AES 256bit 1 : enabled 0: disabled
RSIP_CFG_XTS_AES_128_ENABLE	1	Not used
RSIP_CFG_XTS_AES_256_ENABLE	1	Not used
RSIP_CFG_AES_ECB_CBC_CTR_ENABLE	1	Enable AES ECB/CBC/CTR mode 1 : enabled 0: disabled
RSIP_CFG_AES_XTS_ENABLE	1	Not used
RSIP_CFG_AES_GCM_ENABLE	1	Enable AES GCM mode 1 : enabled 0: disabled
RSIP_CFG_AES_CCM_ENABLE	1	Enable AES CCM mode 1 : enabled 0: disabled
RSIP_CFG_AES_CMAC_ENABLE	1	Enable AES CMAC 1 : enabled 0: disabled
RSIP_CFG_ECC_SECP256R1_ENABLE	1	Enable ECC secp256r1 1 : enabled 0: disabled
RSIP_CFG_ECC_SECP384R1_ENABLE	1	Not used
RSIP_CFG_RSA_2048_ENABLE	1	Not used
RSIP_CFG_RSA_3072_ENABLE	1	Not used
RSIP_CFG_RSA_4096_ENABLE	1	Not used
RSIP_CFG_SHA1_ENABLE	0	Not used
RSIP_CFG_SHA224_ENABLE	1	Enable SHA224 1 : enabled 0: disabled
RSIP_CFG_SHA256_ENABLE	1	Enable SHA256 1 : enabled 0: disabled
RSIP_CFG_SHA384_ENABLE	1	Not used
RSIP_CFG_SHA512_ENABLE	0	Not used

Table 2-2 Configration Options /r_rsip_protected_rx_config.h (2)

Definition	Default Value	Meanings
RSIP_CFG_HMAC_SHA1_ENABLE	0	Not used
RSIP_CFG_HMAC_SHA224_ENABLE	1	Enable HMAC-SHA224 1 : enabled 0: disabled
RSIP_CFG_HMAC_SHA256_ENABLE	1	Enable HMAC-SHA256 1 : enabled 0: disabled
RSIP_CFG_BYTE_SIZE_SHA_BLOCK_MAX	256U	Buffer size for SHA calculation
RSIP_CFG_WORD_SIZE_SHA_INTERNAL_STATE_MAX	20U	Not used
RSIP_CFG_BYTE_SIZE_HMAC_BLOCK_MAX	64U	Buffer size for HMAC calculation
RSIP_CFG_WORD_SIZE_HMAC_INTERNAL_STATE_MAX	20U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_HMAC_MAX	RSIP_BYTE_SIZE_WRAPPED_KEY_HMAC_SHA256	Buffer size to store Wrapped HMAC Key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_KEY_UPDATE_KEY	64U	value field size of rsip_key_update_key_t structure
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _AES_128	36U	value field size of rsip_wrapped_key_t structure for AES-128 key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_AES_192	52U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_AES_256	52U	value field size of rsip_wrapped_key_t structure for AES-256 key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_XTS_AES_128	52U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_XTS_AES_256	84U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_ECC_SECP256R1_PUBLIC	84U	value field size of rsip_wrapped_key_t structure for secp256r1 public key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_ECC_SECP384R1_PUBLIC	116U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_ECC_SECP521R1_PUBLIC	148U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_ECC_BRAINPOOLP256R1_PUBLIC	84U	value field size of rsip_wrapped_key_t structure for brailnpoolP256r1 public key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_ECC_BRAINPOOLP384R1_PUBLIC	116U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_ECC_BRAINPOOLP512R1_PUBLIC	148U	Not used

Table 2-3 Configration Options /r_rsip_protected_rx_config.h (3)

Definition	Default Value	Meanings
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_EDWARDS25519_PUBLIC	52U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_SECP256R1_PRIVATE	52U	value field size of rsip_wrapped_key_t structure for secp256r1 private key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_SECP384R1_PRIVATE	68U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_SECP521R1_PRIVATE	84U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_SECP256K1_PRIVATE	52U	value field size of rsip_wrapped_key_t structure for secp256k1 private key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_BRAINPOOLP256R1_PRIVATE	52U	value field size of rsip_wrapped_key_t structure for brailnpoolP256r1 private key
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_BRAINPOOLP384R1_PRIVATE	68U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_BRAINPOOLP512R1_PRIVATE	84U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _ECC_EDWARDS25519_PRIVATE	52U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_1024_PUBLIC	164U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_2048_PUBLIC	292U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_3072_PUBLIC	420U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_4096_PUBLIC	548U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_1024_PRIVATE	276U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_2048_PRIVATE	532U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_3072_PRIVATE	788U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _RSA_4096_PRIVATE	1044U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _HMAC_SHA1	52U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _HMAC_SHA224	52U	Not used
RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE _HMAC_SHA256	52U	value field size of rsip_wrapped_key_t structure for HMAC-SHA256 key

Table 2-4 Configration Options /r_rsip_protected_rx_config.h (4)

Definition	Default Value	Meanings
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_224_QX	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_224_QY	32U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_256_QX	4U	Byte position of ECC 256bit Qx in Wrapped Key structure
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_256_QY	32U	Byte position of ECC 256bit Qy in Wrapped Key structure
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_384_QX	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_384_QY	52U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_512_QX	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_512_QY	68U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_521_QX	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_521_QY	84U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_ECC_EDWARDS25519_Q	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_1024_N	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_1024_E	132U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_2048_N	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_2048_E	260U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_3072_N	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_3072_E	388U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_4096_N	4U	Not used
RSIP_CFG_BYTE_POS_WRAPPED_PUBLIC_KEY_RSA_4096_E	516U	Not used
RSIP_CFG_SECURE_BOOT	1	Enable Secure Boot 1 : enabled 0: disabled
RSIP_CFG_FIRMWARE_UPDATE	1	Enable Firmware Update 1 : enabled 0: disabled

2.7 Type Difinition

The following table shows the type definitions used in the RSIP PM driver.

Table 2-5 RSIP PM Driver Type Definition

Definition	Data Type	Remarks
rsip_ctrl_t	void	Type definitions for API arguments of the RSIP PM driver management structure Use rsip_instance_ctrl_t for the data type to be used for the arguments.

2.8 Data Structures

The following table shows the data structures used in the RSIP PM driver.

Table 2-6 RSIP PM Driver Data Structures

Definition	Remarks
rsip_instance_ctrl_t	Instance of RSIP PM driver management structure
rsip_cfg_t	Configuration Structure Not used in RX RSIP PM driver.
rsip_wrapped_key_t	Wrapped Key
rsip_key_update_key_t	Key Update Key
rsip_wufpk_t	W-UFPK

2.9 Enumerated Type

The following is the definition of the enumerated type used in the RSIP PM driver.

Table 2-7 Key Type enum rsip_key_type_t

Definition	Value	Remarks
RSIP_KEY_TYPE_INVALID	0x0000	Invalid
RSIP_KEY_TYPE_AES_128	0x1000	AES128bit key
RSIP_KEY_TYPE_AES_256	0x1001	AES256bit key
RSIP_KEY_TYPE_ECC_SECP256R1_PUBLIC	0x2000	secp256r1 public key
RSIP_KEY_TYPE_ECC_SECP256K1_PUBLIC	0x2001	secp256k1 public key
RSIP_KEY_TYPE_ECC_BRAINPOOL_P256R1_PUBLIC	0x2002	brainpoolP256r1 public key
RSIP_KEY_TYPE_ECC_SECP256R1_PRIVATE	0x2100	secp256r1 private key
RSIP_KEY_TYPE_ECC_SECP256K1_PRIVATE	0x2101	secp256k1 private key
RSIP_KEY_TYPE_ECC_BRAINPOOL_P256R1_PRIVATE	0x2102	brainpoolP256r1 private key
RSIP_KEY_TYPE_HMAC_SHA224	0x3000	HMAC SHA224 key
RSIP_KEY_TYPE_HMAC_SHA256	0x3001	HMAC SHA256 key

Table 2-8 Asynmetric Key Type enum rsip_key_pair_type_t

Definition	Value	Remarks
RSIP_KEY_PAIR_TYPE_INVALID	0x000000	Invalid
RSIP_KEY_PAIR_TYPE_ECC_SECP256R1	0x202100	ECC secp256r1 key pair
RSIP_KEY_PAIR_TYPE_ECC_SECP256K1	0x202101	ECC secp256k1 key pair
RSIP_KEY_PAIR_TYPE_ECC_BRAINPOOLP256R1	0x202102	ECC brainpoolP256r1 key pair

Table 2-9 HASH Type enum rsip_hash_type_t

Definition	Value	Remarks
RSIP_HASH_TYPE_SHA224	0	SHA224
RSIP_HASH_TYPE_SHA256	1	SHA256
RSIP_HASH_TYPE_NUM	2	Number of Hash types

Table 2-10 AES Mode Type enum rsip_aes_cipher_type_t

Definition	Value	Remarks
RSIP_AES_CIPHER_MODE_ECB_ENC	0	AES ECB mode encryption
RSIP_AES_CIPHER_MODE_ECB_DEC	1	AES ECB mode decryption
RSIP_AES_CIPHER_MODE_CBC_ENC	2	AES CBC mode encryption
RSIP_AES_CIPHER_MODE_CBC_DEC	3	AES CBC mode decryption
RSIP_AES_CIPHER_MODE_CTR	4	AES CTR mode

Table 2-11 AES AEAD Mode Type enum rsip_aes_aead_type_t

Definition	Value	Remarks
RSIP_AES_AEAD_MODE_GCM_ENC	0	AES GCM mode encryption
RSIP_AES_AEAD_MODE_GCM_DEC	1	AES GCM mode decryption
RSIP_AES_AEAD_MODE_CCM_ENC	2	AES CCM mode encryption
RSIP_AES_AEAD_MODE_CCM_DEC	3	AES CCM mode decryption

Table 2-12 AES MAC Mode Type enum rsip_mac_type_t

Definition	Value	Remarks
RSIP_AES_MAC_MODE_CMAC	0	AES CMAC mode

Table 2-13 Byte Size of the wrapped_key_t Structure enum rsip_byte_size_wrapped_key_t

Definition	Value	Remarks
RSIP_BYTE_SIZE_WRAPPED_KEY_AES_128	40U	AES128 key
RSIP_BYTE_SIZE_WRAPPED_KEY_AES_256	56U	AES256 key
RSIP_BYTE_SIZE_WRAPPED_KEY_ECC_SECP256R1_PUBLIC	88U	secp256r1 public key
RSIP_BYTE_SIZE_WRAPPED_KEY_ECC_SECP256K1_PUBLIC	88U	secp256k1public key
RSIP_BYTE_SIZE_WRAPPED_KEY_ECC_BRAINPOOL256R1_PUBLIC	88U	brainpoolP256r1 public key
RSIP_BYTE_SIZE_WRAPPED_KEY_ECC_SECP256R1_PRIVATE	56U	secp256r1 private key
RSIP_BYTE_SIZE_WRAPPED_KEY_ECC_SECP256K1_PRIVATE	56U	secp256k1 private key
RSIP_BYTE_SIZE_WRAPPED_KEY_ECC_BRAINPOOL256R1_ PRIVATE	56U	brainpoolP256r1 private key
RSIP_BYTE_SIZE_WRAPPED_KEY_HMAC_SHA224	56U	HMAC_SHA224 key
RSIP_BYTE_SIZE_WRAPPED_KEY_HMAC_SHA256	56U	HMAC_SHA256 key

2.10 Return Values

Below are the return values used in the API functions of the RSIP PM driver. The enumeration type of return values is defined as fsp_err_t in /r_bsp/mcu/all/fsp_common_api.h.

Table 2-14 Return Values enum fsp_err_t

Definition	Value	Remarks
FSP_SUCCESS	0x00000	SUCCESS
FSP_ERR_ASSERTION	0x00001	Pointer argument is NULL
FSP_ERR_INVALID_ARGUMENT	0x00003	An invalid value was entered.
FSP_ERR_UNSUPPORTED	0x00006	Selected mode is unsupported
FSP_ERR_NOT_OPEN	0x00007	RSIP driver is not open
FSP_ERR_ALREADY_OPEN	0x0000e	RSIP driver is already open
FSP_ERR_NOT_ENABLED	0x00013	Unable to perform the specified process.
FSP_ERR_INVALID_SIZE	0x00017	Input size incorrect
FSP_ERR_INVALID_STATE	0x0001e	Illegal call state
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	0x10100	HW resource conflict occurs
FSP_ERR_CRYPTO_RSIP_FATAL	0x10101	Fatal error
FSP_ERR_CRYPTO_RSIP_FAIL	0x10102	RSIP internal error
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	0x10103	Incorrect key value entered.
FSP_ERR_CRYPTO_RSIP_AUTHENTICATION	0x10104	Failed verification

2.11 Adding the FIT Module to Your Project

This module must be added to each project in which it is used. Renesas recommends using Smart Configurator as described in (1) or (3) below. However, Smart Configurator does not support all RX devices. If your RX device is not supported, use the method described in (2) or (4).

(1) Adding the FIT module to your project using Smart Configurator in e^2 studio
Using Smart Configurator in e^2 studio allows you to add the FIT module to your project automatically. Refer to the application note “Renesas e^2 studio Smart Configurator User Guide” (R20AN0451) for details.

(2) Adding the FIT module to your project using FIT Configurator in e^2 studio
Using FIT Configurator in e^2 studio allows you to add the FIT module to your project automatically. Refer to the application note “Adding Firmware Integration Technology Modules to Projects (R01AN1723)” for details.

(3) Adding the FIT module to your project using Smart Configurator in CS+
Using Smart Configurator Standalone Version in CS+ allows you to add the FIT module to your project automatically. Refer to the application note “Renesas e^2 studio Smart Configurator User Guide (R20AN0451)” for details.

(4) Adding the FIT module to your project in CS+
Manually add the FIT module to your project in CS+. Refer to the application note “Adding Firmware Integration Technology Modules to CS+ Projects (R01AN1826)” for details.

2.12 *for*, *while*, and *do while* Statements

The RSIP PM driver uses *for*, *while*, and *do while* statements (loop processing) to wait for registers to be updated, etc. Such loop processing is indicated in the comments with the keyword WAIT_LOOP. If you wish to incorporate fail-safe processing into loop processing, you can locate the corresponding processing by searching for the keyword WAIT_LOOP.

Devices for which WAIT_LOOP appears in the comments:

All device groups

A code sample is shown below.

Example *while* statement:

```
/* WAIT_LOOP */
while(0 == SYSTEM.OSCOVFSR.BIT.PLOVF)
{
  /* The delay period needed is to make sure that the PLL has stabilized. */
}
```

Example *for* statement:

```
/* Initialize reference counters to 0. */
/* WAIT_LOOP */
for (i = 0; i < BSP_REG_PROTECT_TOTAL_ITEMS; i++)
{
  g_protect_counters[i] = 0;
}
```

Example *do while* statement:

```
/* Reset completion waiting */
do
{
  reg = phy_read(ether_channel, PHY_REG_CONTROL);
  count++;
} while ((reg & PHY_CONTROL_RESET) && (count < ETHER_CFG_PHY_DELAY_RESET)); /* WAIT_LOOP */
```

3. RSIP PM Driver Usage

The RSIP PM driver for the RX family provides the following functions:

- Random number generation
- Secure key management
- Unauthorized access monitoring
- Acceleration of cryptographic operations

The keys handled by the RSIP PM driver (input and output keys) are opaque keys wrapped using a device-specific key called a hardware unique key (HUK), which is accessible only by the RSIP. In the case of the RX RSIP PM driver, this type of opaque key is called a wrapped key. The RSIP PM driver implements secure key management by wrapping keys using the HUK. This provides key confidentiality and detection of tampering outside of the RSIP.

Unauthorized access monitoring by the RSIP covers all cryptographic processing performed by the driver and is always enabled during cryptographic operations. If tampering with cryptographic operations is detected while the driver is in use, the driver stops operation.

There are two types of APIs provided by the RSIP PM driver for accelerating cryptographic operations: those that provide cryptographic operations with a single API and those that provide them with multiple APIs. In this document, the former are referred to as single-part operations and the latter as multi-part operations.

APIs for multi-part operations are provided for symmetric key cryptography and hashes split on the Init-Update-Finish model, and APIs for single-part operations are provided for other ciphers.

3.1 Recovering after Unauthorized Access Detection

Unauthorized access monitoring by the RSIP is always enabled during execution of all cryptographic APIs. If tampering with cryptographic operations is detected while the driver is in use, the driver enters an infinite loop to stop operation.

Whether or not the operation of the RSIP PM driver is stopped in an infinite loop due to unauthorized access must be detected by the user application using a watchdog timer or other means.

If unauthorized access is detected by the user application, appropriate measures should be taken to satisfy the system security policy, such as log recording or restarting the system.

To recover from unauthorized access detection, close the RSIP PM driver once with R_RSIP_Close() and restart the RSIP with R_RSIP_Open(), or reset the device.

3.2 Avoiding RSIP Access Conflicts

The RSIP PM driver occupies the hardware resources of the RSIP while APIs are running. Even the APIs that provide multi-part operations continue to occupy the RSIP hardware resources until the series of multi-part operations is complete.

Therefore, keep in mind the following two points to avoid RSIP access conflicts when using the RSIP PM driver in a user application program:

1) While an RSIP PM driver API is being executed, other RSIP PM driver APIs must not be executed.

2) In the case of the APIs that provide multi-part operations, other RSIP PM driver APIs cannot execute until the series of operations (Init to Finish or Verify) currently being processed is complete.

If an RSIP PM driver API causes a hardware resource access conflict, the API returns FSP_ERR_INVALID_STATE or FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT.

3.3 BSP FIT Module Integration

The RSIP PM driver uses the following APIs of the BSP FIT module in R_RSIP_Open() and R_RSIP_Close() for module stop release/setting of the RSIP. Even if the BSP FIT module is not used in your program, incorporate the BSP FIT module into your program.

- R_BSP_RegisterProtectEnable()
- R_BSP_RegisterProtectDisable()

For details, refer to the application note “Board Support Module Firmware Integration Technology” (R01AN1685xJxxxx).

For R_RSIP_Open(), it is assumed that BSP FIT startup has completed before it is called. If BSP FIT startup is not used, call R_BSP_StartupOpen() before calling R_RSIP_Open(). R_BSP_StartupOpen() initializes the internal variables used in R_RegisterProtectEnable() and R_RegisterProtectDisable().

3.4 Single-Part and Multi-Part Operations

There are two types of APIs provided by the RSIP PM driver: those that provide operations with a single API and those that provide them with multiple APIs. In this document, the former are referred to as single-part operations and the latter as multi-part operations.

In multi-part operations, a single cryptographic operation is split into a sequence of separate steps (Init-Update-Final) in the form of APIs. This enables fine control over the configuration of the cryptographic operation and allows message data to be processed intermittently instead of all at once.

Refer to section 4.2 for the API specifications for each multi-part operation.

When an API for multi-part operations is called, the API to be called next is managed depending on the internal state of the RSIP PM driver. If the appropriate API is not called, an error is returned as the return value.

3.5 Initialization, Termination, and State Transitions of the Driver

The driver provides the following common function APIs for driver management operations:

No.	API	Description
1	R_RSIP_Open	Opens the RSIP PM driver. Initializes the RSIP and performs a self-test of the RSIP’s fault detection and random number generator circuits.
2	R_RSIP_Close	Closes the RSIP PM driver.
3	R_RSIP_GetVersion	Gets the version number of the RSIP PM driver.

Applications using the driver must call R_RSIP_Open() first to initialize the RSIP and the driver. Also, when terminating use of the driver, R_RSIP_Close() must be called.

If problems occur while using the RSIP PM driver and there is a need to reset the RSIP PM driver and its control target (RSIP) before resuming processing, it is necessary to call R_RSIP_Open() after calling R_RSIP_Close().

R_RSIP_Open() performs a self-test to detect hardware failure of the RSIP and to check for abnormalities in the random number generator circuit. The self-test of the random number generator circuit implements the health test described in NIST SP800-90B on the data generated by the physical random number generator, evaluates the entropy, and generates a random number seed.

To get the version number of the RSIP PM driver, call R_RSIP_GetVersion().

The RSIP PM driver retains five internal states to manage the availability of the RSIP.

State Name	Description
Close	State in which the RSIP PM driver is unavailable before calling R_RSIP_Open(). Calling R_RSIP_Close() from any state will cause a transition to the Close state.
Main	State in which the RSIP PM driver is available after calling R_RSIP_Open(). After a multi-part or single-part operation is completed, the driver returns to this state.
Each Algorithm	The driver transitions to this state after calling an “Init” API for multi-part operations. In this state, the multi-part operations of the algorithm called by the “Init” API can be executed.
Firmware Update	The driver transitions to this state after calling R_RSIP_FWUP_StartUpdateFirmware(). In this state, R_RSIP_FWUP_MAC_Sign_Init/Update/Finish() can be called.
Stop	The driver transitions to this state after execution of R_RSIP_FWUP_MAC_Sign_Finish() finishes.

Figure 3.1 shows the state transition diagram of the RSIP PM driver.

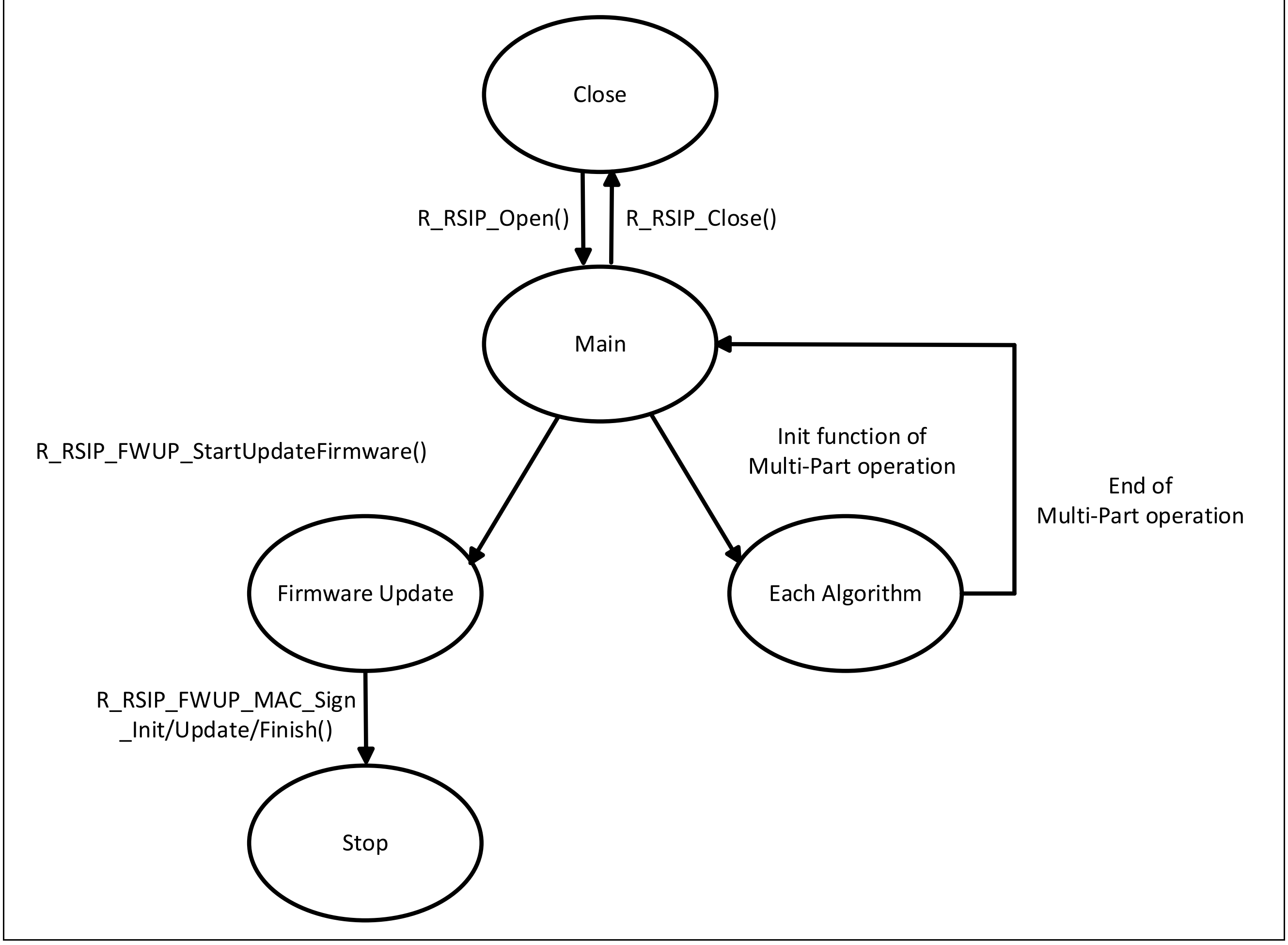


Figure 3.1 State Transition Diagram of the RSIP PM Driver

3.6 Key Management

The driver provides APIs for the following key management operations:

No.	API	Description
1	R_RSIP_EncryptedKeyWrap R_RSIP_InjectedKeyImport R_RSIP_InitialKeyWrap R_RSIP_InitialKeyUpdateKeyWrap	Key updating and injection
2	R_RSIP_KeyGenerate R_RSIP_KeyPairGenerate	Key generation
3	R_RSIP_PublicKeyExport	Plaintext public key extraction

Figure 3.2 illustrates key handling in cryptographic operations performed by the RSIP PM driver.

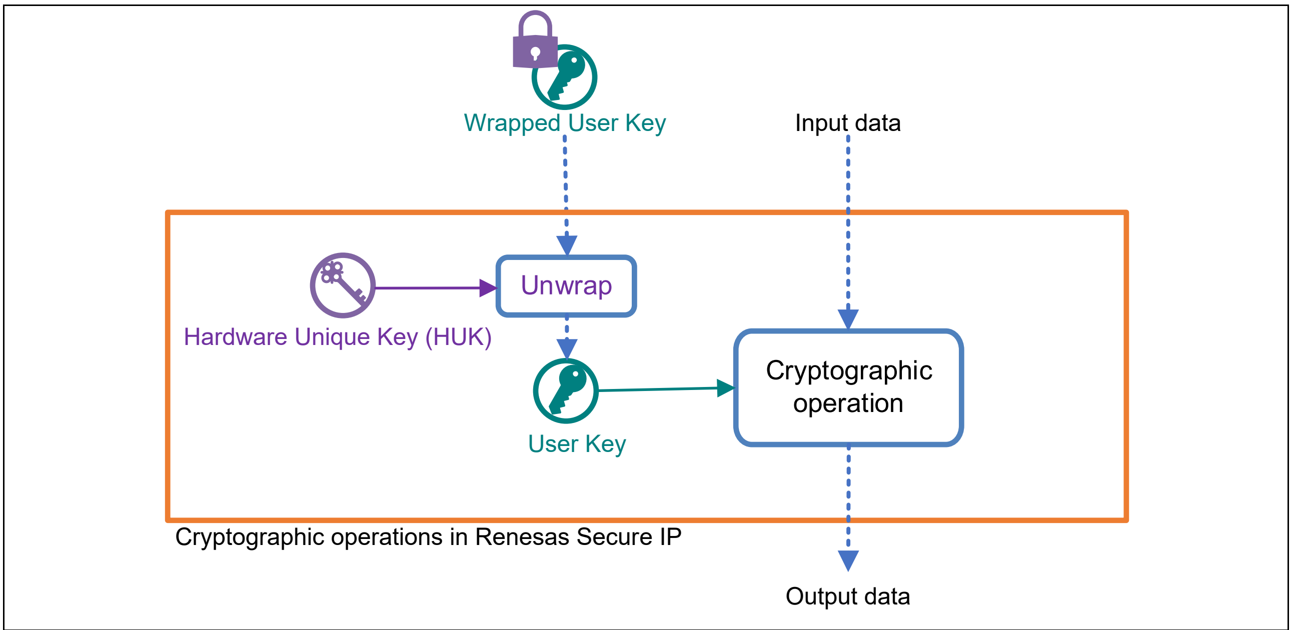


Figure 3.2 Key Handling in Cryptographic Operations by the RSIP PM Driver

The keys that are input and output in the cryptographic operations of the RSIP PM driver are opaque keys wrapped using a device-specific key called an HUK, which is accessible only by the RSIP. In the RSIP PM driver, this type of opaque key is called a wrapped key. Note here that the wrapped public key used in asymmetric key cryptography is in the form of a plaintext public key plus the key management information used in the RSIP PM driver.

The RSIP PM driver implements secure key management by wrapping user keys using the device-specific key. This provides key confidentiality and detection of tampering outside of the RSIP. The wrapping of the wrapped key can be unlocked only by the RSIP, and the unwrapped key exists only within the RSIP during cryptographic processing. Since the wrapped key has been wrapped using a device-specific key, it cannot be unwrapped using a different device-specific key, even if the wrapped key is copied from the nonvolatile memory of one device to another device.

3.6.1 Key Injection and Updating

Key injection and key updating provide a mechanism enabling secure delivery of user keys by converting them into wrapped keys wrapped using an HUK. Figure 3.3 shows the key injection and key updating operation sequence, including use of the Renesas Key Wrap Service.

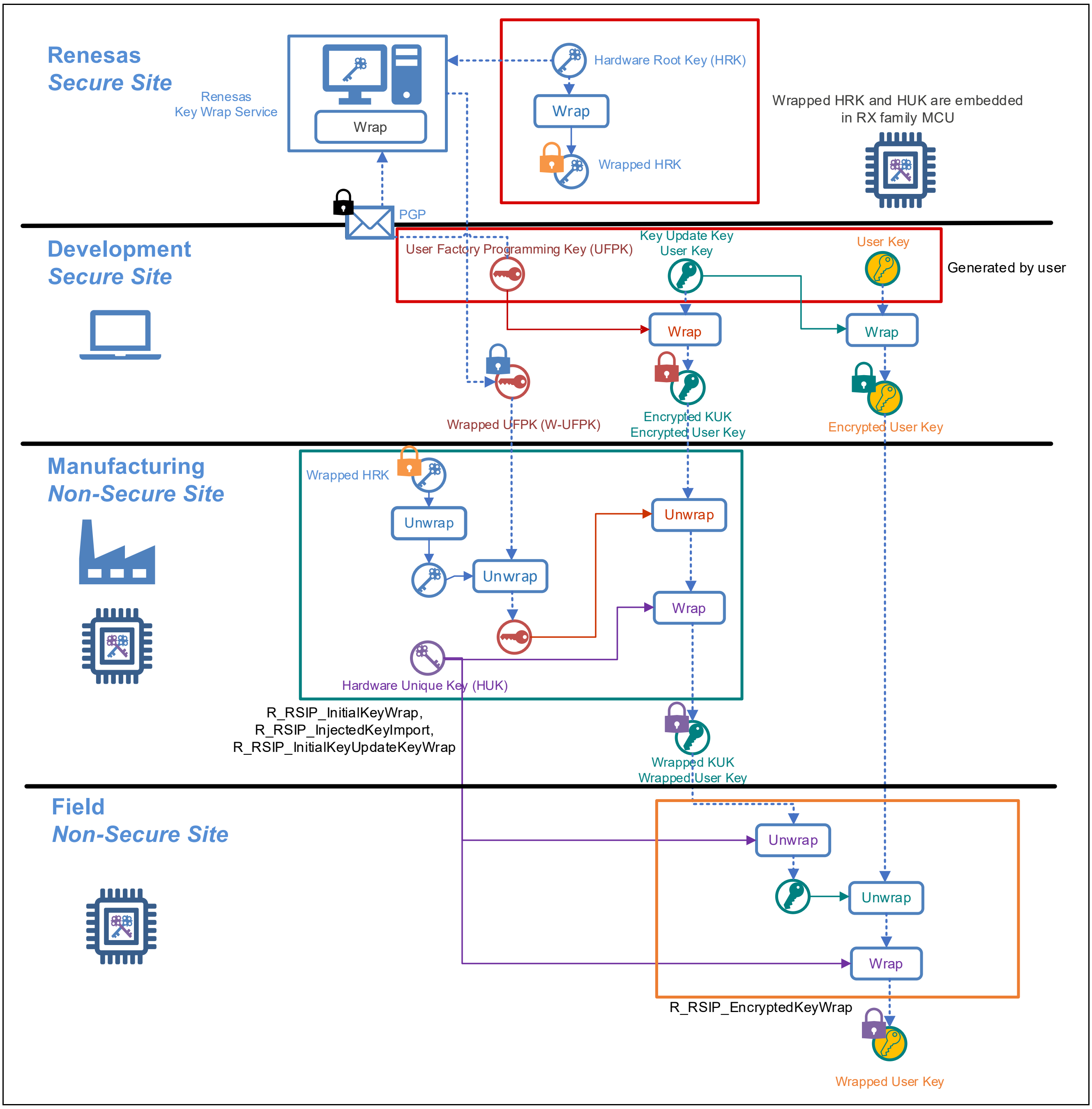


Figure 3.3 Key Injection and Key Updating Operation Sequence

When injecting keys, generate user keys, KUKs, and UFPKs at the customer's secure site (Figure 3.3 Development Secure Site), and wrap the user keys and KUKs with UFPKs. The UFPK used for wrapping should also be used to generate a W-UFPK using the Renesas Key Wrap Service. When updating keys, generate the user key to be updated at the customer's secure site ((Figure 3.3 Development Secure Site) and wrap the user key to be updated with KUK. The Security Key Management Tool can be used for key injection and key wrap for key renewal.

3.6.1.1 Key Wrapping Algorithm

Figure 3.4 shows the user key wrapping scheme used when a UFPK or KUK is used for wrapping during key injection and key updating. The first 128 bits of the UFPK or KUK are used as the CBC key and the trailing 128 bits as the CBC-MAC key for wrapping the user key or KUK. For the data formats of user keys and wrapped keys (encrypted user keys), refer to 5.3 User Key cryptographic format.

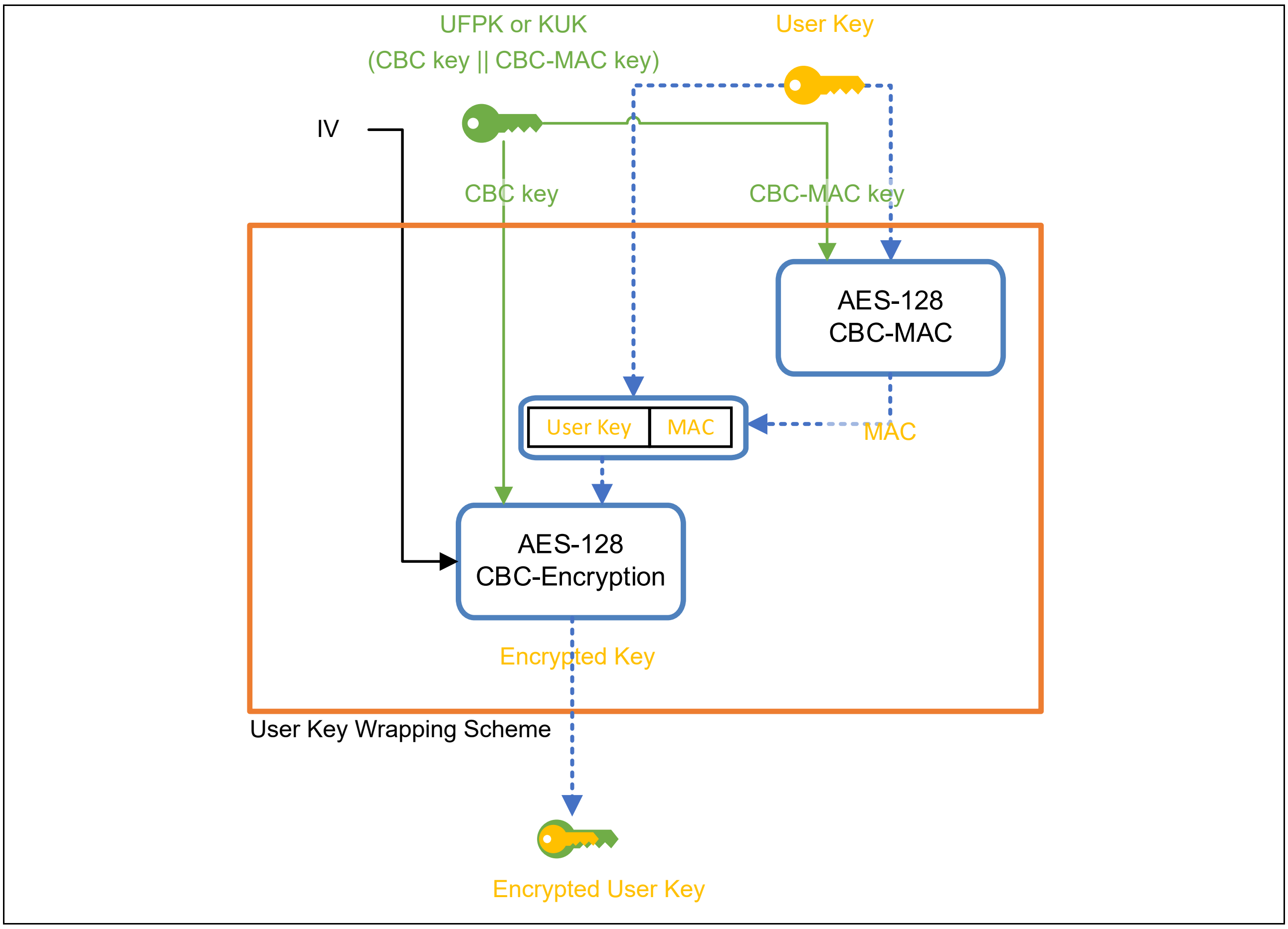


Figure 3.4 User Key Wrapping Scheme during Key Injection and Key Updating

The specific formula for wrapping the user key is as follows:

```
uint32_t user_key[len];
uint32_t MAC[4] = 0;
uint32_t iv[4] = IV;
for (i = 0; i < len; i += 4)
{
  MAC
   = AES_128_ENCRYPT(CBCMACkey[0: 3], xor_16byte(user_key[i: i+3], MAC[0: 3]));
  encrypted_key[i: i+3]
   = AES_128_ENCRYPT(CBCkey[0: 3], xor_16byte(user_key[i: i+3], iv[0: 3]));
  iv[0: 3] = encrypted_key [i: i+3];
}
encrypted_key[i: i+3] = AES_128_ENCRYPT(CBCkey[0: 3], xor_16byte(MAC[0: 3],
iv[0: 3]));
```

The functions used here mean the following processing:

• AES_128_ENCRYPT(Key, Data): Encryption of Data in AES128 ECB mode using the encryption Key

• xor_16byte(data1, data2): XOR operation of 16 bytes of data1 and data2
Also, one element of each array (CBCkey[], CBCMACkey[], MAC[], iv[], user_key[], encrypted_key[]) is 4 bytes in size.

The user key, including the KUK used for key updating, must be created by the user and injected into the device at the time of manufacture. For details of the procedure, refer to 5.1 Key Injection, and 5.2 Key Updating.

3.6.2 Key Generation

In key generation, the random number generation functionality of the RSIP is used to generate a key, which is then output in a wrapped key form that is usable by the RSIP PM driver.

To generate a wrapped key for use in symmetric key cryptography, call R_RSIP_KeyGenerate() with the type of key to be output.

To generate a pair of wrapped keys for use in asymmetric key cryptography, call R_RSIP_KeyPairGenerate() with the type of key to be output.

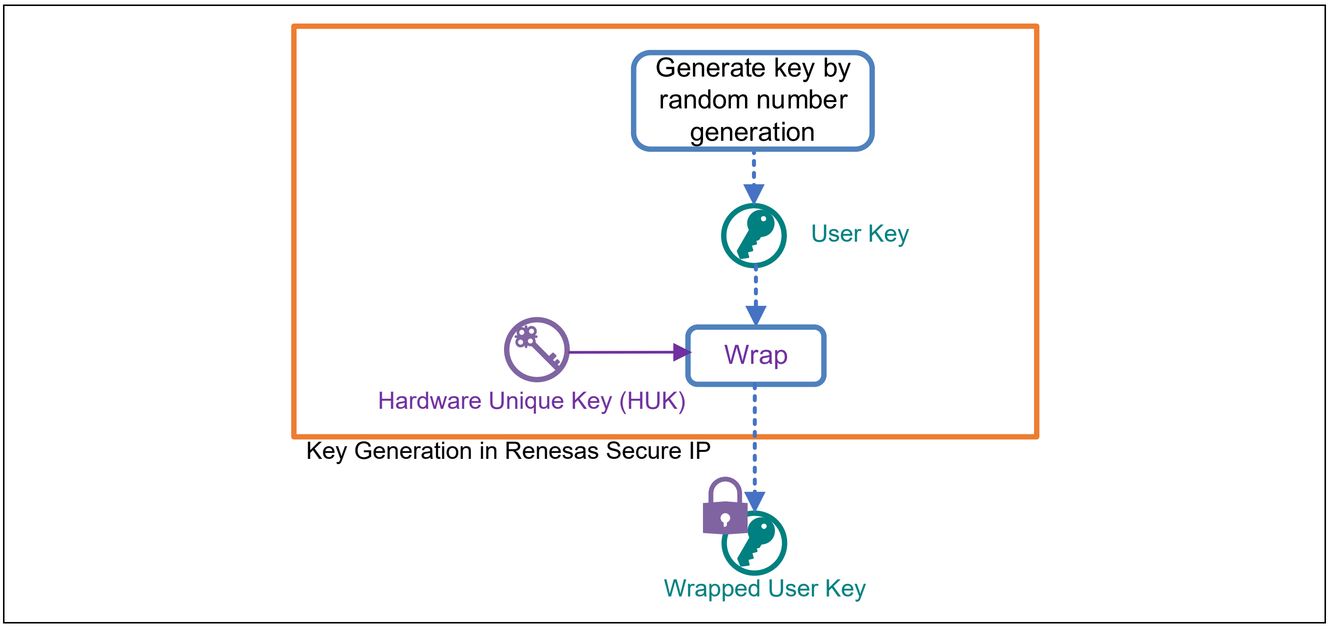


Figure 3.5 Key Generation Sequence

3.6.3 Plaintext Public Key Extraction

The wrapped public key is in the form of a plaintext public key plus the key management information used in the RSIP PM driver. To extract only the plaintext public key from a wrapped key, call R_RSIP_PublicKeyExport(). Refer to 4.2.2.7, R_RSIP_PublicKeyExport for the format of the extracted key.

3.7 Random Number Generation

The driver provides the following random number generation API.

No.	API	Description
1	R_RSIP_RandomNumberGenerate	Generates random numbers using CTR-DRBG as described in NIST SP800-90A.

3.8 Symmetric Key Cryptography

The driver provides APIs for the following symmetric cryptographic operations:

No.	API	Description
1	R_RSIP_AES_Cipher_Init R_RSIP_AES_Cipher_Update R_RSIP_AES_Cipher_Finish	Symmetric key cryptography AES 128-/256-bit ECB, CBC, CTR encryption and decryption
2	R_RSIP_AES_AEAD_Init R_RSIP_AES_AEAD_LengthsSet R_RSIP_AES_AEAD_AADUpdate R_RSIP_AES_AEAD_Update R_RSIP_AES_AEAD_Finish R_RSIP_AES_AEAD_Verify	Authenticated encryption with associated data (AEAD) AES 128-/256-bit GCM, CCM encryption and decryption
3	R_RSIP_AES_MAC_Init R_RSIP_AES_MAC_Update R_RSIP_AES_MAC_SignFinish R_RSIP_AES_MAC_VerifyFinish	Message authentication codes (MAC) AES-CMAC 128-/256-bit MAC generation and verification

A set of API functions that enable multi-part operations is provided for each type of symmetric cryptographic operation. For details on multi-part operations, refer to 3.4, Single-Part and Multi-Part Operations.

3.8.1 Symmetric Key Cryptography

The symmetric cryptographic operation is performed as follows:

Call R_RSIP_AES_Cipher_Init() to specify the encryption mode, required key and initialization vector.

Call the R_RSIP_AES_Cipher_Update() function for the chunks of data comprising the plaintext or ciphertext message in consecutive block units.

To complete the encryption operation, call R_RSIP_AES_Cipher_Finish().

3.8.2 Authenticated Encryption with Associated Data (AEAD)

The authenticated encryption with associated data is performed as follows:

Call R_RSIP_AES_AEAD_Init() to specify the encryption mode, required key and initialization vector.

When the encryption mode is CCM, call R_RSIP_AES_AEAD_LengthsSet() to specify the size of the input data.

Call R_RSIP_AES_AEAD_AADUpdate() to specify AAD.

Call the R_RSIP_AES_AEAD_Update() function for the chunks of data comprising the message in consecutive block units.

To complete the encryption operation and compute the authentication tag, call R_RSIP_AES_AEAD_Finish().

To complete the decryption operation, compute the authentication tag, and verify it against a reference value, call R_RSIP_AES_AEAD_Verify().

3.8.3 Message Authentication Code (MAC)

The message authentication code processing is performed as follows:

Call R_RSIP_AES_MAC_Init() to specify the MAC calculation mode and required key.

Call the R_RSIP_AES_MAC_Update() function for the consecutive chunks of data comprising the message.

In the case of a MAC generation operation, call R_RSIP_AES_MAC_SignFinish() to get the MAC data and complete the cryptographic operation.

To complete MAC verification for the message, call R_RSIP_AES_MAC_VerifyFinish().

3.9 Asymmetric Key Cryptography

The driver provides APIs for the following asymmetric cryptographic operations:

No.	API	Description
1	R_RSIP_ECDSA_Sign R_RSIP_ECDSA_Verify	Generates and verifies ECDSA signatures.

APIs for asymmetric key cryptography provide only single-part operations.

3.10 Hash Functions

The driver provides APIs for the following hash calculation:

No.	API	Description
1	R_RSIP_SHA_Init R_RSIP_SHA_Update R_RSIP_SHA_Finish R_RSIP_SHA_Suspend R_RSIP_SHA_Resume	Message digests SHA-256
2	R_RSIP_HMAC_Init R_RSIP_HMAC_Update R_RSIP_HMAC_SignFinish R_RSIP_HMAC_VerifyFinish	Message authentication codes (HMAC) HMAC-SHA256

A set of API functions that enable multi-part operations is provided for each type of hash calculation. For details on multi-part operations, refer to 3.4, Single-Part and Multi-Part Operations

3.10.1 Message Digest

The message digest generation is performed as follows:

Call R_RSIP_SHA_Init() to specify the hash calculation mode.

Call R_RSIP_SHA_Update() for the consecutive chunks of data comprising the message.

Call R_RSIP_SHA_Finish() to calculate the digest of the message.

After calling R_RSIP_SHA_Update(), the multi-part operations for hash calculation can be suspended by calling R_RSIP_SHA_Suspend(). To resume hash calculation, call R_RSIP_SHA_Resume() and then call R_RSIP_SHA_Update() or R_RSIP_SHA_Finish() again to perform hash calculation.

R_RSIP_SHA_Finish() can be called after R_RSIP_SHA_Suspend() without calling R_RSIP_SHA_Resume() to retrieve calculation results of data while the hash calculation is in progress.

3.10.2 Message Authentication Code (HMAC)

The message authentication code processing is performed as follows:

Call R_RSIP_HMAC_Init() to specify the required key.

Call R_RSIP_AES_HMAC_Update() for the consecutive chunks of data comprising the message.

To complete HMAC generation for the message, call R_RSIP_HMAC_SignFinish().

To verify the HMAC of a message, call R_RSIP_HMAC_VerifyFinish() to specify the HMAC data to be verified.

3.11 Key Wrap

The driver provides APIs for the following key wrapping operations:

No.	API	Description
1	R_RSIP_RFC3394_KeyWrap	Wraps a key with an RFC3394-compliant algorithm.
2	R_RSIP_RFC3394_KeyUnwrap	Unwraps a key with an RFC3394-compliant algorithm.

To wrap a key, call R_RSIP_RFC3394_KeyWrap() to specify the key to be used for wrapping and the key to be wrapped to obtain the wrapped key.

To unwrap a key, call R_RSIP_RFC3394_KeyWrap() to obtain the wrapped key of the unwrapped key, specifying the key to use for unwrapping, the key to wrap, and the type of wrapped key to output.

3.12 Firmware Update/Secure Boot

The driver provides APIs for the following firmware update and secure boot operations:

No.	API	Description
1	R_RSIP_FWUP_StartUpdateFirmware R_RSIP_FWUP_MAC_Sign_Init R_RSIP_FWUP_MAC_Sign_Update R_RSIP_FWUP_MAC_Sign_Finish	Decrypts encrypted firmware, performs MAC verification, and generates a MAC for decrypted plaintext firmware.
2	R_RSIP_SB_MAC_Verify_Init R_RSIP_SB_MAC_Verify_Update R_RSIP_SB_MAC_Verify_Finish	Performs verification of the MAC generated from the plaintext firmware decrypted by R_RSIP_FWUP_MAC_Sign_Update/Finish.

The firmware update functionality provides a mechanism for securely delivering an encrypted program and the key used to encrypt it. Firmware updates can be achieved in conjunction with secure boot. Figure 3.6 shows the program encryption, encryption key injection, and MAC verification operation sequence, including use of the Renesas Key Wrap Service.

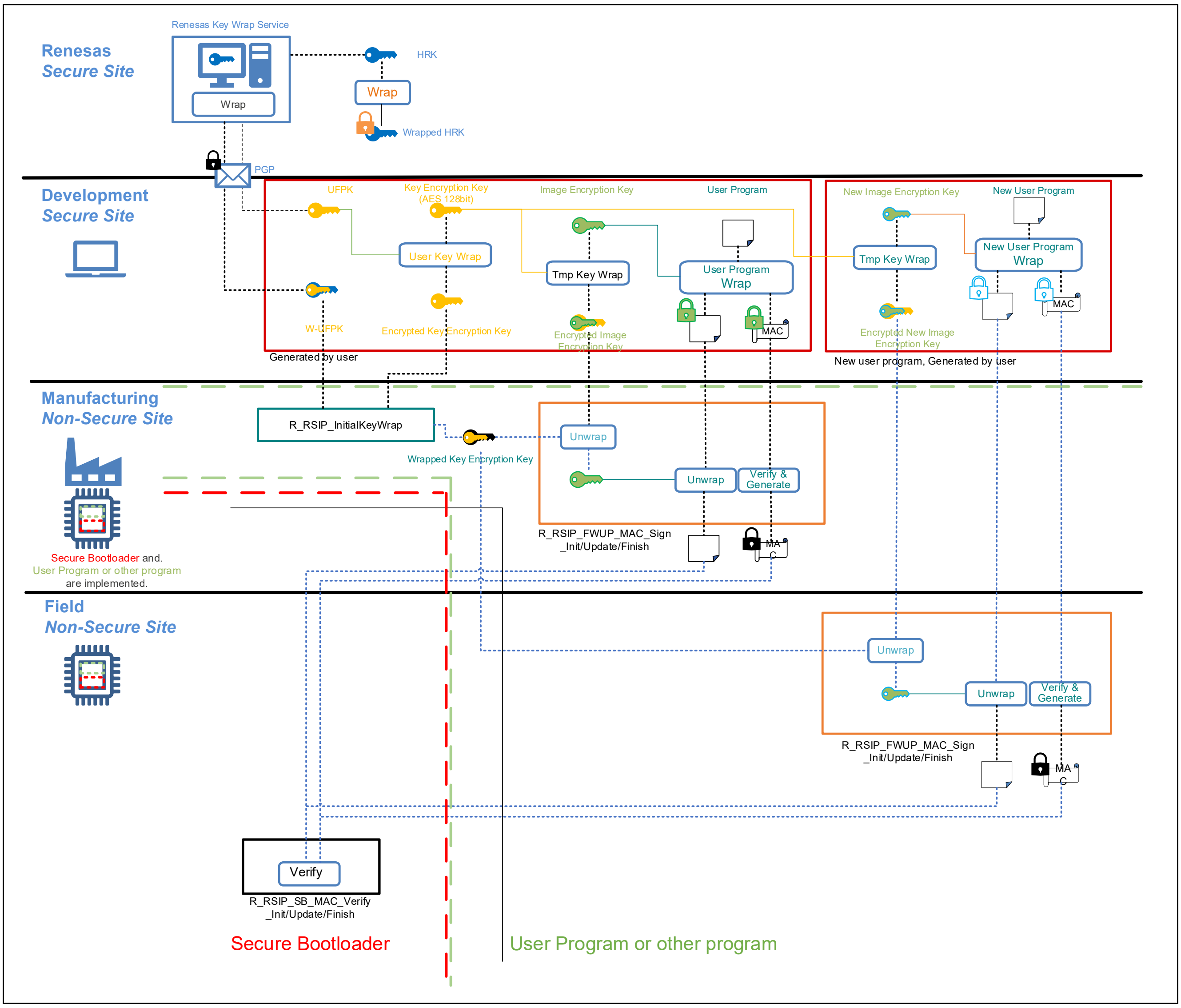


Figure 3.6 Firmware Update Sequence

At your secure site (Figure 3.6 Development Secure Site), generate the UFPK, the key used for encryption of the user program (Image Encryption Key), and the Key Encryption Key, and encrypt the user program and the encrypted program MAC Please generate the key (Image Encryption Key) and Key Encryption Key for encryption of the user program. Also, wrap the Image Encryption Key with the Key Encryption Key. See 3.12.3 Encrypting the User Program for the algorithm of encryption of user program, MAC generation, and wrapping of the key used in encryption. The Security Key Management Tool can be used to encrypt the user program, generate the MAC, and wrap the key used for encryption.

3.12.1 Secure Boot

Secure boot refers to a functionality for detecting tampering with the user program. Before executing the user program after a reset, execute the secure boot program and verify the program to be executed after secure boot.

R_RSIP_SB_MAC_VerifyInit/Update/Finish() can be used to implement secure boot. Run R_RSIP_SB_MAC_VerifyInit/Update/Finish() with the plaintext firmware and MAC value output by R_RSIP_FWUP_MAC_Sign_Update/Finish() as input.

3.12.2 Firmware Update

Firmware update is a functionality that updates the firmware currently running to add new functionalities or to repair defects.

R_RSIP_FWUP_MAC_Sign_Init/Update/Finish(), which decrypts an encrypted program and performs MAC verification, can be used for firmware update implementation. When MAC verification is successful, R_RSIP_FWUP_MAC_Sign_Finish() newly generates a new MAC for plaintext firmware with a key newly linked to the HUK.

R_RSIP_FWUP_MAC_Sign_Init/Update/Finish() can be run after first calling R_RSIP_StartUpdateFirmware() to put the RSIP into the Firmware Update state.

3.12.3 Encrypting the User Program

Figure 3.7 shows the method for encrypting the user program.

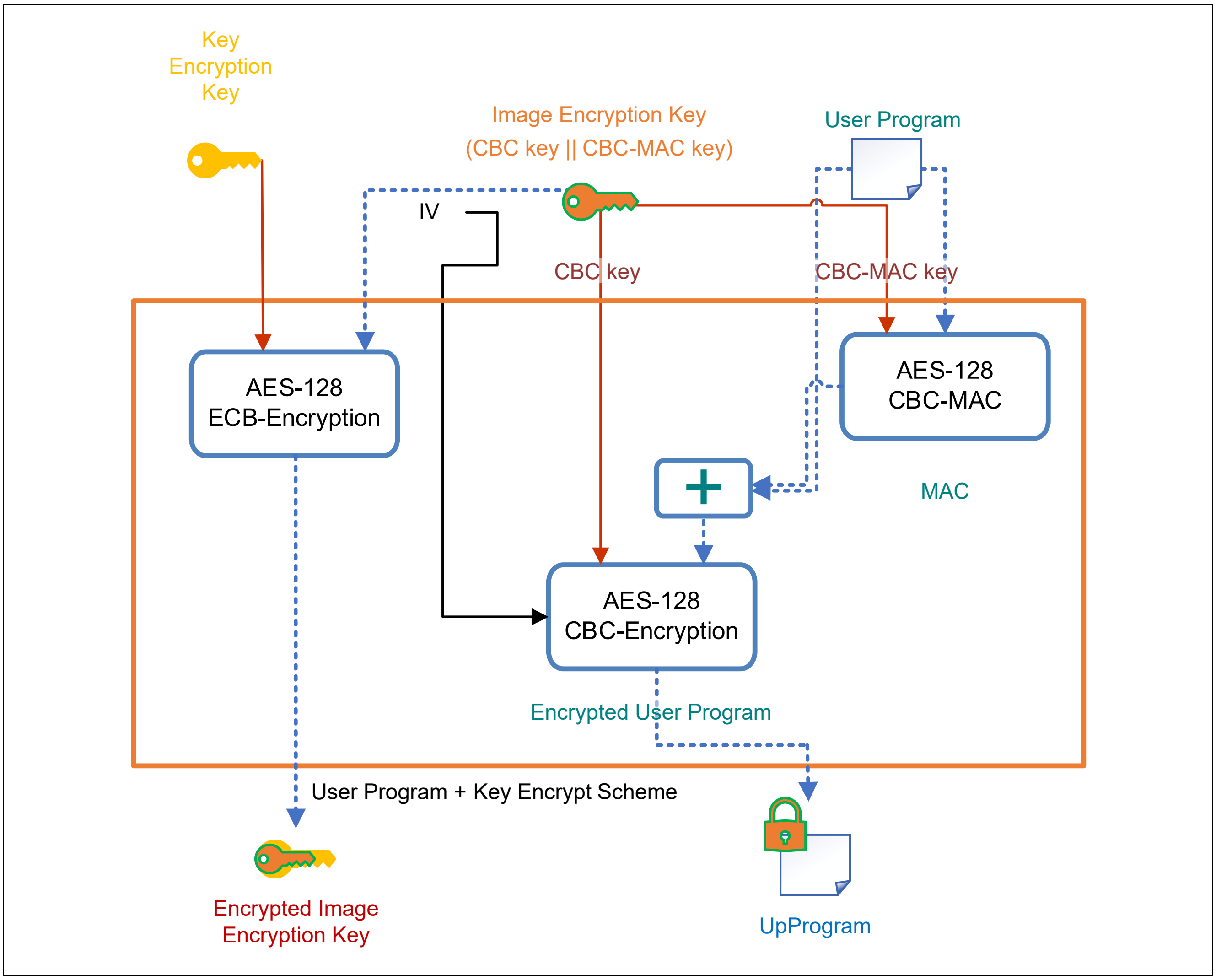


Figure 3.7 Firmware and Session Key Encryption Method

First, a key for encrypting the user program (image encryption key) and a user program key (key encryption key) for encrypting the image encryption key are prepared. Then the image encryption key is used to generate a MAC and encrypt the user program (UpProgram). The key encryption key is used to wrap the image encryption key, and an encrypted image encryption key (session key) is generated.

4. API Functions

4.1 List of APIs

The RSIP PM driver implements the following APIs:

1. Common function APIs
2. Key Management APIs
3. Random number generation API
4. AES encryption/decryption APIs
5. ECC signature generation/verification APIs
6. HASH calculation APIs
7. HMAC generation/verification APIs
8. Key wrap APIs
9. Firmware update/secure boot APIs

The APIs implemented in the RSIP PM driver are summarized in the tables below. "XXX" in the name of an API represents either the bit length or the SHA mode.

Table 4-1 Common Function APIs

API	Description
R_RSIP_Open	Exits RSIP from the module stop state and opens the RSIP PM driver.
R_RSIP_Close	Place RSIP in module stop state and close the RSIP PM driver.
R_RSIP_GetVersion	Outputs the version of the RSIP PM driver.

Table 4-2 Key Management APIs

API	Description
R_RSIP_InitialKeyWrap	Used during key injection. Generates the binary value of the Wrapped Key from the UFPK wrapped user key.
R_RSIP_InjectedKeyImport	Converts the binary value of the Wrapped Key from the key generated by R_RSIP_InitialKeyWrap to a format usable by the RSIP PM driver.
R_RSIP_InitialKeyUpdateKeyWrap	Used during key injection. Generates KUK Wrapped Key from KUK wrapped in UFPK.
R_RSIP_EncryptedKeyWrap	Used for key update. Generates a Wrapped Key from a KUK-wrapped user key.
R_RSIP_KeyGenerate	Generates keys for symmetric key cryptography.
R_RSIP_KeyPairGenerate	Generates keys for asymmetric key cryptography.
R_RSIP_PublicKeyExport	Exports a plain-text public key from the Wrapped Key of the public key.

Table 4-3 Random Number Generation API

API	Description
R_RSIP_RandomNumberGenerate	Generates random number.

Table 4-4 AES Encryption/Decryption APIs

API	Description
R_RSIP_AES_Cipher_Init	Prepares to perform AES cryptographic operations.
R_RSIP_AES_Cipher_Update	Performs AES cryptographic operations.
R_RSIP_AES_Cipher_Finish	Terminates AES cryptographic operation.
R_RSIP_AES_AEAD_Init	Prepares to perform the AES AEAD operation.
R_RSIP_AES_AEAD_LengthsSet	Specifies the size of the data used in the AES AEAD operation.
R_RSIP_AES_AEAD_AADUpdate	Specifies additional authentication data to be used in the AES AEAD operation.
R_RSIP_AES_AEAD_Update	Performs AES AEAD operation.
R_RSIP_AES_AEAD_Finish	Terminates the encryption operation of the AES AEAD.
R_RSIP_AES_AEAD_Verify	Terminates the decryption operation of the AES AEAD.
R_RSIP_AES_MAC_Init	Prepares to perform the AES MAC operation.
R_RSIP_AES_MAC_Update	Performs AES MAC operation.
R_RSIP_AES_MAC_SignFinish	Terminates the generation operation of the AES MAC.
R_RSIP_AES_MAC_VerifyFinish	Terminates the verification operation of the AES MAC.

Table 4-5 ECC Signature Generation/Verification APIs

API	Description
R_RSIP_ECDSA_Sign	Performs ECDSA signature generation operations.
R_RSIP_ECDSA_Verify	Performs ECDSA signature verification operations.

Table 4-6 HASH Calculation APIs

API	Description
R_RSIP_SHA_Init	Prepares to perform SHA calcuration operations.
R_RSIP_SHA_Update	Performs SHA calcuration operations.
R_RSIP_SHA_Finish	Terminates SHA calcuration operations.
R_RSIP_HMAC_Init	Prepares to perform the HMAC operation.
R_RSIP_HMAC_Update	Performs HMAC operation.
R_RSIP_HMAC_SignFinish	Terminates the generation operation of the HMAC.
R_RSIP_HMAC_VerifyFinish	Terminates the verification operation of the HMAC.

Table 4-7 Key Exchange APIs

API	Description
R_RSIP_RFC3394_KeyWrap	Wraps the key with an RFC3394 compliant algorithm.
R_RSIP_RFC3394_KeyUnwrap	Unwraps the key with an RFC3394 compliant algorithm.

Table 4-8 Firmware Update/Secure Boot APIs

API	Description
R_RSIP_FWUP_StartUpdateFirmware	Transitions to firmware update mode.
R_RSIP_FWUP_MAC_Sign_Init	Decrypt encrypted firmware and prepare for MAC generation.
R_RSIP_FWUP_MAC_Sign_Update	Decrypts encrypted firmware and outputs plain-text firmware.
R_RSIP_FWUP_MAC_Sign_Finish	Decrypts encrypted firmware and verifies the MAC to generate a plaintext firmware MAC.
R_RSIP_SB_MAC_Verify_Init	Prepare to verify the MAC of the plaintext firmware.
R_RSIP_SB_MAC_Verify_Update	Performs MAC operations on plaintext firmware.
R_RSIP_SB_MAC_Verify_Finish	Performs MAC verification of plaintext firmware.

4.2 Detailed Descriptions of API Functions

4.2.1 Common Functions

4.2.1.1 R_RSIP_Open

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_Open(
        rsip_ctrl_t * const p_ctrl,
        rsip_cfg_t const * const p_cfg
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_cfg	Input	Configuration structure

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_ALREADY_OPEN	Driver already open
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API releases the RSIP from the module stop state, initializes the RSIP, and opens the RSIP PM driver.

For p_ctrl, input the management structure used commonly by the RSIP PM driver. p_ctrl should be held until R_RSIP_Close() is called.

For p_cfg, input the pin configuration structure of the device. It is not used in the RX RSIP PM driver, but a null cannot be specified. Input a pointer to any rsip_cfg_t structure.

Reentrant

Not supported.

4.2.1.2 R_RSIP_Close

Format

```
#include “r_rsip_protected_rx_if.h”
fsp_err_t R_RSIP_Close (
        rsip_ctrl_t * const p_ctrl
)
```

Parameters

p_ctrl	Output	RSIP PM driver management structure

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API puts the RSIP into the module stop state and closes the RSIP PM driver.

For p_ctrl, specify the RSIP PM driver management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.1.3 R_RSIP_GetVersion

Format

```
#include "r_rsip_protected_rx_if.h"
uint32_t R_RSIP_GetVersion(void)
```

Parameters

None

Return Values

Upper 2 bytes:	Major version (decimal notation)
Lower 2 bytes:	Minor version (decimal notation)

Description

This API can be used to obtain the RSIP PM driver version.

Reentrant

Not supported.

4.2.2 Key Management

4.2.2.1 R_RSIP_InitialKeyWrap

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_InitialKeyWrap(
        rsip_ctrl_t * const p_ctrl,
        rsip_wufpk_t * const p_wrapped_user_factory_programming_key,
        uint8_t const * const p_initial_vector,
        rsip_key_type_t const key_type,
        uint8_t const * const p_encrypted_key,
        uint8_t * const p_injected_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_user_factory_programming_key	Input	W-UFPK
p_initial_vector	Input	Initialization vector (16 bytes)
key_type	Input	Type of the input encrypted key
p_encrypted_key	Input	Encrypted key
p_injected_key	Output	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of the key specified in p_encrypted_key
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API generates binary data of the wrapped user key from the UFPK-wrapped user key. For p_wrapped_user_factory_programming_key, specify the W-UFPK of the UFPK used in wrapping the user key. For p_initial_vector, specify the initialization vector used in wrapping the user key. For key_type, specify the user key algorithm. For p_encrypted_key, specify the user key wrapped with a UFPK. Binary data of the wrapped key is output to p_injected_key. Convert p_injected_key into rsip_wrapped_key_t type used by the RSIP PM driver by using the R_RSIP_InjectedKeyImport() function.
For key_type, input a value defined in Table 2-7.
The byte size of the output wrapped key is the size of

RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_XXX defined in エラー! 参照元が見つかりません。エラー! 参照元が見つかりません。. Allocate an area equal to or greater than the RSIP_CFG_BYTE_SIZE_WRAPPED_KEY_VALUE_XXX size according to the algorithm specified in key_type.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.2.2 R_RSIP_InjectedKeyImport

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_InjectedKeyImport(
        rsip_key_type_t const key_type,
        uint8_t const * const p_injected_key,
        rsip_wrapped_key_t * const p_wrapped_key,
        uint32_t const wrapped_key_buffer_length
)
```

Parameters

key_type	Input	Type of the generated wrapped key
p_injected_key	Input	Encrypted key
p_wrapped_key	Output	Wrapped key
wrapped_key_buffer_length	Input	Byte size of the wrapped key area

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_UNSUPPORTED	Input of an unsupported key type for key_type
FSP_ERR_INVALID_SIZE	Insufficient size of the area specified by wrapped_key_buffer_length

Description

This API converts the value of binary data p_injected_key output from R_RSIP_InitialKeyWrap() into the rsip_wrapped_key_t type used by the RSIP PM driver, and outputs the result to p_wrapped_key. For key_type, specify the type of wrapped key. For wrapped_key_buffer_length, specify the byte size of the p_wrapped_key area.
For key_type, input a value defined in Table 2-7.
For p_wrapped_key, allocate a larger area than the size of the wrapped_key_t structure for each algorithm defined in Table 2-13 Byte Size of the wrapped_key_t Structure enum rsip_byte_size_wrapped_key_t.

Reentrant

Not supported.

4.2.2.3 R_RSIP_InitialKeyUpdateKeyWrap

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_InitialKeyUpdateKeyWrap(
        rsip_ctrl_t * const p_ctrl,
        rsip_wufpk_t const * const p_wrapped_user_factory_programming_key,
        uint8_t const * const p_initial_vector,
        uint8_t const * const p_encrypted_key,
        rsip_key_update_key_t * const p_wrapped_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_user_factory_programming_key	Input	W-UFPK
p_initial_vector	Input	Initialization vector (16 bytes)
p_encrypted_key	Input	KUK wrapped with UFPK
p_wrapped_key	Output	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of the key specified in p_encrypted_key
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine

Description

This API generates a wrapped key of the KUK from the UFPK-wrapped KUK.
For p_wrapped_user_factory_programming_key, specify the W-UFPK of the UFPK used in wrapping the KUK. For p_initial_vector, specify the initialization vector used in wrapping the KUK. For p_encrypted_key, specify the KUK wrapped with a UFPK. A wrapped key of the KUK is output to p_wrapped_key.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.2.4 R_RSIP_EncryptedKeyWrap

Format

```
#include “r_rsip_protected_rx_if.h”
fsp_err_t R_RSIP_EncryptedKeyWrap(
        rsip_ctrl_t * const p_ctrl,
        rsip_key_update_key_t const * const p_key_update_key,
        uint8_t const * const p_initial_vector,
        rsip_key_type_t const key_type,
        uint8_t const * const p_encrypted_key,
        rsip_wrapped_key_t * const p_wrapped_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_key_update_key	Input	Key update key
p_initial_vector	Input	Initialization vector (16 bytes)
key_type	Input	Type of the generated wrapped key
p_encrypted_key	Input	Encrypted key
p_wrapped_key	Output	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for key_type
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API generates a wrapped key from the KUK-wrapped user key.
It unwraps the KUK-wrapped user key input in p_encrypted_key using the wrapped key of the KUK input in p_key_update_key and the initialization vector p_initial_vector used when wrapping the user key with a KUK. It then outputs the wrapped key of the user key to p_wrapped_key.
For key_type, input a value defined in Table 2-7.
For p_wrapped_key, allocate a larger area than the size of the wrapped_key_t structure for each algorithm defined in Table 2-13 Byte Size of the wrapped_key_t Structure enum rsip_byte_size_wrapped_key_t.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.2.5 R_RSIP_KeyGenerate

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_KeyGenerate(
        rsip_ctrl_t * const p_ctrl,
        rsip_key_type_t const key_type,
        rsip_wrapped_key_t * const p_wrapped_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
key_type	Input	Type of the generated key
p_wrapped_key	Output	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for key_type
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API outputs the wrapped key of the symmetric key specified in key_type to p_wrapped_key.
For key_type, input a value defined in Table 2-7.
For p_wrapped_key, allocate a larger area than the size of the wrapped_key_t structure for each algorithm defined in Table 2-13 Byte Size of the wrapped_key_t Structure enum rsip_byte_size_wrapped_key_t.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.2.6 R_RSIP_KeyPairGenerate

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_KeyPairGenerate(
        rsip_ctrl_t * const p_ctrl,
        rsip_key_pair_type_t const key_type,
        rsip_wrapped_key_t *const p_wrapped_public_key,
        rsip_wrapped_key_t * const p_wrapped_private_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
key_type	Input	Type of the generated key
p_wrapped_public_key	Output	Wrapped public key
p_wrapped_private_key	Output	Wrapped private key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for key_type
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API outputs the wrapped key of the asymmetric key specified in key_type to p_wrapped_public_key and p_wrapped_public_key.
For key_type, input a value defined in Table 2-8.
For p_wrapped_public_key and p_wrapped_public_key, allocate a larger area than the size of the wrapped_key_t structure for each algorithm defined in Table 2-13 Byte Size of the wrapped_key_t Structure enum rsip_byte_size_wrapped_key_t.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.2.7 R_RSIP_PublicKeyExport

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_PublicKeyExport(
        rsip_wrapped_key_t const * const p_wrapped_public_key,
        uint8_t * const p_raw_public_key
)
```

Parameters

p_wrapped_public_key	Input	Wrapped public key
p_raw_public_key	Output	Plaintext public key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Input of an unsupported key type for p_wrapped_public_key

Description

This API extracts a plaintext public key from the wrapped public key.

It outputs the plaintext public key from the wrapped key specified in p_wrapped_public_key to p_raw_public_key.

The public key output to p_raw_public_key will be in the following format:

secp256r1, brainpoolP256r1,secp256k1:
  p_raw_public_key[0:31] = Public key Qx
  p_raw_public_key[32:63] = Public key Qy

Reentrant

Not supported.

4.2.3 Random Number Generation

4.2.3.1 R_RSIP_RandomNumberGenerate

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_RandomNumberGenerate(
        rsip_ctrl_t * const p_ctrl,
        uint8_t * const p_random
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_random	Output	16-byte random number

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API outputs a 16-byte random number value compliant with NIST SP800-90A to p_random.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.4 AES

4.2.4.1 R_RSIP_AES_Cipher_Init

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_Cipher_Init(
        rsip_ctrl_t * const p_ctrl,
        rsip_aes_cipher_mode_t const mode,
        rsip_wrapped_key_t const * const p_wrapped_key,
        uint8_t const * const p_initial_vector
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
mode	Input	Block encryption mode to be executed
p_wrapped_key	Input	Wrapped key
p_initial_vector	Input	Initialization vector (16 bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key
FSP_ERR_INVALID_ARGUMENT	Invalid input key type or mode
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of the key specified in p_wrapped_key
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs preparations for execution of an AES operation.

For mode, specify the AES block encryption mode to be executed. For p_wrapped_key, specify the wrapped key used for encryption and decryption. The meaning of the data specified for p_initial_vector varies depending on the mode: Initialization vector for CBC, nonce for CTR, or not used for ECB.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The result of the R_RSIP_AES_Cipher_Init() function execution is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_AES_Cipher_Update() and R_RSIP_AES_Cipher_Finish() functions.

Reentrant

Not supported.

4.2.4.2 R_RSIP_AES_Cipher_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_Cipher_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_input,
        uint8_t * const p_output,
        uint32_t const length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_input	Input	Input data area
p_output	Output	Output data area
length	Input	Byte length of input data (must be a multiple of 16)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_INVALID_SIZE	Invalid input size

Description

This API performs encryption or decryption operations.
When encryption operation is specified in mode of R_RSIP_AES_Cipher_Init(), this API encrypts the plaintext input to p_input for the size specified by length and outputs it to p_output.
When decryption operation is specified in mode of R_RSIP_AES_Cipher_Init(), this API decrypts the ciphertext input to p_input for the size specified by length and outputs it to p_output.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_Cipher_Init() function.

Reentrant

Not supported.

4.2.4.3 R_RSIP_AES_Cipher_Finish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_Cipher_Finish(
        rsip_ctrl_t *const p_ctrl
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API ends a cryptographic operation.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_Cipher_Init() and R_RSIP_AES_Cipher_Update() functions.

Reentrant

Not supported.

4.2.4.4 R_RSIP_AES_AEAD_Init

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_AEAD_Init(
        rsip_ctrl_t * const p_ctrl,
        rsip_aes_aead_mode_t const mode,
        rsip_wrapped_key_t const * const p_wrapped_key,
        uint8_t const * const p_nonce,
        uint32_t const nonce_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
mode	Input	AEAD mode to be executed
p_wrapped_key	Input	Wrapped key
p_nonce	Input	Nonce
nonce_length	Input	Byte length of the nonce (must be greater than or equal to 1)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key
FSP_ERR_INVALID_ARGUMENT	Invalid input key type or mode
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of the key specified in p_wrapped_key
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

The R_RSIP_AES_AEAD_Init() function performs preparations for execution of an AES AEAD operation.

For mode, specify the AEAD mode to be executed. For p_wrapped_key, specify the wrapped key used for AEAD. The meaning of the data specified for p_nonce varies depending on the mode: Initialization vector when the GCM mode was specified, or nonce when the CCM mode was specified. For nonce_length, input the initialization vector specified in p_nonce or the byte length of the nonce.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_OPEN() function. The result of the R_RSIP_AES_AEAD_Init() function is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_AES_AEAD_LengthsSet(), R_RSIP_AES_AEAD_AADUpdate(), R_RSIP_AES_AEAD_Update(), R_RSIP_AES_AEAD_Finish(), and R_RSIP_AES_AEAD_Verify() functions.

Reentrant

Not supported.

4.2.4.5 R_RSIP_AES_AEAD_LengthsSet

Format

```
#include "r_rsip_protected_rx_if.h"
 fsp_err_t R_RSIP_AES_AEAD_LengthsSet(
        rsip_ctrl_t * const p_ctrl,
        uint32_t const total_aad_length,
        uint32_t const total_text_length,
        uint32_t const tag_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
total_aad_length	Input	Byte length of AAD (110 bytes or less)
total_text_length	Input	Byte length of input/output data
tag_length	Input	Byte length of the authentication tag (4, 6, 8, 10, 12, 14, or 16 bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_SIZE	Invalid input size
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver

Description

This API is used when performing AES CCM operations. Specify the byte lengths of AAD, input/output data, and authentication tag.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_AEAD_Init() function.

Reentrant

Not supported.

4.2.4.6 R_RSIP_AES_AEAD_AADUpdate

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_AEAD_AAdUpdate(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_aad,
        uint32_t const aad_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_aad	Input	AAD area
aad_length	Input	Byte length of AAD (0 byte to any length of bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key which is input in R_RSIP_AES_AEAD_Init
FSP_ERR_CRYPTO_RSIP_FAIL	Internal error
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API specifies the AAD used in an AES AEAD operation.
For p_aad, input the AAD. For aad_length, input the byte size of the AAD.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_AEAD_Init() and R_RSIP_AES_AEAD_LengthsSet() functions.

Before calling the R_RSIP_AES_AEAD_Update() function, input AAD with this function.

Reentrant

Not supported.

4.2.4.7 R_RSIP_AES_AEAD_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_AEAD_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_input,
        uint32_t const input_length,
        uint8_t * const p_output,
        uint32_t * const p_output_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_input	Input	Input data area
input_length	Input	Byte length of input data (0 byte to any length of bytes)
p_output	Output	Output data area
p_output_length	Output	Byte length of output data

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_INVALID_SIZE	Invalid byte size specified for Input_length

Description

This API performs an AES AEAD operation.
When encryption operation is specified in mode of R_RSIP_AES_AEAD_Init(), the API encrypts the plaintext input to p_input for the size specified by input_length and outputs encrypted data to p_output. If the size specified in input_length is not 16-byte aligned, the API encrypts the fraction of 16-byte alignment in the R_RSIP_AES_AEAD_Update(), R_RSIP_AES_AEAD_Finish(), or R_RSIP_AES_AEAD_Verify() which is called next. The size which is encrypted and then output to p_output is output to p_output_length.
When decryption operation is specified in mode of R_RSIP_AES_AEAD_Init(), this API decrypts the ciphertext input to p_input for the size specified by length and outputs decrypted data to p_output. If the size specified in input_length is not 16-byte aligned, the API decrypts the fraction of 16-byte alignment in the R_RSIP_AES_AEAD_Update(), R_RSIP_AES_AEAD_Finish(), or R_RSIP_AES_AEAD_Verify() which is called next. The size which is decrypted and then output to p_output is output to p_output_length.
Except in cases where the addresses are the same, specify areas for p_input and p_output that do not overlap.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_AEAD_Init(), R_RSIP_AES_AEAD_LengthsSet(), and R_RSIP_AES_AEAD_AADUpdate() functions.

Reentrant

Not supported.

4.2.4.8 R_RSIP_AES_AEAD_Finish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_AEAD_Finish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t * const p_output,
        uint32_t * const p_output_length,
        uint8_t * const p_tag
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_output	Output	Output data area
p_output_length	Output	Byte length of output data
p_tag	Output	Authentication tag area (16 bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_FAIL	Occurrence of internal error
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs AES AEAD encryption and authentication tag generation.
If the total data size input by R_RSIP_AES_AEAD_Update() is not 16-byte aligned, the API outputs the ciphertext data for the fraction of 16-byte alignment in p_output of the R_RSIP_AES_AEAD_Finish() function, and the size of the ciphertext data output from this API in p_output_length. An authentication tag will be output to p_tag.
Use R_RSIP_AES_AEAD_Verify() for decryption and tag verification.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_AEAD_Init(), R_RSIP_AES_AEAD_LengthsSet(), R_RSIP_AES_AEAD_AADUpdate(), and R_RSIP_AES_AEAD_Update() functions.

Reentrant

Not supported.

4.2.4.9 R_RSIP_AES_AEAD_Verify

Format

```
#include "r_rsip_protected_rx_if.h"
 fsp_err_t R_RSIP_AES_AEAD_Verify(
        rsip_ctrl_t * const p_ctrl,
        uint8_t * const p_output,
        uint32_t * const p_output_length,
        uint8_t * const p_tag,
        uint32_t const tag_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_output	Output	Output data area
p_output_length	Output	Byte length of output data
p_tag	Input	Authentication tag area
tag_length	Input	Byte length of the authentication tag (1 to 16 bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_INVALID_SIZE	Invalid tag_length value
FSP_ERR_CRYPTO_RSIP_FAIL	Occurrence of internal error
FSP_ERR_CRYPTO_RSIP_AUTHENTICATION	Authentication error
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs decryption and tag verification.
If the total data size input by R_RSIP_AES_AEAD_Update() is not 16-byte aligned, the API outputs the plaintext data for the fraction in p_output of the R_RSIP_AES_AEAD_Verify() function, and the size of the plaintext data output from this API in p_output_length. For p_tag, input the authentication tag value to be used for authentication. For tag_length, input the byte length of the tag to be used for tag authentication. Use R_RSIP_AES_AEAD_Finish() for encryption and tag generation.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_AEAD_Init(), R_RSIP_AES_AEAD_LengthsSet(), R_RSIP_AES_AEAD_AADUpdate(), and R_RSIP_AES_AEAD_Update() functions.

Reentrant

Not supported.

4.2.4.10 R_RSIP_AES_MAC_Init

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_MAC_Init(
        rsip_ctrl_t * const p_ctrl,
        rsip_aes_mac_mode_t const mode,
        rsip_wrapped_key_t const * const p_wrapped_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
mode	Input	MAC calculation mode to be executed
p_wrapped_key	Input	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs preparations for execution of an AES MAC calculation.
For mode, specify the MAC mode to be executed. For p_wrapped_key, specify the wrapped key used for MAC calculation.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The preparation result for AES MAC calculation execution is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_AES_MAC_Update(), R_RSIP_AES_MAC_Finish(), and R_RSIP_AES_MAC_Verify() functions.

Reentrant

Not supported.

4.2.4.11 R_RSIP_AES_MAC_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_MAC_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_message,
        uint32_t const message_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_message	Input	Message data area
message_length	Input	Byte length of message data (0 byte to any length of bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver

Description

This API performs an AES MAC calculation. After the calculation is complete, the API calls R_RSIP_AES_MAC_SignFinish() or R_RSIP_AES_MAC_VerifyFinish().
For p_message, specify the message to be MAC-verified or generated. For message_length, specify the length of the message to be input.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_MAC_Init() function.

Reentrant

Not supported.

4.2.4.12 R_RSIP_AES_MAC_SignFinish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_MAC_SignFinish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t * const p_mac
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_mac	Output	MAC data area (16 bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_FAIL	Internal error
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API generates a MAC.
It outputs the MAC value of the message input by the R_RSIP_AES_MAC_Update() function to p_mac.
Use R_RSIP_AES_MAC_VerifyFinish() to perform MAC verification.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_MAC_Init() and R_RSIP_AES_MAC_Update() functions.

Reentrant

Not supported.

4.2.4.13 R_RSIP_AES_MAC_VerifyFinish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_AES_MAC_VerifyFinish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_mac,
        uint32_t const mac_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_mac	Input	MAC data area
mac_length	Input	Byte length of MAC data (2 to 16 bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_INVALID_SIZE	Invalid size specified for mac_length
FSP_ERR_CRYPTO_RSIP_FAIL	Internal error
FSP_ERR_CRYPTO_RSIP_AUTHENTICATION	MAC verification error
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs MAC verification.
It verifies the MAC value of the message input in the R_RSIP_AES_MAC_Update() function against the MAC input in p_mac. It verifies the MAC value input in p_mac as a valid MAC value for the number of bytes specified in mac_length.
Use R_RSIP_AES_MAC_SignFinish() to perform MAC generation.

For p_ctrl, specify p_ctrl used in the R_RSIP_AES_MAC_Init() and R_RSIP_AES_MAC_Update() functions.

Reentrant

Not supported.

4.2.5 ECC

4.2.5.1 R_RSIP_ECDSA_Sign

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_ECDSA_Sign(
        rsip_ctrl_t * const p_ctrl,
        rsip_wrapped_key_t const * const p_wrapped_private_key,
        uint8_t const * const p_hash,
        uint8_t *const p_signature
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_private_key	Input	Wrapped key
p_hash	Input	Hash value A hash value of the same size as the key length is input.
p_signature	Output	Signature A signature twice the size of the key length is output.

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter or occurrence of error in signature generation
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API generates an ECDSA signature.
It outputs the ECDSA signature of the hash value input in p_hash to p_signature using the private key input in p_wrapped_private_key.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.5.2 R_RSIP_ECDSA_Verify

Format

```
#include "r_rsip_protected_rx_if.h"
 fsp_err_t R_RSIP_ECDSA_Verify(
        rsip_ctrl_t *const p_ctrl,
        rsip_wrapped_key_t const * const p_wrapped_public_key,
        uint8_t const * const p_hash,
        uint8_t const * const p_signature
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_public_key	Input	Wrapped key
p_hash	Input	Hash value to be verified A hash value whose byte length is the same size as the key length is input.
p_signature	Input	Signature to be verified A signature twice the size of the key length is input.

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter or occurrence of error in signature verification
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs ECDSA signature verification.
It uses the public key input in p_wrapped_public_key to verify the hash value input in p_hash and the ECDSA signature value input in p_signature.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.6 Hash

4.2.6.1 R_RSIP_SHA_Init

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SHA_Init(
        rsip_ctrl_t * const p_ctrl,
        rsip_hash_type_t const hash_type
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
hash_type	Input	Hash calculation mode to be executed

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported hash calculation mode specified for hash_type
FSP_ERR_INVALID_ARGUMENT	Invalid input key type or mode

Description

This API performs preparations for execution of a hash calculation.
For hash_type, specify the hash calculation mode to be executed.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The preparation result for hash calculation execution is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_SHA_Update() and R_RSIP_SHA_Finish() functions.

Reentrant

Not supported.

4.2.6.2 R_RSIP_SHA_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SHA_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_message,
        uint32_t const message_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_message	Input	Message data area
message_length	Input	Byte length of message data (0 byte to any length of bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs a hash calculation.
For p_message, input the message to be hash-calculated. For message_length, specify the length of the message to be input in p_message.

For p_ctrl, specify p_ctrl used in the R_RSIP_SHA_Init() function.

Reentrant

Not supported.

4.2.6.3 R_RSIP_SHA_Finish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SHA_Finish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t * const p_digest
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_digest	Output	Hash data area

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API outputs the result of SHA calculation.
It outputs the hash value of the message input in the R_RSIP_SHA_Update() function to p_digest.

For p_ctrl, specify p_ctrl used in the R_RSIP_SHA_Init() and R_RSIP_SHA_Update() functions.

Reentrant

Not supported.

4.2.6.4 R_RSIP_SHA_Suspend

Format

```
#include "r_rsip_protected_rx_if.h"
 fsp_err_t R_RSIP_SHA_Suspend(
        rsip_ctrl_t * const p_ctrl,
        rsip_sha_handle_t * const p_handle
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_handle	Output	Control information for hash calculation

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver

Description

After execution with the R_RSIP_SHA_Init() and R_RSIP_SHA_Update() functions, this API suspends a hash calculation midway so that other multi-part or single-part operations can be performed. It outputs the intermediate value of the suspended hash calculation to p_handle.
If R_RSIP_SHA_Finish() function is called after R_RSIP_SHA_Suspend() function is called, this API outputs the hash value of the message input to R_RSIP_SHA_Update() function up to that point.
To resume the hash calculation, call the R_RSIP_SHA_Suspend() function.

For p_ctrl, specify p_ctrl used in the R_RSIP_SHA_Init() and R_RSIP_SHA_Update() functions.

Reentrant

Not supported.

4.2.6.5 R_RSIP_SHA_Resume

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SHA_Suspend(
        rsip_ctrl_t * const p_ctrl,
        rsip_sha_handle_t * const p_handle
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_handle	Input	Control information for hash calculation

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver

Description

This API resumes the hash calculation suspended by the R_RSIP_SHA_Suspend() function.
For p_handle, input p_handle output by the R_RSIP_SHA_Suspend() function.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The intermediate value of the hash calculation held by the R_RSIP_SHA_Suspend() function is set in p_ctrl and used in the subsequent R_RSIP_SHA_Update() and R_RSIP_SHA_Finish() functions.

Reentrant

Not supported.

4.2.6.6 R_RSIP_HMAC_Init

Format

```
#include “r_rsip_protected_rx_if.h”
fsp_err_t R_RSIP_HMAC_Init(
        rsip_ctrl_t * const p_ctrl,
        rsip_wrapped_key_t const * const p_wrapped_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_key	Input	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs preparations for execution of an HMAC calculation.
For p_wrapped_key, specify the wrapped key to be used for HMAC generation and verification.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The preparation result for HMAC calculation execution is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_HMAC_Update(), R_RSIP_HMAC_SignFinish(), and R_RSIP_HMAC_VerifyFinish() functions.

Reentrant

Not supported.

4.2.6.7 R_RSIP_HMAC_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_HMAC_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_message,
        uint32_t const message_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_message	Input	Message data area
message_length	Input	Byte length of message data (0 byte to any length of bytes)

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key which is input in R_RSIP_HMAC_Init
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key which is input in R_RSIP_HMAC_Init
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs an HMAC calculation.
For p_message, input the message to be hash-calculated. For message_length, specify the length of the message to be input in p_message.

For p_ctrl, specify p_ctrl used in the R_RSIP_HMAC_Init() function.

Reentrant

Not supported.

4.2.6.8 R_RSIP_HMAC_SignFinish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_HMAC_SignFinish(
        rsip_ctrl_t *const p_ctrl,
        uint8_t * const p_mac
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_mac	Output	HMAC data area

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key which is input in R_RSIP_HMAC_Init
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key which is input in R_RSIP_HMAC_Init
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API generates an HMAC.
It outputs the HMAC value of the message input by the R_RSIP_HMAC_Update() function to p_mac.
Use R_RSIP_HMAC_VerifyFinish() to perform HMAC verification.

For p_ctrl, specify p_ctrl used in the R_RSIP_HMAC_Init() and R_RSIP_HMAC_Update() functions.

Reentrant

Not supported.

4.2.6.9 R_RSIP_HMAC_VerifyFinish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_HMAC_VerifyFinish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_mac,
        uint32_t const mac_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_mac	Input	HMAC data area to be verified
mac_length	Input	Byte length of HMAC data to be verified

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_INVALID_SIZE	Invalid mac_length
FSP_ERR_NOT_ENABLED	Unsupported key type specified for p_wrapped_key which is input in R_RSIP_HMAC_Init
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Occurrence of error in verification of p_wrapped_key which is input in R_RSIP_HMAC_Init
FSP_ERR_CRYPTO_RSIP_FAIL	MAC verification error
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption detected

Description

This API performs HMAC verification.
It verifies the HMAC value of the message input in the R_RSIP_HMAC_Update() function against the HMAC value input in p_mac. It verifies the MAC value input in p_mac as a valid MAC value for the number of bytes specified in mac_length.
R_RSIP_HMAC_SignFinish() is used for HMAC generation.

For p_ctrl, specify p_ctrl used in the R_RSIP_HMAC_Init() and R_RSIP_HMAC_Update() functions.

Reentrant

Not supported.

4.2.7 Key Wrap

4.2.7.1 R_RSIP_RFC3394_KeyWrap

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_RFC3394_KeyWrap(
        rsip_ctrl_t * const p_ctrl,
        rsip_wrapped_key_t const * const p_wrapped_kek,
        rsip_wrapped_key_t const * const p_wrapped_target_key,
        uint8_t * const p_rfc3394_wrapped_target_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_kek	Input	Key used for wrapping
p_wrapped_target_key	Input	Key to be wrapped
p_rfc3394_wrapped_target_key	Output	Wrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type in this functionality (depending on the setting)
FSP_ERR_INVALID_ARGUMENT	Invalid input key type or mode
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Invalid key input
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API wraps a key with an RFC3394-compliant algorithm.
It wraps p_wrapped_target_key with the key specified in p_wrapped_kek. The wrapped key is output to p_rfc3394_wrapped_target_key.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.7.2 R_RSIP_RFC3394_KeyUnwrap

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_RFC3394_KeyUnwrap(
        rsip_ctrl_t * const p_ctrl,
        rsip_wrapped_key_t const * const p_wrapped_kek,
        rsip_key_type_t const key_type,
        uint8_t const * const p_rfc3394_wrapped_target_key,
        rsip_wrapped_key_t * const p_wrapped_target_key
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_kek	Input	Key used for unwrapping
key_type	Input	Type of output wrapped key
p_rfc3394_wrapped_target_key	Input	Wrapped key
p_wrapped_target_key	Output	Unwrapped key

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_NOT_ENABLED	Unsupported key type in this functionality (depending on the setting)
FSP_ERR_INVALID_ARGUMENT	Invalid input key type or mode
FSP_ERR_CRYPTO_RSIP_FAIL	Invalid input parameter
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Invalid key input
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FATAL	Software corruption or hardware failure detected

Description

This API unwraps a key with an RFC3394-compliant algorithm.

It unwraps p_rfc3394_wrapped_target_key with the key specified in p_wrapped_kek. The unwrapped key is output to p_wrapped_target_key in the wrapped key format. For key_type, specify the type of key to be unwrapped.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.8 Firmware Update/Secure Boot

4.2.8.1 R_RSIP_FWUP_StartUpdateFirmware

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_FWUP_StartUpdateFimware(
        rsip_ctrl_t * const p_ctrl
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine

Description

This API transitions the RSIP PM driver to the Firmware Update state.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function.

Reentrant

Not supported.

4.2.8.2 R_RSIP_FWUP_MAC_Sign_Init

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_FWUP_MAC_Sign_Init(
        rsip_ctrl_t * const p_ctrl,
        rsip_wrapped_key_t const * const p_wrapped_key_encryption_key,
        uint8_t const * const p_encrypted_image_encryption_key,
        uint8_t const * const p_initial_vector,
        uint32_t const firmware_size
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_wrapped_key_encryption_key	Input	Wrapped key of the key used for wrapping the image encryption key
p_encrypted_image_encryption_key	Input	Image encryption key wrapped with a key encryption key
p_initial_vector	Input	Initialization vector used in firmware encryption
firmware_size	Input	Total byte length of encrypted firmware

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_KEY_SET_FAIL	Invalid key input

Description

This API decrypts encrypted firmware, performs MAC verification, and performs preparations for generation of a MAC for plaintext firmware.

For p_wrapped_key_encryption_key, input a wrapped key of the key encryption key used for wrapping the key used for encrypting firmware (image encryption key). For p_encrypted_image_encryption_key, input the image encryption key wrapped with the key encryption key. For p_initial_vector, input the initialization vector used for firmware encryption. For firmware_size, input the byte size of the encrypted firmware to be decrypted.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The result of the R_RSIP_FWUP_MAC_Sign_Init() function execution is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_FWUP_MAC_Sign_Update() and R_RSIP_FWUP_MAC_Sign_Finish() functions.

Reentrant

Not supported.

4.2.8.3 R_RSIP_FWUP_MAC_Sign_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_FWUP_MAC_Sign_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_input,
        uint8_t * const p_output,
        uint32_t const input_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_input	Input	Encrypted firmware
p_output	Output	Plaintext firmware
input_length	Input	Byte length of input encrypted firmware Input in a multiple of 16 bytes.

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_INVALID_ARGUMENT	Invalid input data

Description

This API decrypts the encrypted firmware input to p_input for the size specified by length, and outputs the plaintext firmware to p_output.

Use R_RSIP_FWUP_MAC_Sign_Update() for decryption if the decryption process needs to be performed more than once, for example, because the encrypted firmware exists in multiple areas. This API, however, decrypts the encrypted firmware including the last 16 bytes using R_RSIP_FWUP_MAC_Sign_Finish(). If there is no need to perform the decryption process more than once, do not use R_RSIP_FWUP_MAC_Sign_Update(), but use R_RSIP_FWUP_MAC_Sign_Finish().

For p_ctrl, specify p_ctrl used in the R_RSIP_FWUP_MAC_Sign_Init() function.

Reentrant

Not supported.

4.2.8.4 R_RSIP_FWUP_MAC_Sign_Finish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_FWUP_MAC_Sign_Finish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_input,
        uint8_t const * const p_input_mac,
        uint8_t * const p_output,
        uint8_t * const p_output_mac,
        uint32_t const input_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_input	Input	Input firmware area
p_input_mac	Input	MAC value of input firmware (16 bytes)
p_output	Output	Output firmware area
p_output_mac	Output	MAC value of output firmware (16 bytes)
input_length	Input	Byte length of input firmware. Input in a multiple of 16 bytes.

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_FAIL	Abnormal termination

Description

This API decrypts the encrypted firmware input to p_input for the size specified by length, and outputs the plaintext firmware to p_output. It then performs MAC verification of the encrypted firmware input to p_input_mac. If the MAC verification of the encrypted firmware is successful, the API generates a MAC value of the plaintext firmware and outputs it to p_output_mac.

For p_ctrl, specify p_ctrl used in the R_RSIP_FWUP_MAC_Sign_Init() and R_RSIP_FWUP_MAC_Sign_Update() functions.

Reentrant

Not supported.

4.2.8.5 R_RSIP_SB_MAC_Verify_Init

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SB_MAC_Verify_Init(
        rsip_ctrl_t * const p_ctrl
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver

Description

This API performs preparations for MAC verification for plaintext firmware.

For p_ctrl, specify the pointer to the management structure used in the R_RSIP_Open() function. The result of the R_RSIP_SB_MAC_Verify_Init() function execution is stored in p_ctrl. The value output to p_ctrl is used by the R_RSIP_SB_MAC_Verify_Update() and R_RSIP_SB_MAC_Verify_Finish() functions.

Reentrant

Not supported.

4.2.8.6 R_RSIP_SB_MAC_Verify_Update

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SB_MAC_Verify_Update(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_input,
        uint32_t const input_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_input	Input	Input firmware area
input_length	Input	Byte length of input firmware. Input in a multiple of 16 bytes.

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FAIL	Abnormal termination

Description

This API performs MAC calculation on plaintext firmware which is input to p_input for the size specified by input_length.

Use R_RSIP_SB_MAC_Verify_Update() if the plaintext firmware needs to be input more than once, for example, because the plaintext firmware exists in multiple areas. Input the plaintext firmware including the last 16 bytes by using R_RSIP_SB_MAC_Verify_Finish(). If there is no need to divide plaintext firmware input, use R_RSIP_SB_MAC_Verify_Finish() instead of R_RSIP_SB_MAC_Verify_Update().

For p_ctrl, specify p_ctrl used in the R_RSIP_SB_MAC_Verify_Init() function.

Reentrant

Not supported.

4.2.8.7 R_RSIP_SB_MAC_Verify_Finish

Format

```
#include "r_rsip_protected_rx_if.h"
fsp_err_t R_RSIP_SB_MAC_Verify_Finish(
        rsip_ctrl_t * const p_ctrl,
        uint8_t const * const p_input,
        uint8_t const * const p_mac,
        uint32_t const input_length
)
```

Parameters

p_ctrl	Input/output	RSIP PM driver management structure
p_input	Input	Input firmware area
p_mac	Input	MAC value of input firmware (16 bytes)
input_length	Input	Byte length of input firmware. Input in a multiple of 16 bytes.

Return Values

FSP_SUCCESS	Normal termination
FSP_ERR_ASSERTION	Null pointer argument
FSP_ERR_NOT_OPEN	RSIP PM driver not open
FSP_ERR_INVALID_STATE	Invalid internal state of the RSIP PM driver
FSP_ERR_CRYPTO_RSIP_RESOURCE_CONFLICT	Occurrence of resource conflict because a hardware resource needed by the processing routine was in use by another processing routine
FSP_ERR_CRYPTO_RSIP_FAIL	Abnormal termination

Description

This API performs MAC verification for input plaintext firmware.

For p_ctrl, specify the argument used in the R_RSIP_SB_MAC_Verify_Init() and R_RSIP_SB_MAC_Verify_Update() functions.

Reentrant

Not supported.

5. Key Injection and Updating

This section describes how to write encryption keys handled by the RSIP PM driver to nonvolatile memory such as the on-chip flash memory.

5.1 Key Injection

The procedure used to safely inject keys into products as part of the customer's manufacturing process is presented below. Refer to 3.7.1, Key Injection and Updating, for an explanation of the RSIP PM driver's key injection mechanism.

The Renesas Key Wrap Service provided by Renesas and a key injection program running on the RX Family MCU are required for user key injection. Supplementary tools such as Security Key Management Tool can be used to simplify the process.

The demo project accompanying this application note includes a sample key injection program that can be used for reference.

The process for implementing user key injection is as follows:

1. Preparing the key data necessary for user key injection
   Use a tool of your choice to prepare a 256-bit UFPK and 128-bit IV to use for wrapping the user key to be injected. The example below uses OpenSSL to generate a UFPK and IV.

   ```
   > openssl rand 32 > ufpk.bin
   > openssl rand 16 > iv.bin
   ```

   Use the Renesas Key Wrap Service (https://dlm.renesas.com/keywrap) to generate a W-UFPK by wrapping ufpk.bin using the HRK. For detailed information, refer to the Renesas Key Wrap Service FAQ.

   As described in section 3.7.1, which explains the user key wrapping scheme (Figure 3.3, User Key Wrapping Scheme during Key Injection and Key Updating), generate an encrypted key by wrapping the user key using the UFPK (ufpk.bin).

2. Creating a user key injection program
   Input the encrypted key, ufpk.bin, and iv.bin generated in step 1 to the key injection API for the cryptographic algorithm being used to generate a user wrapped key, and create a program to write it to nonvolatile memory. Refer to 3.7.1, Key Injection and Updating, for a description of how to use the key injection APIs.

3. Key injection
   Run the user key injection program on the RX Family MCU to inject the user key into the flash memory. It is recommended that the key injection data included in the user key injection program be deleted after key injection finishes.

Secure Key Management Tool is available as a supplementary tool for performing steps 1 and 2. Refer to sections 5.3 and 5.4 for details of this tool.

5.2 Key Updating

The procedure used to safely inject or update keys in products in the field is presented below. Refer to 3.7.1, Key Injection and Updating, for an explanation of the RSIP PM driver's key update mechanism.

To be able to inject or update keys in the field, the application program of the customer's product must be provided with key update functionality beforehand.

Key update functionality is implemented using a KUK and key update API. The KUK must be written to the flash memory during the product's manufacturing process using the method described in section 5.1, Key Injection. The process for implementing user key updating is as follows:

1. Creating a user application incorporating key update functionality
   Create a user application incorporating key update functionality by making use of a key update API. Implementing key update functionality requires processing to receive the encrypted key using a communication interface, to convert it to a wrapped key using a key update API, and then to write it to the flash memory.
   Refer to 3.7.1, Key Injection and Updating, for an explanation of how to use key update APIs.
2. Injecting the KUK and user key into the device
   Refer to section 5.1 and create a user key injection program including the KUK, then inject the KUK and user key into the flash memory. It is recommended that the key injection data included in the user key injection program be deleted after key injection finishes.
3. Programming the user application program incorporating key update functionality to the device
   Use a programming method of your choice to program to user application program incorporating key update functionality to the flash memory.
4. Creating the user key data to be used for the update
   As described in section 3.7.1, which explains the user key wrapping scheme (Figure 3.3, User Key Wrapping Scheme during Key Injection and Key Updating), generate an encrypted key by wrapping the user key using the KUK.
5. Updating the user key
   Pass the encrypted key to the user application program incorporating key update functionality running on the RX Family MCU. The operation of the key update functionality of the user application program implements updating of the key stored in the on-chip flash memory of the RX Family MCU. Depending on the functionality implemented in the user application program, it is also possible to inject a new user key.

Secure Key Management Tool is available as a supplementary tool for performing step 4. Refer to sections 5.3 and 5.4 for details of this tool.

5.3 User Key cryptographic format

The format of the input when encrypting a user key/KUK is shown below: Encrypted Key is generated by key wrapping in the manner shown in 3.6.1.1 Key Wrapping Algorithm.

・AES 128bit key

Input (User Key)

byte	16			
	4	4	4	4
0-15	128 bit AES key			

・AES 256bit key

Input (User Key)

byte	16			
	4	4	4	4
0-31	256 bit AES key			

・ECC secp256r1, brainpoolP256r1, secp256k1 public key

Input (User Key)

byte	16			
	4	4	4	4
0-31	ECC 256 bit public key Qx			
32-63	ECC 256 bit public key Qy			

・ECC secp256r1, brainpoolP256r1, secp256k1 private key

Input (User Key)

byte	16			
	4	4	4	4
0-31	ECC 256 bit private key d			

・HMAC-SHA224 key

Input(User Key)

byte	16			
	4	4	4	4
0-15	HMAC-SHA224 key			
16-31				0 padding

・HMAC-SHA256 key

Input (User Key)

byte	16			
	4	4	4	4
0-31	HMAC-SHA256 key			

・KUK

Input (User Key)

byte	16			
	4	4	4	4
0-15	AES 128bit CBC key			
16-31	AES 128bit CBCMAC key			

5.4 Generating an Encrypted Key Using Security Key Management Tool

You can use Security Key Management Tool to generate encrypted user keys. Security Key Management Tool is also available in a command line interface (CLI) version that can easily be deployed in settings such as the production line in a factory.

Security Key Management Tool

https://www.renesas.com/software-tool/security-key-management-tool

Refer to the user's manual for detailed instructions on how to use Security Key Management Tool.

5.4.1 Key Injection Procedure

The procedure for generating a key file to be used for key injection is described below. In the following example, C source code for AES is generated.

5.4.1.1 Procedure for CLI Version

1. Generating a UFPK
   In a terminal emulator, run the following genufpk command.

   > skmt.exe /genufpk
   /ufpk "2222222222222222222222222222222211111111111111111111111111111111"
   /output "C:\work\ufpk.key"

```
C:¥Renesas¥SecurityKeyMangementTool¥cli>skmt.exe /genufpk /ufpk "22222222222222222222222222222222
11111111111111111111111111111111" /output "C:¥work¥ufpk.key"
UFPK: 2222222222222222222222222222222211111111111111111111111111111111
Output File: C:¥work¥ufpk.key
```

Figure 5.1 genufpk Command Execution Result

2. Obtaining a W-UFPK
   Send the ufpk.key file generated in step 1 to the Renesas Key Wrap service (https://dlm.renesas.com/keywrap) to obtain a W-UFPK. For detailed information, refer to the Renesas Key Wrap Service FAQ.

3. Generating an AES 128 key file as a C source file
   In the terminal emulator, run the following genkey command.

   > skmt.exe /genkey /iv "55aa55aa55aa55aa55aa55aa55aa55aa" /ufpk file="C:\work\ufpk.key" /wufpk file="C:\work\ufpk.key_enc.key" /mcu "RX-RSIP-E11A" /keytype "AES-128" /key "11111111222222223333333344444444" /filetype "csource" /keyname "euk_aes128" /output "C:\work\euk_aes128.c"

   Use the UFPK file generated in step 1 and the W-UFPK file generated in step 2.

```
C:\Renesas\SecurityKeyManagementTool\cli>skmt.exe /genkey /iv "55aa55aa55aa55aa55aa55aa55aa55aa5
5aa" /ufpk file="C:\work\ufpk.key" /wufpk file="C:\work\ufpk.key_enc.key" /mcu "RX-RSIP-E11A
" /keytype "AES-128" /key "11111111222222223333333344444444" /filetype "csource" /keyname "e
uk_aes128" /output "C:\work\euk_aes128.c"
Output File: C:\work\euk_aes128.h
Output File: C:\work\euk_aes128.c
UFPK: 2222222222222222222222222222222211111111111111111111111111111111
W-UFPK: 00000000C6989581F469C1A0DF4F8DF5FC244A3100D4AC37247CE82EF9FC41B521B19C6F
IV: 55AA55AA55AA55AA55AA55AA55AA55AA
Encrypted key: 9206ACBC67367501A27EB48604AC77C6CB6CF84B4EBFF149B79DD6C0018FE0F9
```

Figure 5.2 genkey Command Execution Example

5.4.1.2 Procedure for GUI Version

1. Selecting an MCU or MPU and an encryption engine
   On the **Overview** tab, select an MCU or MPU and an encryption engine.

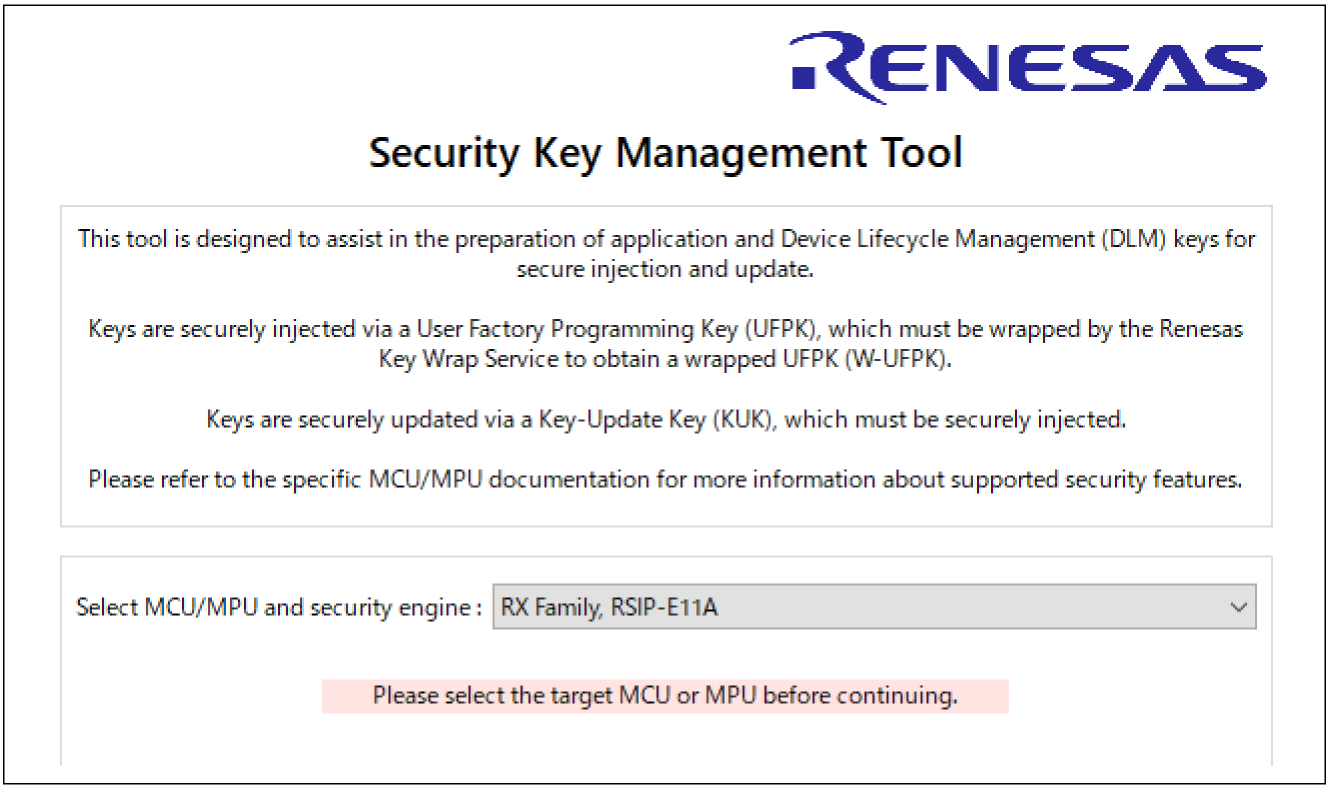


Figure 5.3 Overview Tab

2. Generating a UFPK
   On the **Generate UFPK** tab, specify a UFPK value and a file name with the extension *.key to generate an UFPK file. This example uses the file name **ufpk.key**.

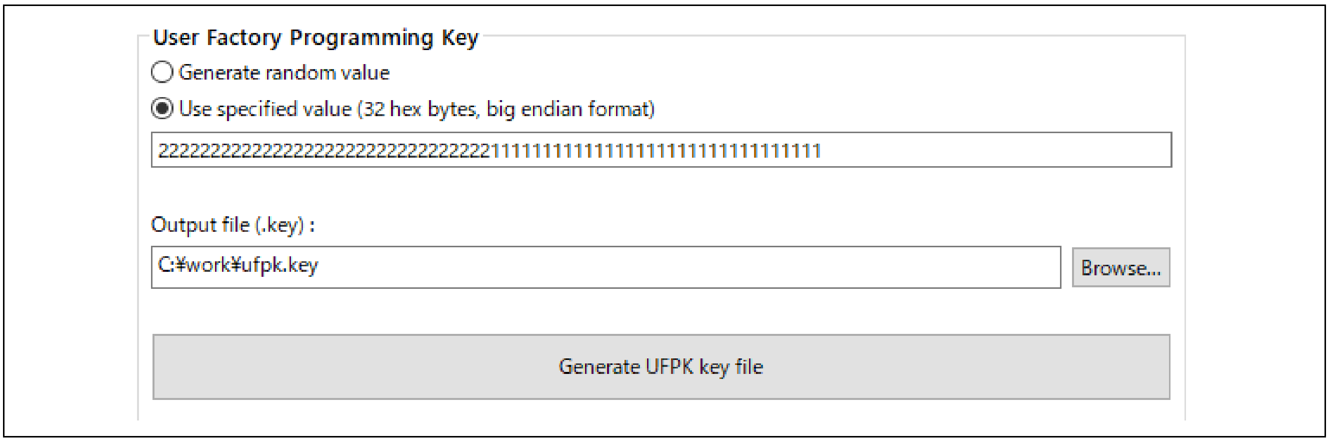


Figure 5.4 Example of UFPK Generation by Specifying Values on Generate UFPK Tab

Click the **Generate UFPK key file** button to generate an UFPK file. The following execution result is output when the file is generated successfully.

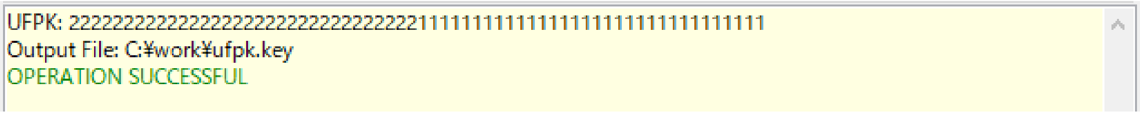


Figure 5.5 Generate UFPK Tab Execution Result

3. Obtaining a W-UFPK
   Send the ufpk.key file generated in step 2 to the Renesas Key Wrap service (https://dlm.renesas.com/keywrap) to obtain a W-UFPK. For detailed information, refer to the Renesas Key Wrap Service FAQ.

4. Generating an AES 128 key file as a C source file
   On the **Wrap Key** tab, generate an AES 128 key file. On the **Key Type** tab, select **AES** and **128 bits**, and on the **Key Data** tab, enter the AES 128 key data. For **Wrapping Key**, specify the UFPK file generated in step 2 and the W-UFPK file obtained in step 3. For **Format:** select **C Source**.

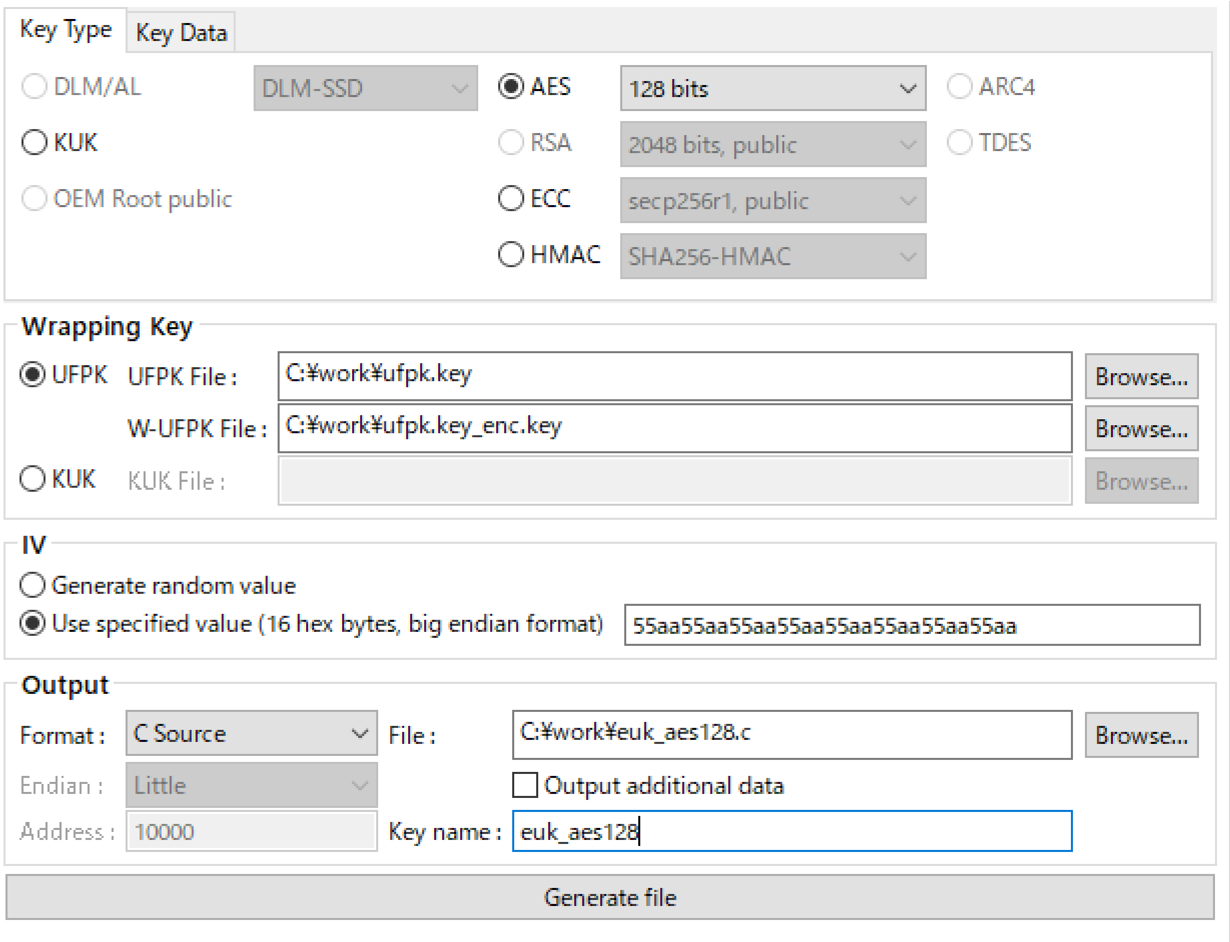


Figure 5.6 Example AES 128 Key File Output Settings on Wrap Key – Key Type Tab

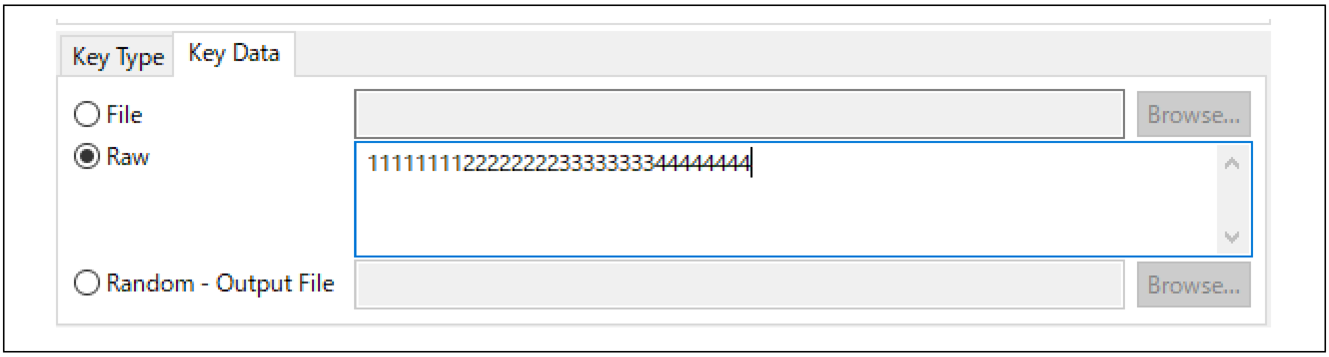


Figure 5.7 Example AES 128 Key C Source Output Settings on Wrap Key – Key Data Tab

The following is displayed when the operation completes successfully.

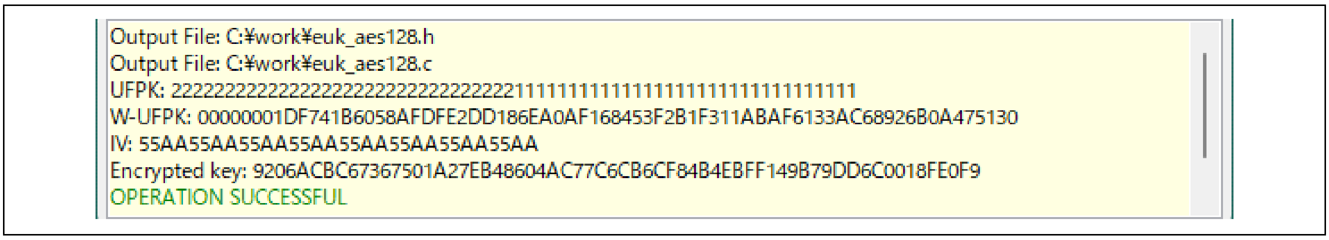


Figure 5.8 Wrap Key Tab Execution Result

Incorpolate the data in the output C source file into your project with the same method in 5.4.1.1.

5.4.2 Key Update Operation Procedure

If a KUK has been injected beforehand, it is not necessary to obtain a new UFPK when performing a key update.

5.4.2.1 Procedure for CLI Version

1. Generating a UFPK
   In a terminal emulator, run the following command:

   > skmt.exe /genufpk
   /ufpk "2222222222222222222222222222222211111111111111111111111111111111"
   /output "C:\work\ufpk.key"

```
C:¥Renesas¥SecurityKeyMangementTool¥cli>skmt.exe /genufpk /ufpk "22222222222222222222222222222222
11111111111111111111111111111111" /output "C:¥work¥ufpk.key"
UFPK: 2222222222222222222222222222222211111111111111111111111111111111
Output File: C:¥work¥ufpk.key
```

Figure 5.9 genufpk Command Execution Result

2. Obtaining a W-UFPK
   Send the ufpk.key file generated in step 1 to the Renesas Key Wrap service (https://dlm.renesas.com/keywrap) to obtain a W-UFPK.
   For detailed information, refer to the Renesas Key Wrap Service FAQ or the relevant application note.

3. Generating a KUK
   In the terminal emulator, run the following genkuk command.

   > skmt.exe /genkuk /output "C:\work\kuk.key"
   /kuk "d0aec19726cbc0e2fb403866b9b465a6c0d05b7a60362d5f435f9a3e98c79084"

```
C:\work\skmt\tool>skmt.exe /genkuk /output "C:\work\kuk.key" /kuk "d0aec19726cbc0e2fb40
3866b9b465a6c0d05b7a60362d5f435f9a3e98c79084"
KUK: D0AEC19726CBC0E2FB403866B9B465A6C0D05B7A60362D5F435F9A3E98C79084
Output File: C:\work\kuk.key
```

Figure 5.10 genkuk Command Execution Result

4. Generating an encrypted user key file containing a KUK encrypted using a UFPK
   In the terminal emulator, run the genkey command to encrypt a KUK using a UFPK.

   > skmt.exe /genkey /ufpk file="c:\work\ufpk.key" /wufpk file="C:\work\ufpk.key_enc.key"
   /mcu "RX-RSIP-E11A" /keytype "key-update-key" /key file="C:\work\kuk.key" /filetype "csource"
   /output "C:\work\kuk.c"

Use the UFPK file generated in step 1 and the W-UFPK file generated as described in step 2.

```
C:\Renesas\SecurityKeyManagementTool\cli>skmt.exe /genkey /ufpk file="c:\work\ufpk.key" /wuf
pk file="C:\work\ufpk.key_enc.key" /mcu "RX-RSIP-E11A" /keytype "key-update-key" /key file="
C:\work\kuk.key" /filetype "csource" /output "C:\work\kuk.c"
Output File: C:\work\kuk.h
Output File: C:\work\kuk.c
UFPK: 2222222222222222222222222222222211111111111111111111111111111111
W-UFPK: 00000000C6989581F469C1A0DF4F8DF5FC244A3100D4AC37247CE82EF9FC41B521B19C6F
IV: 0DA41458F21567D8AB26503AA287EA0A
Encrypted key: CDB1E35254A026DC0898F5DE60A8639D7168A034E9454CC3D0D0B333997EE0571598182CD3771
AA893843B43C7F0858A
```

Figure 5.11 genkey Command Execution Example

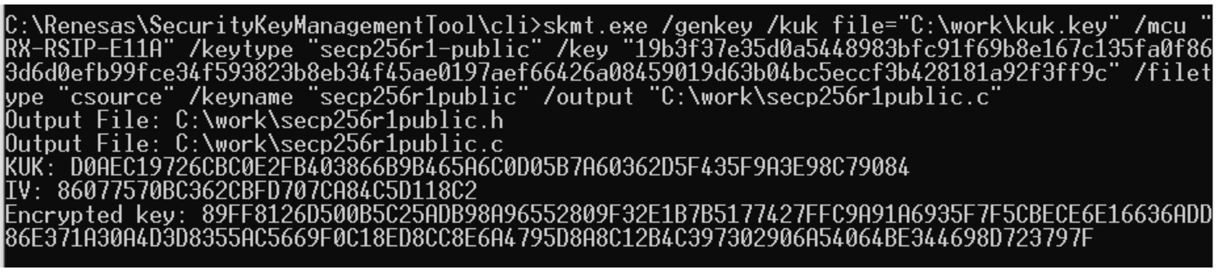
Use the data from the output C source file to inject the KUK by calling the R_RSIP_InitialKeyUpdateKeyWrap() function in your program.

Next, the wrapping method using a KUK for key updating in the field is described.

5. Generating an encrypted file containing a secp256r1 public key
   In the terminal emulator, run the following genkey command.

   **> skmt.exe /genkey /kuk file="C:\work\kuk.key" /mcu "RX-RSIP-E11A"
   /keytype "secp256r1-public" /key
   "19b3f37e35d0a5448983bfc91f69b8e167c135fa0f863d6d0efb99fce34f593823b8eb34f45ae0197aef66426a08459019d63b04bc5eccf3b428181a92f3ff9c"
   /filetype "csource” /keyname "secp256r1public"
   /output "C:\work\secp256r1public.c"**

Use the file generated in step 3 as the KUK file.



```
C:\Renesas\SecurityKeyManagementTool\cli>skmt.exe /genkey /kuk file="C:\work\kuk.key" /mcu "
RX-RSIP-E11A" /keytype "secp256r1-public" /key "19b3f37e35d0a5448983bfc91f69b8e167c135fa0f86
3d6d0efb99fce34f593823b8eb34f45ae0197aef66426a08459019d63b04bc5eccf3b428181a92f3ff9c" /filet
ype "csource" /keyname "secp256r1public" /output "C:\work\secp256r1public.c"
Output File: C:\work\secp256r1public.h
Output File: C:\work\secp256r1public.c
KUK: D0AEC19726CBC0E2FB403866B9B465A6C0D05B7A60362D5F435F9A3E98C79084
IV: 86077570BC362CBFD707CA84C5D118C2
Encrypted key: 89FF8126D500B5C25ADB98A96552809F32E1B7B5177427FFC9A91A6935F7F5CBECE6E16636ADD
86E371A30A4D3D8355AC5669F0C18ED8CC8E6A4795D8A8C12B4C397302906A54064BE344698D723797F
```

Figure 5.12 genkey Command Execution Example

Input the data from the output C source file to the external interface of the device, and pass the data to the parameters of the R_RSIP_EncryptedKeyWrap() function to output an updated secp256r1 public key wrapped key.

5.4.2.2 Procedure for GUI Version

1. Selecting an MCU or MPU and an encryption engine
   On the **Overview** tab, select an MCU or MPU and an encryption engine.

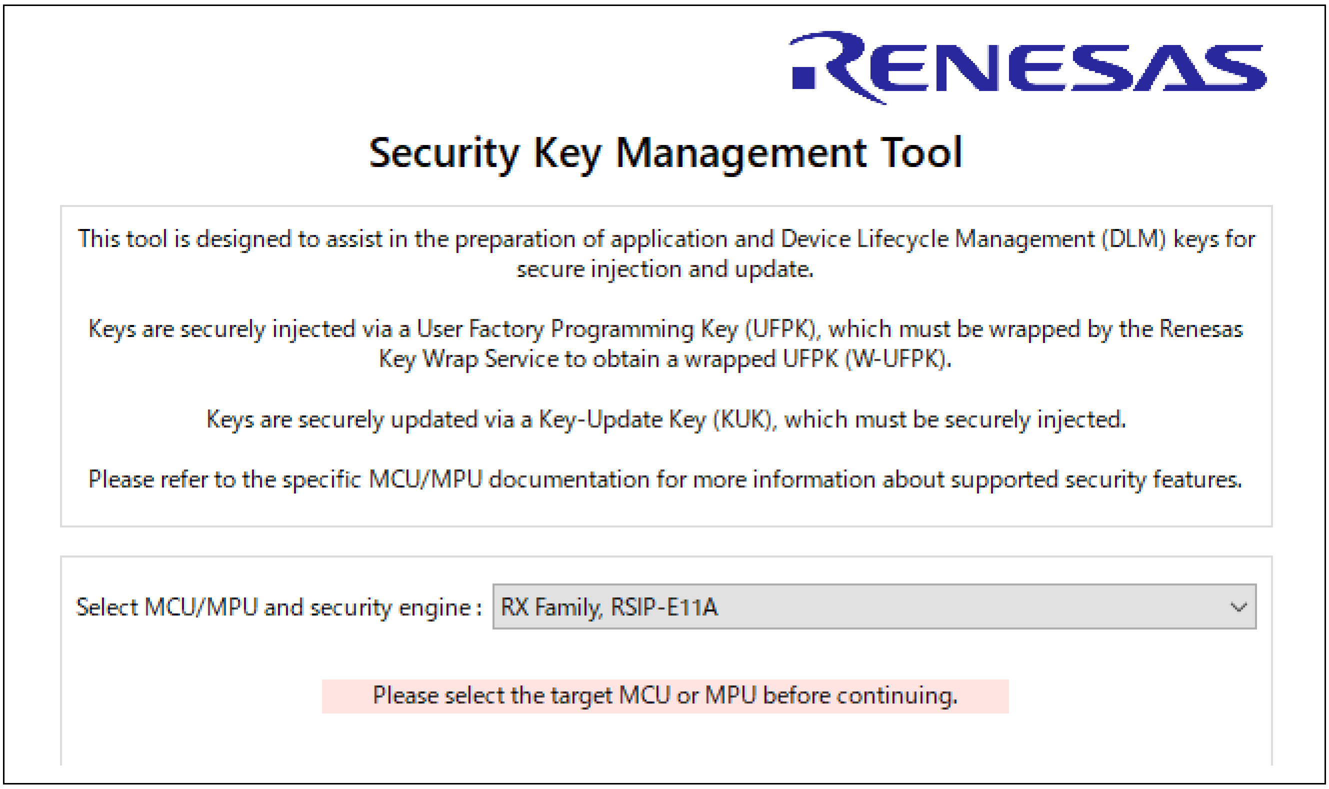


Figure 5.13 Overview Tab

2. Generating a UFPK
   On the Generate UFPK tab, specify an UFPK value and a file name with the extension *.key to generate an UFPK file. This example uses the file name ufpk.key.

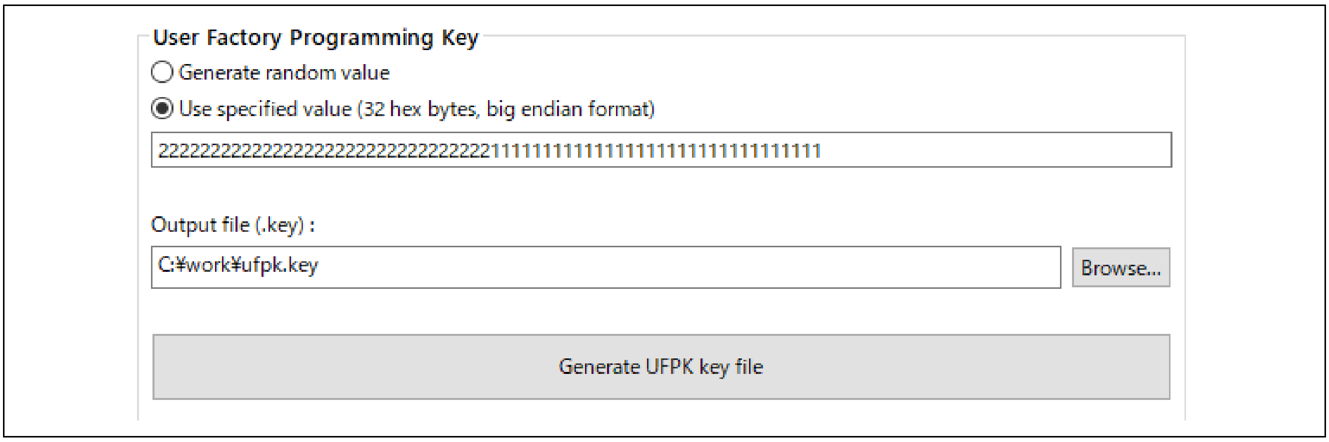


Figure 5.14 Example UFPK File Generation Settings on Generate UFPK Tab

Click the **Generate UFPK key file** button to generate an UFPK file. The following is displayed when the operation completes successfully.

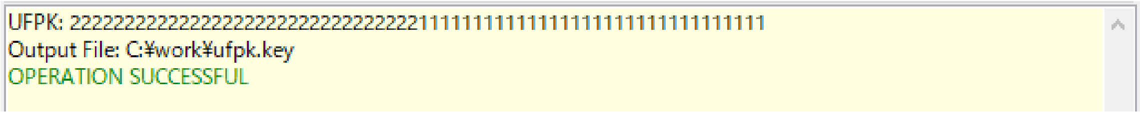


Figure 5.15 Generate UFPK Tab Execution Result

3. Obtaining a W-UFPK
   Send the ufpk.key file generated in step 2 to the Renesas Key Wrap service (https://dlm.renesas.com/keywrap) to obtain a W-UFPK.
   For detailed information, refer to the Renesas Key Wrap Service FAQ or the relevant application note.

4. Generating a KUK
   On the Generate KUK tab, select whether to use the tool to generate a random value for the KUK or to enter a 256-bit value for the KUK. Enter a file name with the extension *.key. This example uses the file name kuk.key.

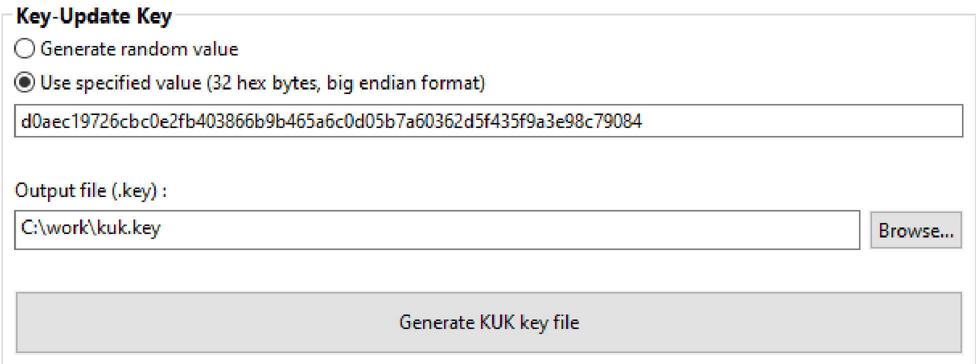


Figure 5.16 Example KUK File Generation Settings on Generate KUK Tab

Cluck the **Generate KUK key file** button to generate a KUK file. The following is displayed when the operation completes successfully.

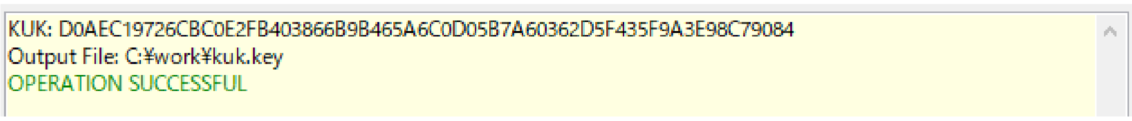


Figure 5.17 Generate KUK Tab Execution Result

5. Generating a KUK file in C source file format
   Select **KUK** on the Key Type tab, which is on the Wrap Key tab. On the Key Data tab, enter the file name of the KUK file generated in the preceding step (**kuk.key** in this example). For **Wrapping Key**, select **UFPK** and select the UFPK file generated in step 2 and the W-UFPK file obtained as described in step 3. In this example, **Generate random value** is selected for **IV** in the interest of simplicity. In the **Output** panel, select **C Source** for **Format:** and enter the file name of the C source file.

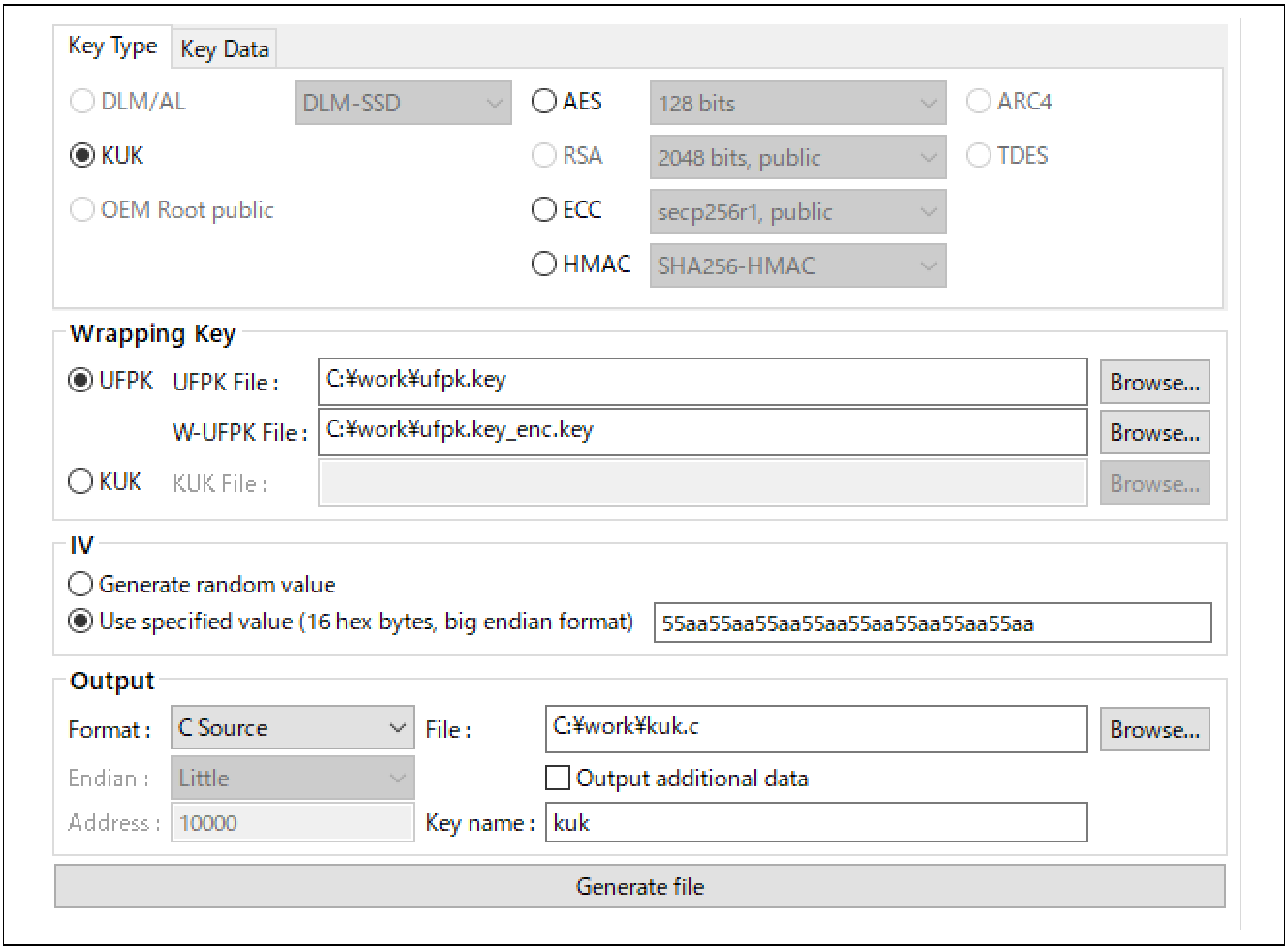


Figure 5.18 Example C Source File Output Settings for KUK File on Wrap Key – Key Type Tab

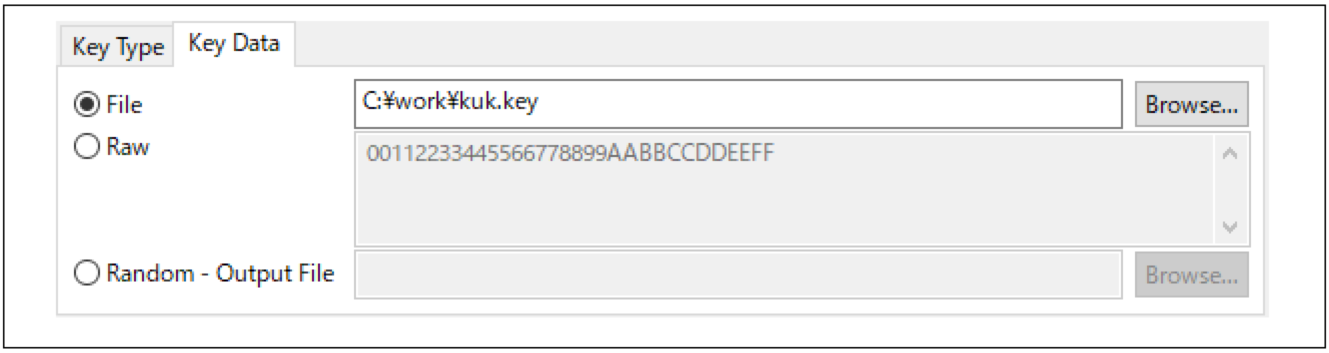


Figure 5.19 Example C souce File Output Settings for KUK File on Wrap Key – Key Type Tab

Use the data from the output C source file to inject the KUK by calling the R_RSIP_InitialKeyUpdateKeyWrap() function in your program.

Next, the wrapping method using a KUK for key updating in the field is described.

6. Generating a secp256r1 public key file in C source file format
   On the Wrap Key tab, generate a secp256r1 public key file in C source file format.
   On the Key Type tab, select **ECC** and **256 bits, public**, and on the Key Data tab, enter the secp256r1 256 public key data.
   For **Wrapping Key**, specify the KUK file generated in 4. In this example, **Generate random value** is selected for **IV** in the interest of simplicity. Under **Output**, select **C Source** for **Format:** and enter a file name with the extension *.c.

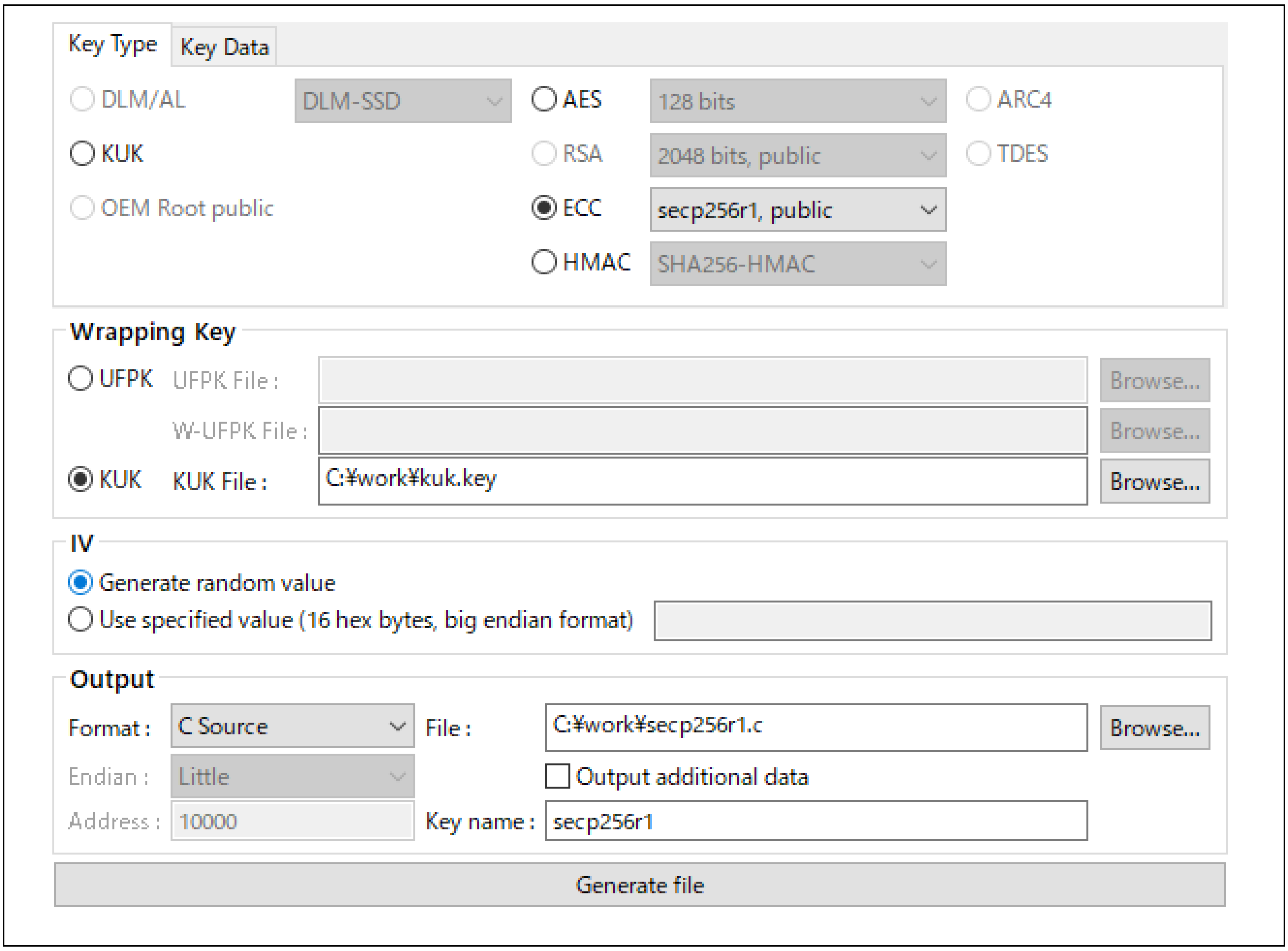


Figure 5.20 Example secp256r1 Public Key C Source File Generation Settings on Wrap Key – Key Type Tab

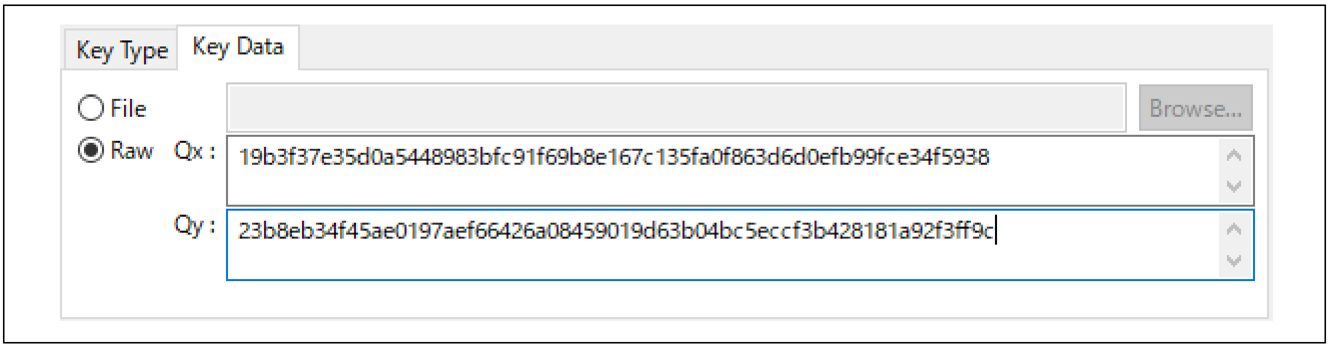
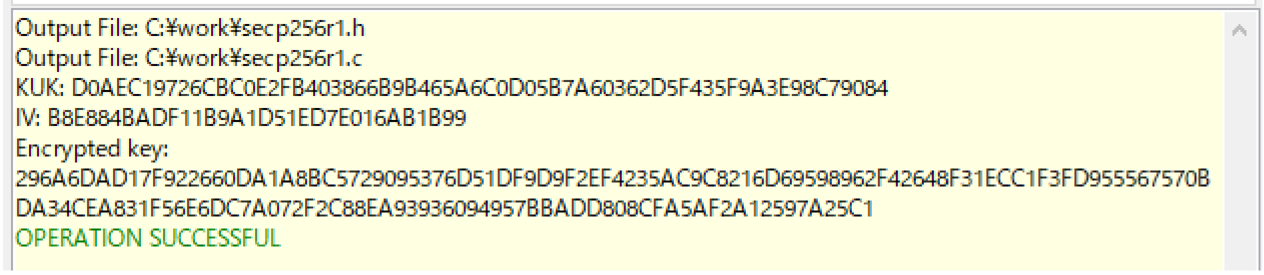


Figure 5.21 Example secp256r1 Public Key C Source File Generation Settings on Wrap Key – Key Data Tab

The following is displayed when the operation completes successfully.



```
Output File: C:¥work¥secp256r1.h
Output File: C:¥work¥secp256r1.c
KUK: D0AEC19726CBC0E2FB403866B9B465A6C0D05B7A60362D5F435F9A3E98C79084
IV: B8E884BADF11B9A1D51ED7E016AB1B99
Encrypted key:
296A6DAD17F922660DA1A8BC5729095376D51DF9D9F2EF4235AC9C8216D69598962F42648F31ECC1F3FD955567570B
DA34CEA831F56E6DC7A072F2C88EA93936094957BBADD808CFA5AF2A12597A25C1
OPERATION SUCCESSFUL
```

Figure 5.22 Wrap Key Tab Execution Result

You can perform key updating in the field by incorporating the generated C source file into your project and using it to create update data.

6. Sample Programs

6.1 Confirming Operation of How to Use Key Injection and Cryptography

The demo project listed in Table 6.1 shows the usages of cryptographic operation and random number generation APIs provided by RSIP PM driver.

Table 6-1 Demo Projects to used on each MCU

MCU	Demo Project
RX261	rx261_ek_rsip_sample

The demo project outputs the operation result with UART. So the running board is connected with PC which terminal sofyware is installed.

The demo project operates with using little-endian byte ordering.

6.1.1 Setting Up the Demo Project

Wiring connections between the PC and board are shown below.

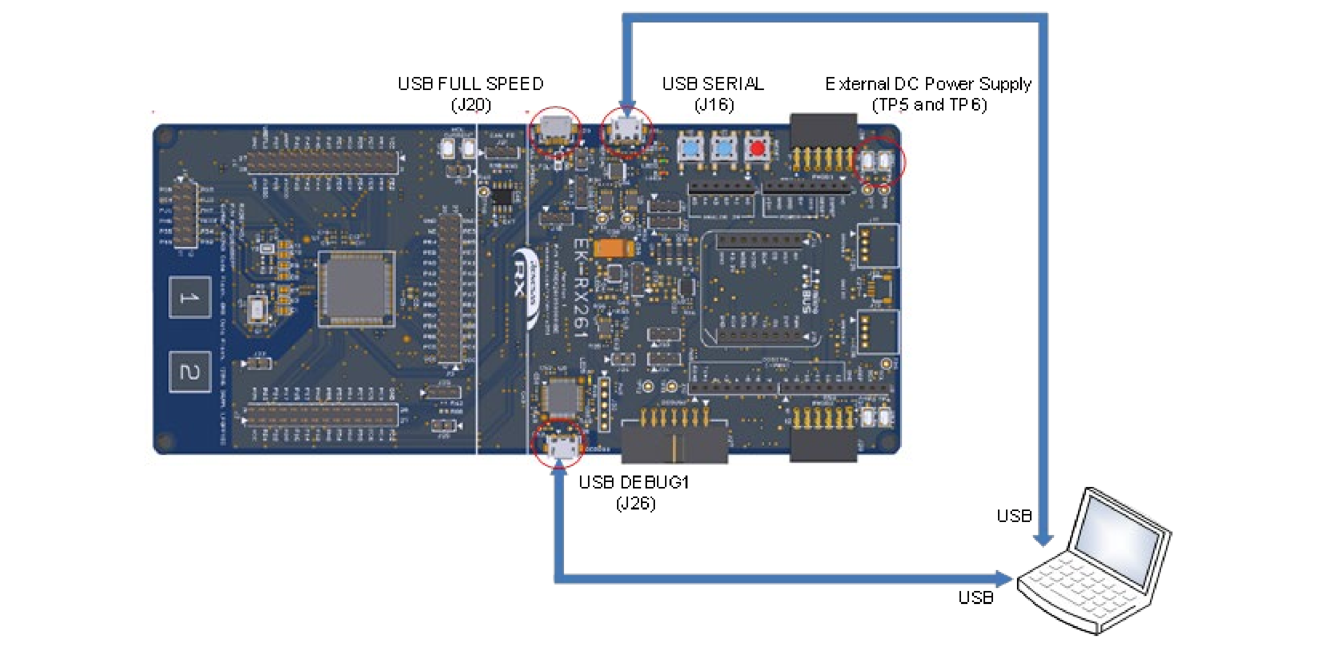


Figure 6.1 Wiring Connections between PC and EK-RX261 Board

The USB DEBUG1, USB FULL SPEED, USB SERIAL and external DS power supply can be used to supply electricity to EK-RX261 Board. Please supply electricity with either port.

The serial settings in Tera Term are as follows:

- Speed: 115200 bps
- Data: 8 bit
- Parity: None
- Stop bits: 1 bit
- New-line code (Transmit): CR

6.1.2 Overview of Demo Project

The flow chart of the demo project is shown in Figure 6.2.

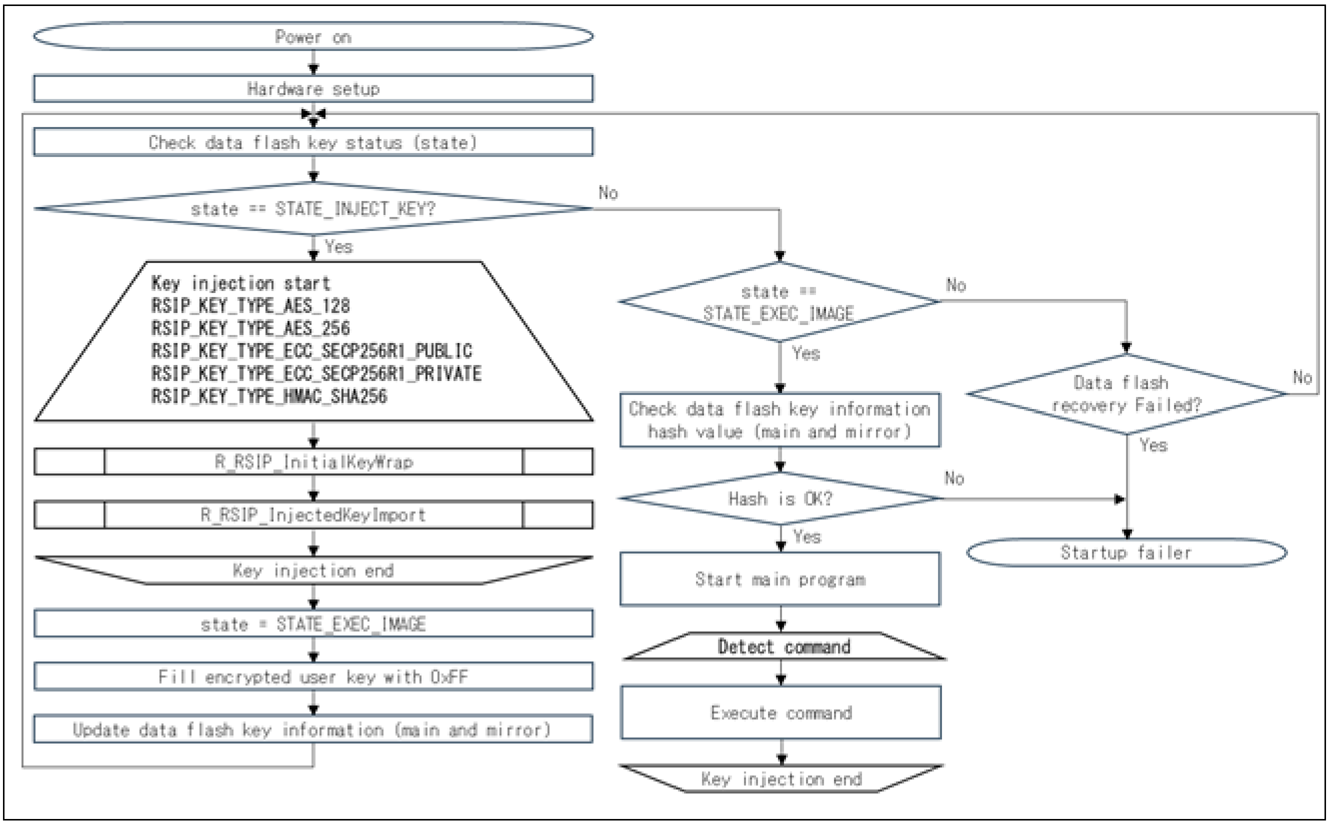


Figure 6.2 Flow chart of Confirming Operation of How to Use Key Injection and Cryptography

The behavior of the demo project is managed with the state transition and the state is managed with the flag in the data flash.

Table 6-2 State of the demo project

State	Operation content
STATE_INJECT_KEY	Inject the wrapped keys to the data flash. In the demo project, the area to store the keys I the data flash is dvided to main area and mirror area. The key data can be recovered with the structure if the power shutoff has occurred while writing the keys. After injecting the keys, transit the state to STATE_EXEC_IMAGE. The key injection is executed only in the first time of the start operation. After the time, the state begins with the state STATE_EXEC_IMAGE.
STATE_EXEC_IMAGE	Confirm the key data in the data flash with checking its hash value. When the validity is confirmed, the project begins accepting the commands.

The commands implemented in the demo project is shown below.

Table 6-3 Commands of the demo project

Command	Operation
display	Displays the wrapped keys.
encdemo [Arg1]	Encrypts the Arg1 value in AES 128-bit ECB mode.
function	Performs the following tests. - AES128/256 ECB, CBC, CTR, CCM, GCM encryption/decryption - AES128/256 CMAC generation/verification - SHA-224/256 HMAC generation/verification - ECDSA P256 signature generation/verification
random	Generates a pseudo random value.

6.1.2.1 Characteristics of Wrapped Keys and how to check them in the demo project

The RSIP PM driver does not use user keys in plain text. This means that when the software is reverse engineered, the plain-text user key is not exposed. The demo project uses the Wrapped Key of the user key injected into the data flash. When reading the data flash area (0x00100000) where the Wrapped Key of the user key is placed, we can confirm that the plain text of the user key is not written.
Since the Wrapped Key is generated in conjunction with the HUK, the Wrapped Key generated on one chip cannot be copied to another chip for use. This is meant to prevent dead copies of user keys. If you try to use a Wrapped Key generated by another device in your demo project, you can be sure that the RSIP PM driver will fail.
Also, since Wrapped Keys contain random numbers, even if the same device generates a Wrapped Key for the same user key, it will generate a different value. This makes it difficult to guess the user key from the Wrapped Key. These Wrapped Key features can be seen in the demo project. Download the demo project again and you will see that the Wrapped Key value changes each time you run the display command.

6.1.3 Demo Project Execution Example

Figure 6.3 shows the terminal output when key installation completes successfully after the program is downloaded to the MCU and run for the first time, and Figure 6.4 shows the terminal output when the program is run from a state other than when it has been newly downloaded to the MCU. After the above output is displayed, the program is ready to accept the commands listed in Table 6-3.

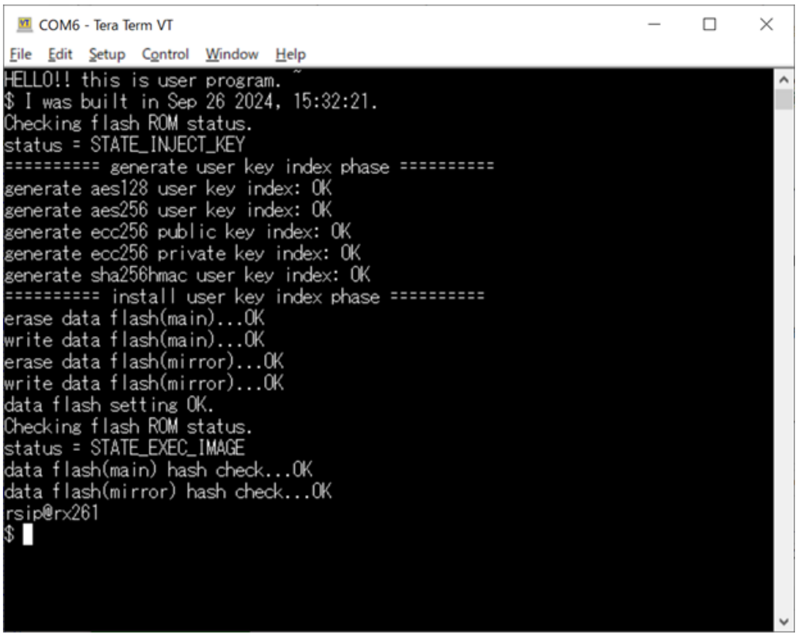


Figure 6.3 Tera Term Display (Initial Execution)

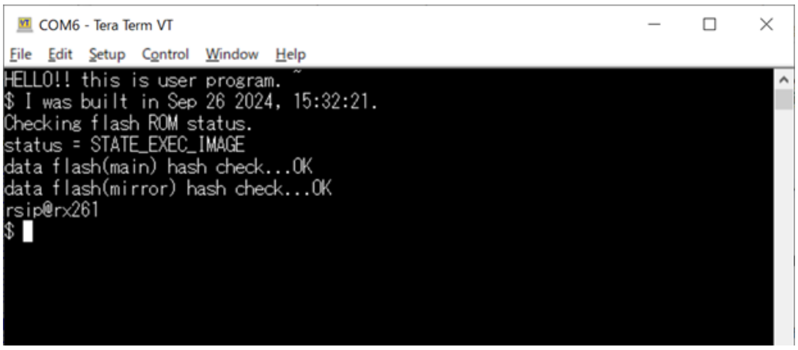


Figure 6.4 Tera Term Display (2nd and Subsequent Executions)

As an example of the command usage, the usage of encdemo command is shown below.

The encdemo command performs the encryption of the data inputted as the argument of the command by AES ECB mode with using AES 128-bit key injected before the procedure.

The demo project

Figure 6.12 shows a usage example in which the command and argument **encdemo aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa** are entered and encryption is performed using an AES 128-bit key index. The key used for encryption is the user key (16 bytes (128 bits)) input to Security Key Management Tool. When the command is run using the default value of **0x11, 0x11, 0x11, 0x11, 0x22, 0x22, 0x22, 0x22, 0x33, 0x33, 0x33, 0x33, 0x44, 0x44, 0x44, 0x44**, the result is as shown in the screenshot below.

Figure 6.5 Tera Term Display (encdemo Command)

6.2 Confirming Operation of the Secure Boot and Firmware Update

The secure bootloader and firmware update demo projects show how to realize the secure boot and firmware update. In this demo proect, two methods to set up the program of secure boot and firmware update to the device are shown below.

1. A method that firstly only the secure boot program is downloaded, secondly the firmware update program is written to the flash memory by the function of the secure boot program (two-step setup)
2. A method to make a Motorola S format file which includes both secure boot program and firmware update program and write it to the flash memory (inclusive setup)

The secure bootloader and firmware update demo projects decrypt the firmware update program which is encrypted with the method described in 4.2.8 Firmware Update/Secure Boot with using the APIs descried in 3.12.3 Encrypting the User Program. Secure firmware update can be executed by starting after verifying encrypted firmware update program and writing it to the flash memory. And secure boot can be executed by verifying the firmware update program before starting.

The demo project has two projects, secure boot project and firmware update project. The secure boot project executes not only secure boot but also firmware update to write fariware update program to the device.

Secure bootloader project: rx261_ek_rsip_secure_boot

Firmware update project: rx261_ek_rsip_user_program

The firmware update functionality of the demo projects supports use of a UART or USB interface to send the initial program or the updated program to the device. In addition, Security Key Management Tool can be used to generate a file in Motorola S format*[1] containing both the secure bootloader and the encrypted user program (factory programming function).

The demo projects can use dual bank mode for firmware update operation on devices with on-chip flash ROM that supports dual bank mode.

Notes: 1. Motorola S format files containing a secure bootloader and an encrypted user program can be decrypted by a corresponding RX RSIP–equipped device if the Motorola S format file itself is stolen. It is therefore necessary to ensure that programming to devices of encrypted user programs with secure bootloaders takes place in a secure facility.

The demo projects use a UART to output the result and operate firmware update via UART. Please connect a PC which terminal software is installed to the board to operate the demo projects. In the explanation below, Tera Term is used as the terminal software.
The demo projects operate using little-endian byte ordering.

The version of the FIT modules which is used in the dem oprojects are shown below. Some of the internal functions which are used to execute secure boot procedure are allocated to the SECURE_BOOT section.

Table 6-4 FIT modules used in the demo projects

FIT modules	version
r_bsp	7.51
r_byteq	2.10
r_cmt_rx	5.70
r_flash_rx	5.20
r_fwup	2.04
r_sci_rx	5.30
r_sha_rx	1.05
r_sys_time_rx	1.01
r_tfat_driver_rx	2.40
r_tfat_rx	4.11
r_usb_basic_mini	1.30
r_usb_hmsc_mini	1.30

6.2.1 Setting Up the Demo Project

The demo projects will run on the boards listed in Table 6.5. To use the board, please set the board for the interface to use.

Table 6-5 Boards used in the demo project and their settings

Boards	Jumper setting to use UART	Jumper setting to use USB
EK-RX261	-	J17 : open J18 : open J19 : 1-2 short

Connections between the PC and board are shown below.

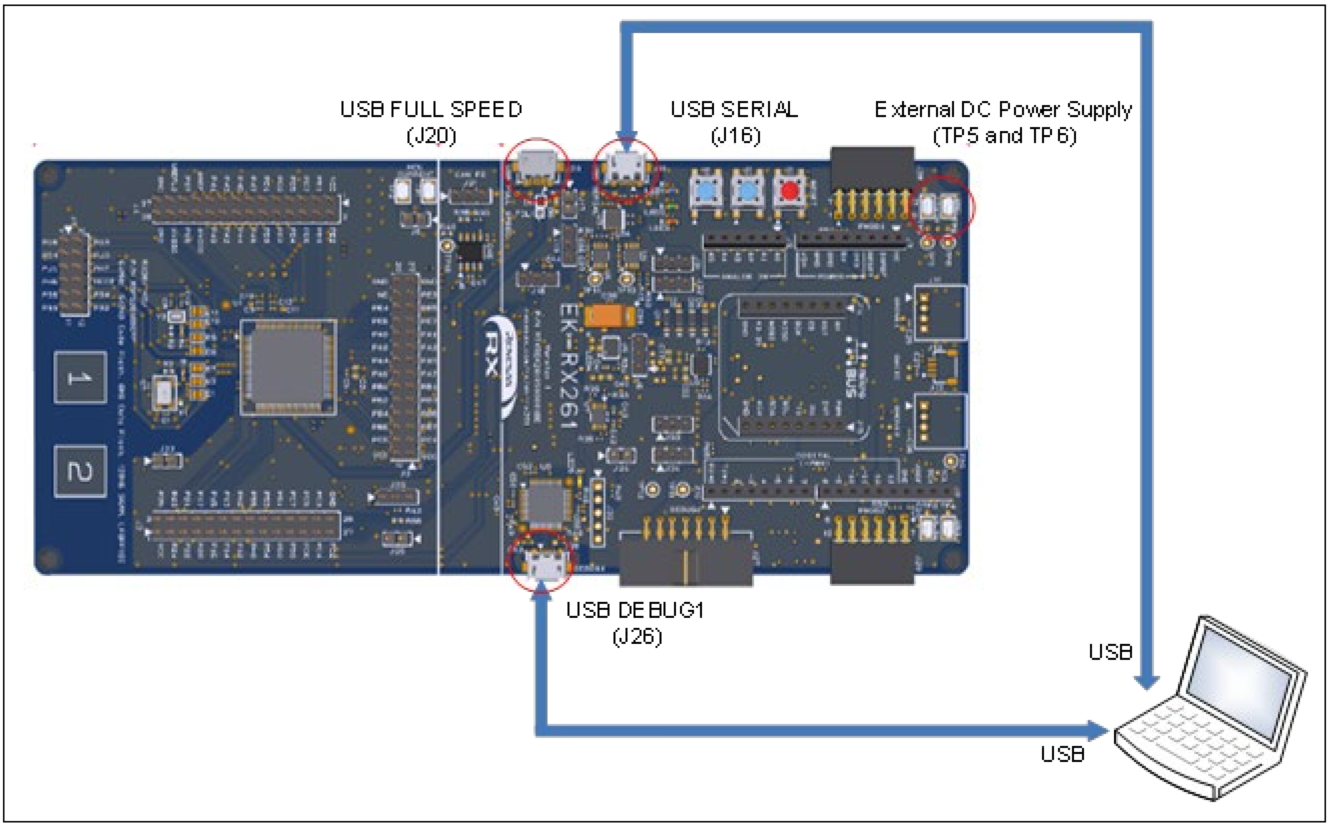


Figure 6.6 Connections between EK-RX261 and PC for Firmware Updates Using UART

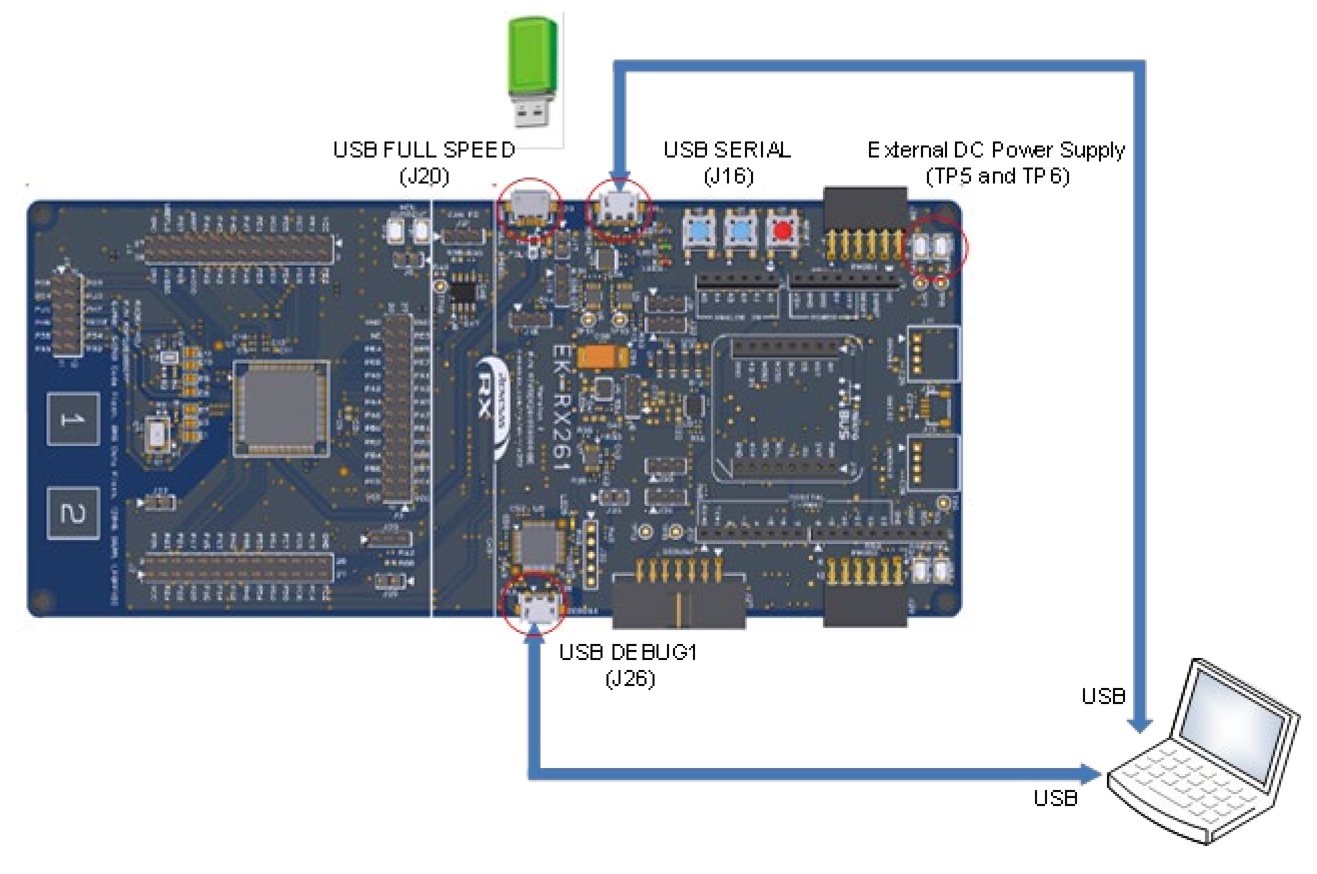


Figure 6.7 Connections between EK-RX261 and PC for Firmware Updates Using USB

Tera Term serial settings are as follows.

Table 6-6 Tera Term settings

Item	Value
Speed	115200bps
Data	8bit
Parity	none
Stop bit	1bit
Flow control	RTS/CTS
New-line code (Transmit)	CR
Local echo	OFF

6.2.2 Overview of Secure Bootloader and Firmware Update Demo Projects

The directory structure of the secure bootloader project and firmware update demo project is described in Table 6-7.

Table 6-7 Directory structure of secure bootloader project and firmware update project

Directory Name	Description
rx261_ek_rsip_secure_update	Secure boot/secure update implementation example
rx261_ek_rsip_secure_boot	Secure boot firmware
key	UFPK and W-UFPK file which can be used to execute example
skmt	Settign file of Security Key Management Tool
src	Source code of the secure boot firmware
rx261_ek_rsip_user_program	Firmware update program
src	Source code of the firmware update program

The secure bootloader and firmware update demo projects handle flash memory area with dividing into two sections, which are used as the main area and buffer area.

Main area: Storage area for program to be executed

Buffer area: Storage area for program to be applied as an update

6.2.2.1 Secure Bootloader project

A flowchart of the secure bootloader project is shown below.

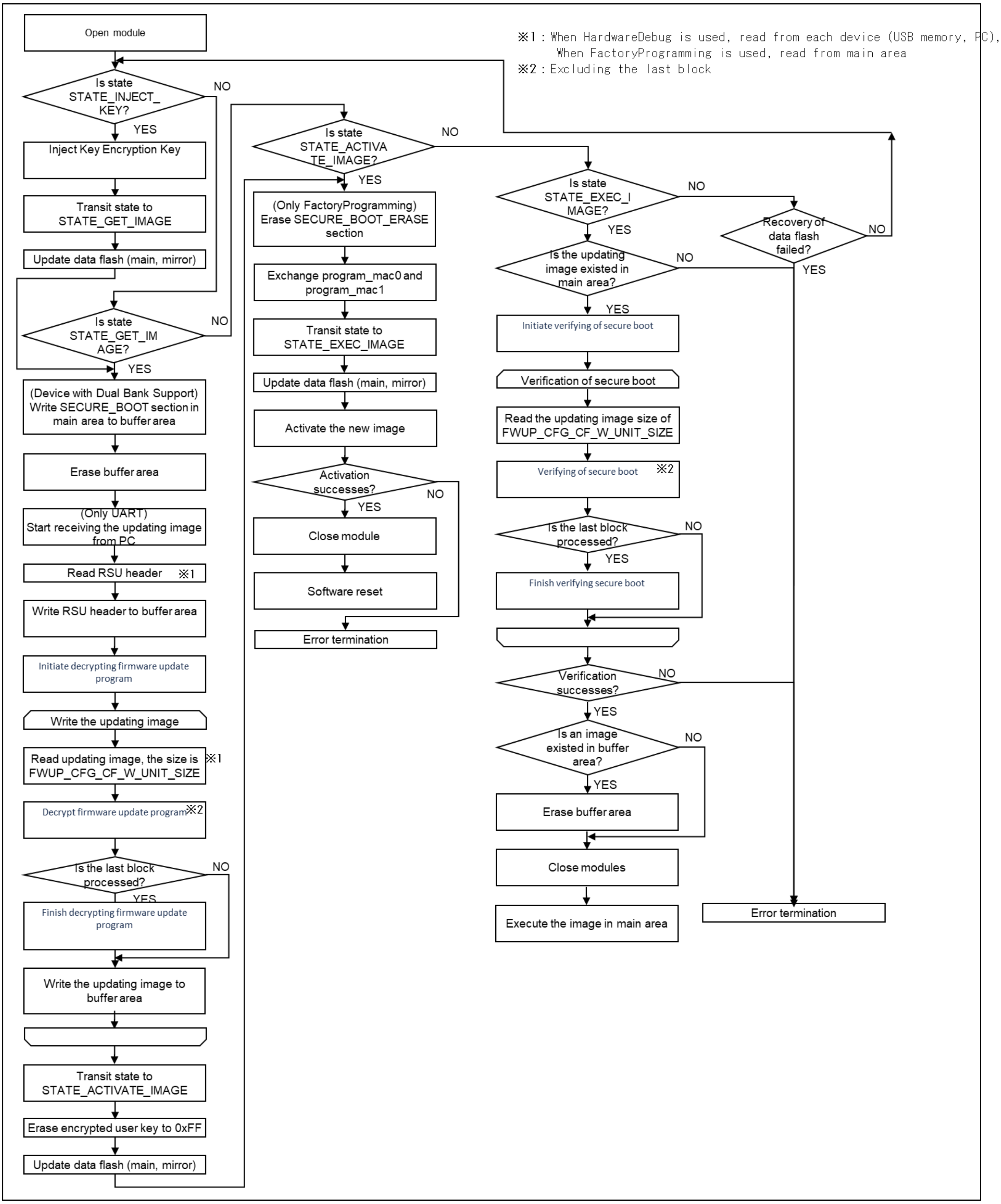


Figure 6.8 Secure Bootloader project flowchart

Secure bootloader project manages the operation with using state transition. The state is managed by the flag which is stored in the data flash. Each state and their operation contents are shown in .

Table 6-8 State of the Secure Boot project

State	Operation Content
STATE_INJECT_KEY	Store wrapped keys to the data flash. Then, the wrapped keys are stored both main area and buffer area to prevent an elimination of the wrapped keys which is caused by a failure of writing to the memory because of cutoff energy while updating. After key injection is finished, the state transits to STATE_GET_IMAGE.
STATE_GET_IMAGE	Get encrypted firmware update program and decrypt it. Firstly, erase the buffer area. While getting an encrypted firmware update program thorough UART or USB memory, decrypt it and write to the buffer area. After erasing the encrypted key, the state transits to STATE_ACTIVATE_IMAGE.
STATE_ACTIVATE_IMAGE	Activate the updating image. When the inclusive setup is used, the process to inject key is erased firstly. After copying the firmware update program to the main area, the state transits to STATE_EXEC_IMAGE and software reset is executed.
STATE_EXEC_IMAGE	Verify MAC of the program stored in main area. When an image is stored in the buffer area, erase it. And start the program in the main area.

6.2.2.2 Firmware Update Project

A flowchart of the firmware update project is shown below.

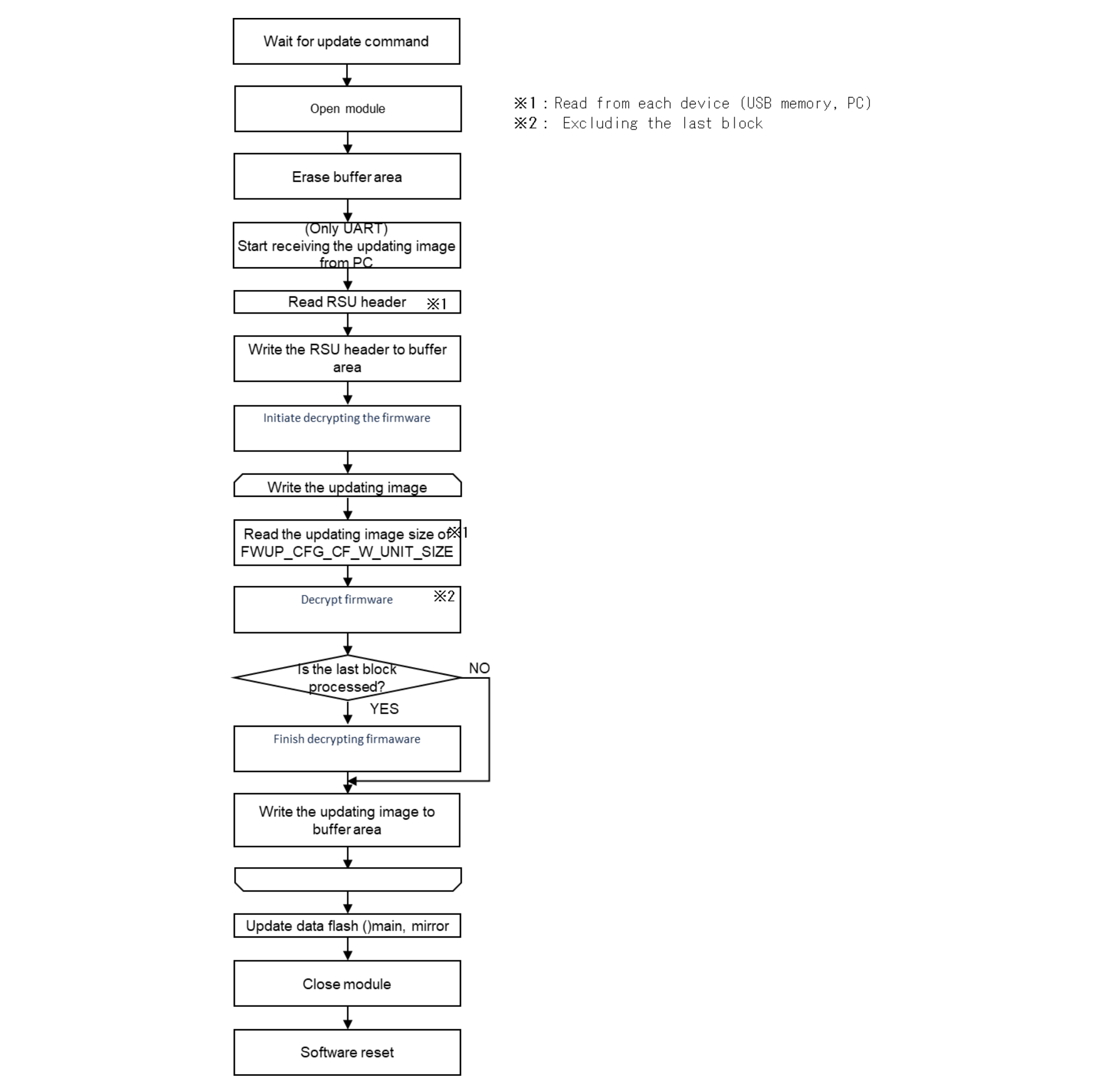


Figure 6.9 Firmware Update Flowchart

In the firmware update project, a command is implemented described below.

Table 6-9 Command of th eFirmware Update project

Command	Operation
update	Execute firmware update. Firstly, erase the buffer area. While getting an encrypted user program thorough UART or USB memory, decrypt it and write to the buffer area. After the firmware update is terminated normally, transits the state to STATE_ACTIVATE_IMAGE and execute software reset.

6.2.3 Execution Example of the Demo Project

6.2.3.1 Execution Example of Two-Step Setup

(1) Generating an Encryption Key File for the Firmware Update

First, on the **Wrap Key** tab of Security Key Management Tool, generate a key file to encrypt the image encryption key used to encrypt the firmware update program.

The secure bootloader project uses the following values for **UFPK** and **Key Encryption Key**.

UFPK = 2222222222222222222222222222222211111111111111111111111111111111

Key Encryption Key = 0123456789abcdef0123456789abcdef

- Command line version
  Run the following command.

  > skmt.exe /genkey /iv "55aa55aa55aa55aa55aa55aa55aa55aa" /ufpk file="{$skmt_loc}\..\key\sample.key"
  /wufpk file="{$skmt_loc}\key\sample.key_enc.key"
  /mcu "RX-RSIP-E11A" /keytype "AES-128" /key "0123456789ABCDEF0123456789ABCDEF"
  /filetype "csource" /keyname "euk_aes128" /output "{$skmt_loc}\genkey\euk_aes128.c"

  For {$skmt_loc}, substitute the path of the secure bootloader project folder.

- Standalone version
  Enter the following values.
  - **Key Type** tab
    Select **AES** – **128 bits**.
  - **Key Data** tab
    Enter the string **0123456789abcdef0123456789abcdef** as plaintext data.
  - **Wrapping Key**
    UFPK File: **sample_key.key** included in the sample
    W-UFPK File: **sample_key_enc.key** included in the sample
  - **IV**
    Select **Use specified value** and enter **"55aa55aa55aa55aa55aa55aa55aa55aa"**.
  - **Output**
    Format: C source
    File: euk_aes128.c
    Key name: euk_aes128

To use the above settings, you can load the Security Key Management Tool settings file rx261_SecureUpdate.skmt included in the sample.

The file rx261_SecureUpdate.skmt is in xml format and can be edited as text. For **{$skmt_loc}** in rx261_SecureUpdate.skmt, substitute the path of the secure bootloader project folder.

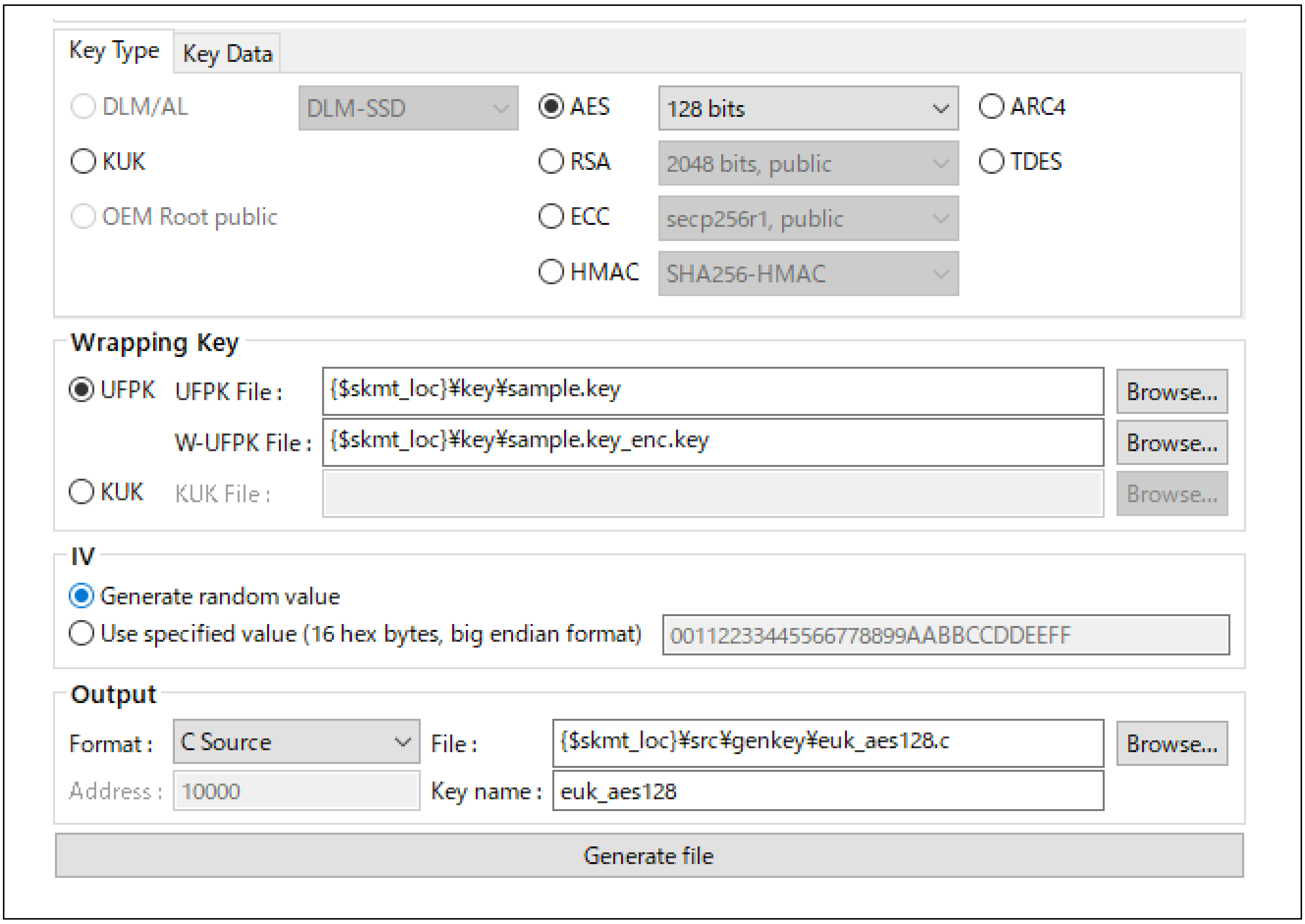


Figure 6.10 Generating a Key Data File (Wrap Key Tab)

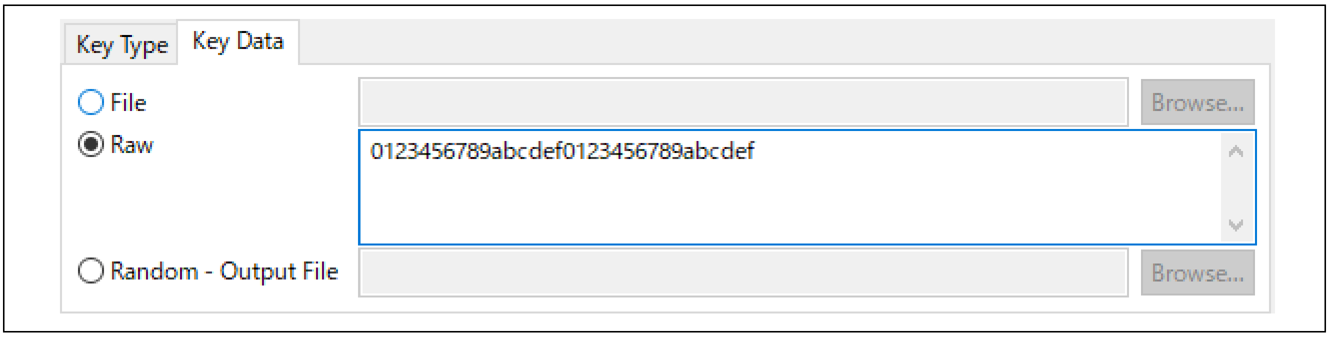


Figure 6.11 Generating a Key Data File (Wrap Key Tab – Key Data Tab)

(2) Building the Secure Bootloader Project

After importing the secure bootloader project (rx261_ek_rsip_secure_boot) into the e^2 studio workspace, place euk_aes128.c and euk_aes128.h generated in step (1) in the src folder of the rx261_ek_tsip_secure_boot project.

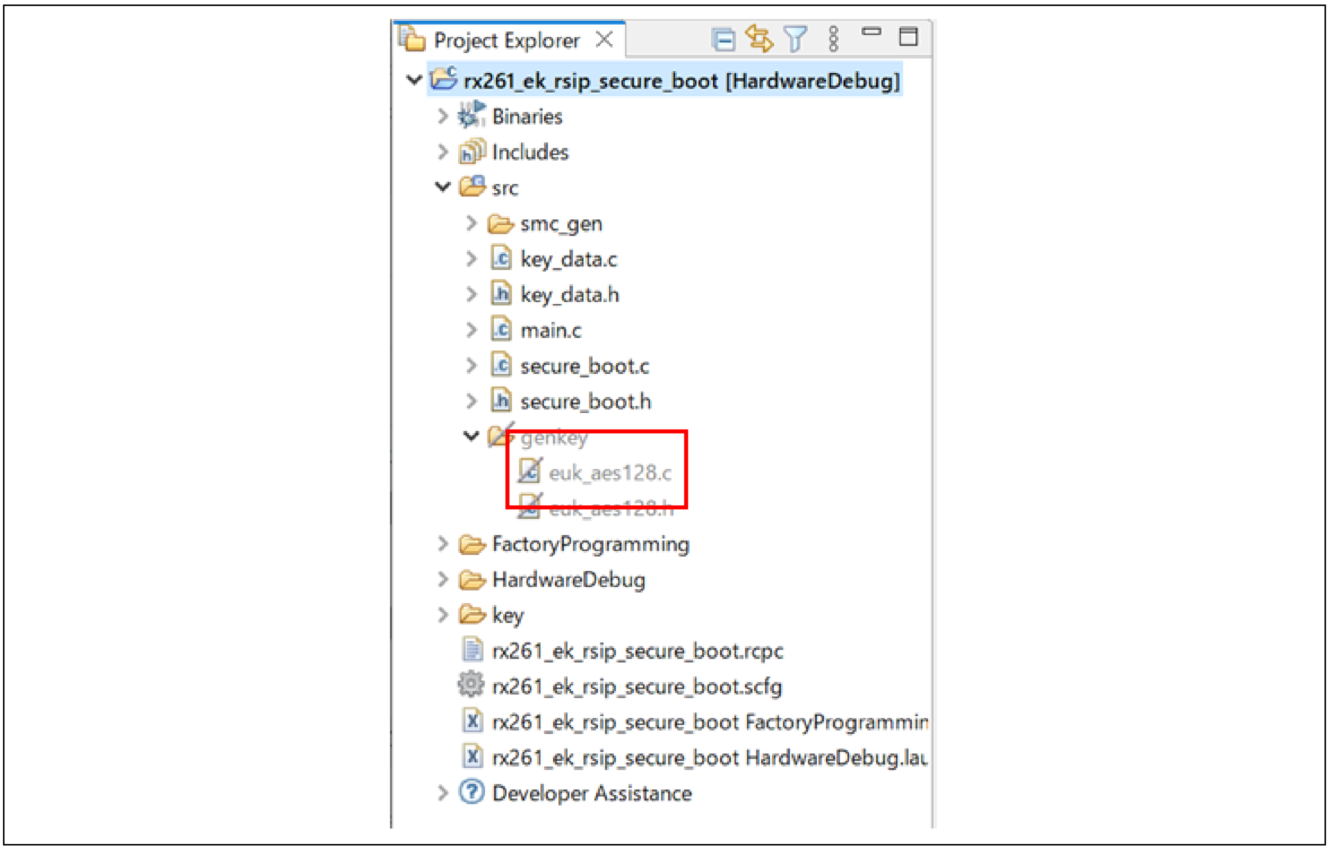


Figure 6.12 e^{2}studio Project Explorer

Also, to use USB flash drive with the supported board, in Macro definition, set as below.

```
ENABLE_USB=1
```

After making the changes, build the project in e^2 studio.

(3) Building the Firmware Update Project

After importing the firmware update project (rx261_ek_rsip_user_program) into the e^2 studio workspace, use USB flash drive with the supported board, as in step (2), in Macro definition, set as below.

```
ENABLE_USB=1
```

After making the changes, build the project in e^2 studio.

(4) Encrypting the Firmware Update Program

- Command line version
  Run the following command.

> skmt.exe /enctsip /mode "update" /ver "2" /prg
"{$skmt_loc}\..\rx261_ek_rsip_user_program\Release\rx261_ek_rsip_user_program.mot"
/enckey "0123456789abcdef0123456789abcdef"
/startaddr "FFEB8300" /endaddr "FFFEFFFF" /filetype "bin"
/output ""{$skmt_loc}\userprog.rsu"

For {$skmt_loc}, substitute the path of the secure bootloader project folder.

The settings values of /stardaddr and /endaddr differ depending on the MCU. Refer to the table below and enter the appropriate values.

Table 6-10 Specifying address for the MCU

MCU	Parameter		Address
	GUI	**CLI**	
RX261	Start address	/startaddr	FFFB8300
	End address	/endaddr	FFFEFFFF

- Standalone version
  Enter the following values.
  — **Output Image**
    Select **Secure Update**.
  — **Firmware Image**
    Motorola S format file output by firmware update project (rx261_ek_rsip_user_program.mot)
  — **Encrypted Address Range** tab
    The values differ depending on the MCU. Refer to Table 6-10and select the appropriate values to match the MCU.
  — **IV** tab
    Select **Use specified value** and enter **"55aa55aa55aa55aa55aa55aa55aa55aa"**.
  — **RSU Header** tab
    RSU header Ver: e
  — **Output**
    Format: Binary
    File: userprog.rsu

To use the above settings, you can load the Security Key Management Tool settings file rx261_SecureUpdate.skmt included in the sample.

The file rx261_SecureUpdate.skmt is in xml format and can be edited as text. For **{$skmt_loc}** in rx261_SecureUpdate.skmt, substitute the path of the secure bootloader project folder.

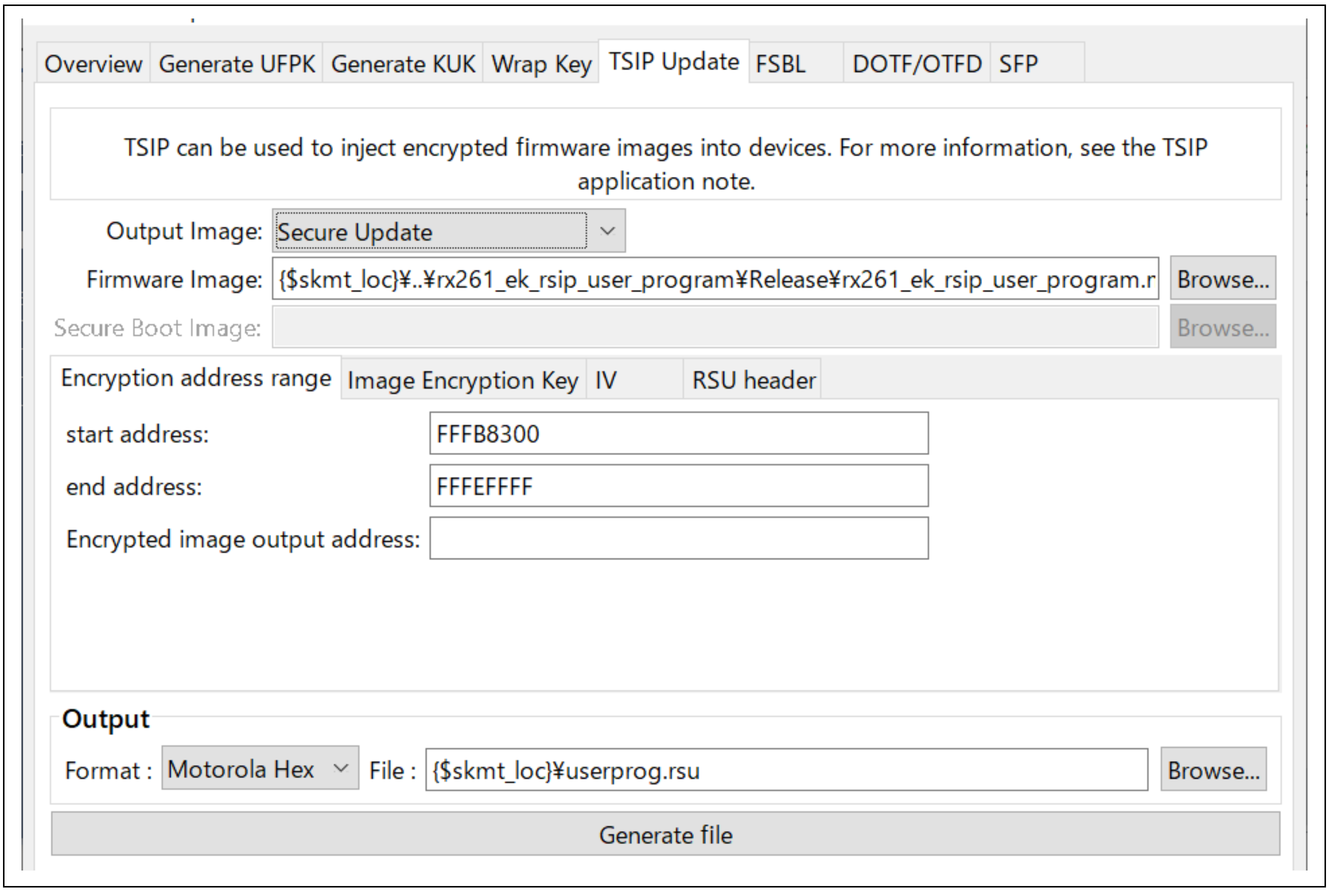


Figure 6.13 Generating an Encrypted File (TSIP UPDATE Tab)

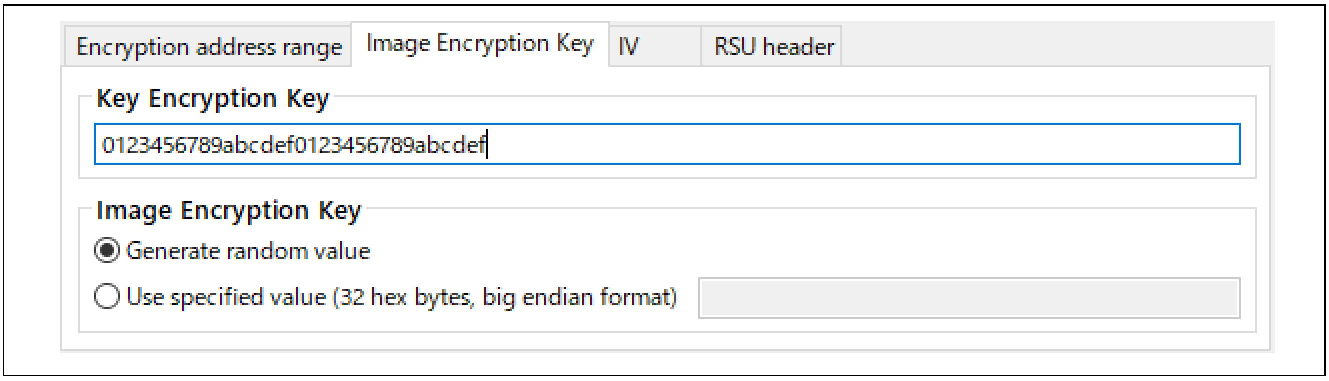


Figure 6.14 Generating an Encrypted File (TSIP UPDATE Tab – Image Encryption Key Tab)

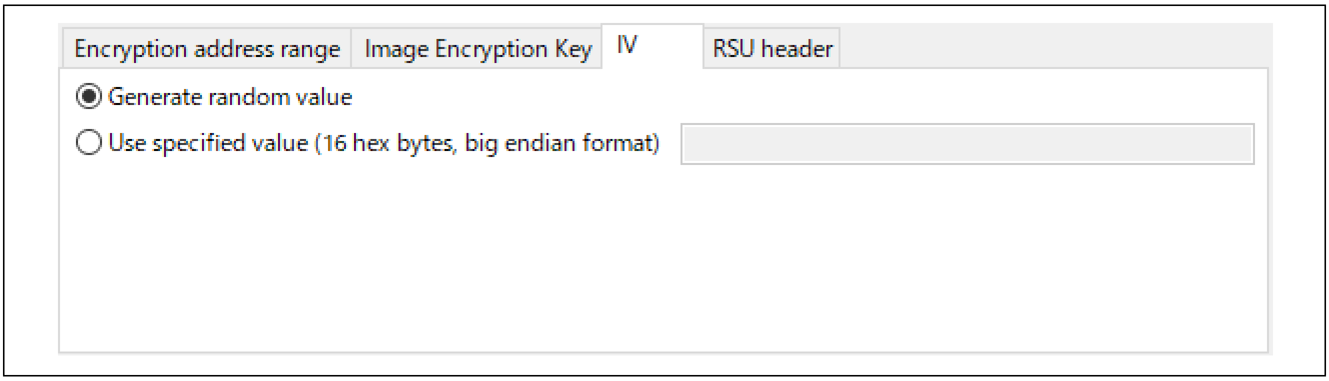


Figure 6.15 Generating an Encrypted File (TSIP UPDATE Tab – IV Tab)

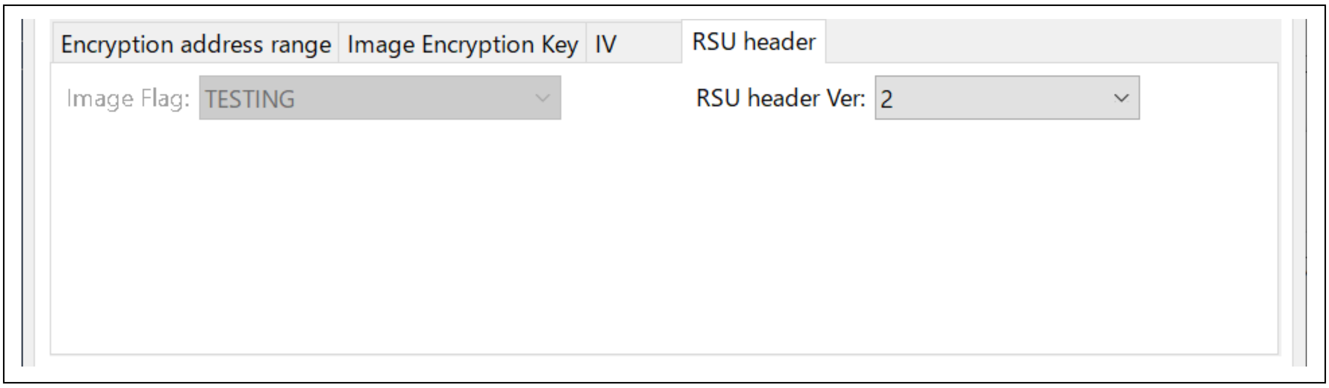


Figure 6.16 Generating an Encrypted File (TSIP UPDATE Tab – RSU Header Tab)

Use the generated file (default file name: userprog.rsu) as shown below.

- When using UART, send the file with Tera Term.

- When using USB flash drive, store the file into the USB memory and attach it to the board.

(5) Starting the Terminal Emulator (Tera Term)

Make connections as shown in the applicable connection diagram in 6.2.1, Demo Project Setup, then launch Tera Term. Refer to Table 6-6, Tera Term settings to make serial setting.

(6) Running the Secure Bootloader Project

Select **rx261_ek_rsip_secure_boot** in e[2] studio's Project Explorer, then click the button to execute the Secure Bootloader project.

If the on-chip flash memory of the board to be used has not been completely erased, the project will not run properly. Use the **Erase Chip** option in Renesas Flash Programmer to completely erase the flash memory.

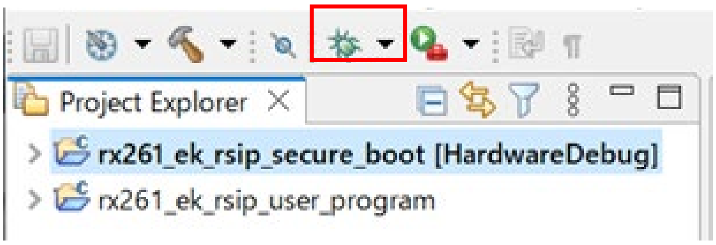


Figure 6.17 Running the Secure Bootloader Project

(7) Installing the Initial User Program

When the secure bootloader project is run, the encrypted user program is decrypted, and then the user program is executed.

If this works correctly, silillar to the following is displayed in Tera Term.

```
HELLO!! this is boot program. ~
$ I was built in Sep 27 2024, 09:29:33.
Checking flash ROM status.
status = STATE_INJECT_KEY
========== generate user key index phase ==========
generate aes128 user program mac key index: OK
========== install user key index phase ==========
erase data flash(main)...OK
write data flash(main)...OK
erase data flash(mirror)...OK
write data flash(mirror)...OK
data flash setting OK.
Checking flash ROM status.
status = STATE_GET_IMAGE

==== Image updater [with buffer] ====
Erase buffer area...OK
send image(*.rsu) via UART.
```

Figure 6.18 Log Output of Secure Bootloader up to Wait for Updating Image

When using USB flash drive, attach USB memory to the board.

When using UART, in Tera Term, select **File** > **Send file…** and specify the firmware update program (**userprog.rsu** in the sample) that was encrypted in step (3). Then check the box for **Binary** under **Option** and click the **Open** button.

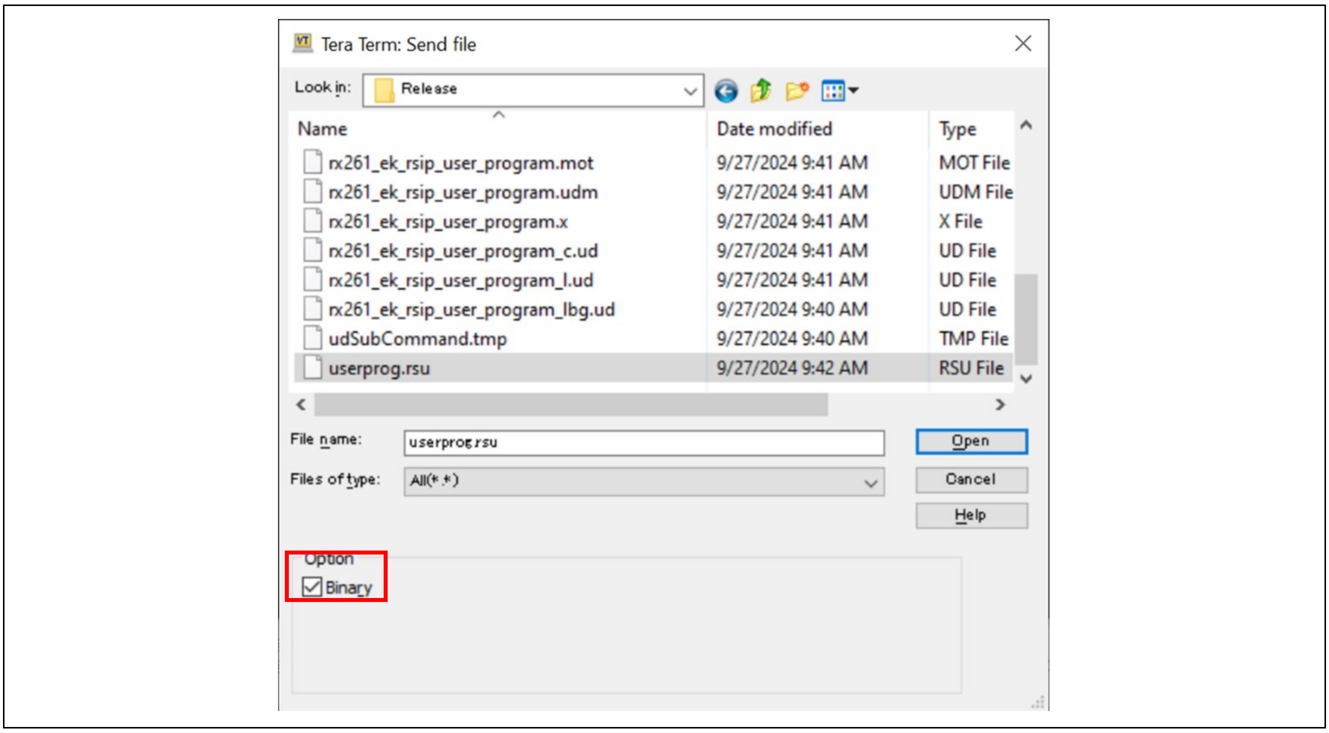


Figure 6.19 Tera Term: Send file Dialog Box

If the firmware update program is successfully programmed to the flash memory, output similar to the following is displayed in Tera Term.

```
erase data flash(main)...OK
write data flash(main)...OK
erase data flash(mirror)...OK
write data flash(mirror)...OK
data flash setting OK.
Checking flash ROM status.
status = STATE_ACTIVATE_IMAGE
update data flash
erase data flash(main)...OK
write data flash(main)...OK
erase data flash(mirror)...OK
write data flash(mirror)...OK
data flash setting OK.
activating image ... OK
software reset...
HELLO!! this is boot program. ~
$ I was built in Sep 27 2024, 09:29:33.
Checking flash ROM status.
status = STATE_EXEC_IMAGE

==== BootLoader [with buffer] ====
secure boot sequence: success.
execute image ...
HELLO!! this is user program. ~
$ I was built in Sep 27 2024, 09:40:38.
Version ver 1.00.
rsip@rx261
$
```

Figure 6.20 Log Output of Secure Bootloader When Writing Firmware Update Program

(8) Firmware Update Operation

Next, change some of the source code of the user program project and update the firmware. Change the version number in the user program main.c of the user program project from **ver 1.00** to **ver 1.01**. After building the project and generating a Motorola S format file as described in step (3), encrypt it as described in step (4).

```
/* Command prompt related */
#define PROMPT                    ("rsip@rx261\r\n$ ")
#define VERSION                   ("ver 1.00")
#define HELLO_MESSAGE             ("HELLO!! this is user program. ~\r\n$ ")
```

Figure 6.21 Modified Location in main.c

Execute the **update** command. Install the firmware update program that has been updated to Ver 1.01 as described in step (7). After the upload finishes, the system reboots. According to the log output, a part of the output which is described in Figure 6.20 with boldfaced type is updated.

6.2.3.2 Execution Example of Inclusive Setup

This section describes how to create a Motorola S format file containing a secure bootloader and encrypted firmware update program and how to program it to a device using Renesas Flash Programmer.

(1) Generating an Encryption Key File for the Firmware Update

Generate a key file to encrypt the image. The procedure is same to 6.2.3.1 (1), Execution Example of Two-Step Setup.

(2) Building the Secure Bootloader Project

After importing the secure bootloader project (rx261_ek_rsip_secure_boot) into the e² studio workspace, place euk_aes128.c and euk_aes128.h generated in step (1) in the src folder of the rx261_ek_rsip_secure_boot project.

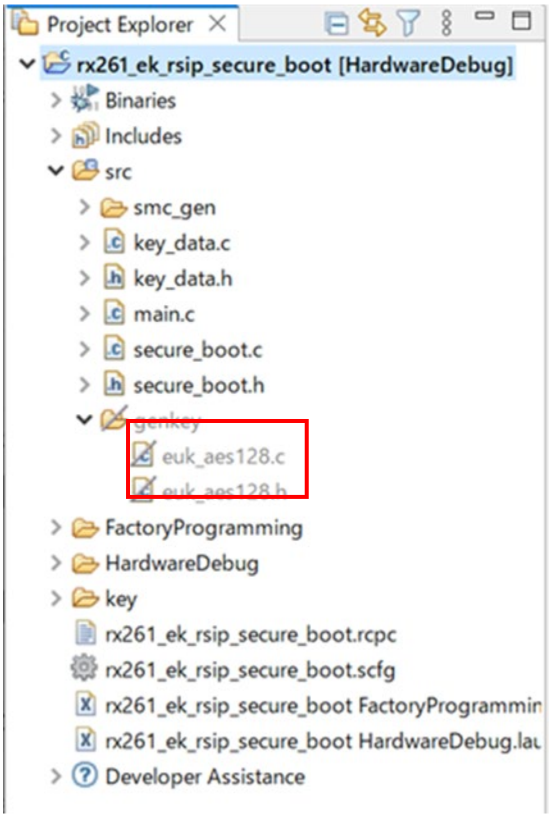


Figure 6.22 e²studio Project Explorer

Next, change the setting of **Build Configuration** to **Factory Programming**.

In e² studio's Project Explorer, right-click the secure update project and on the menu that appears select **Build Configuration** > **Activate** > **Factory Programming**.

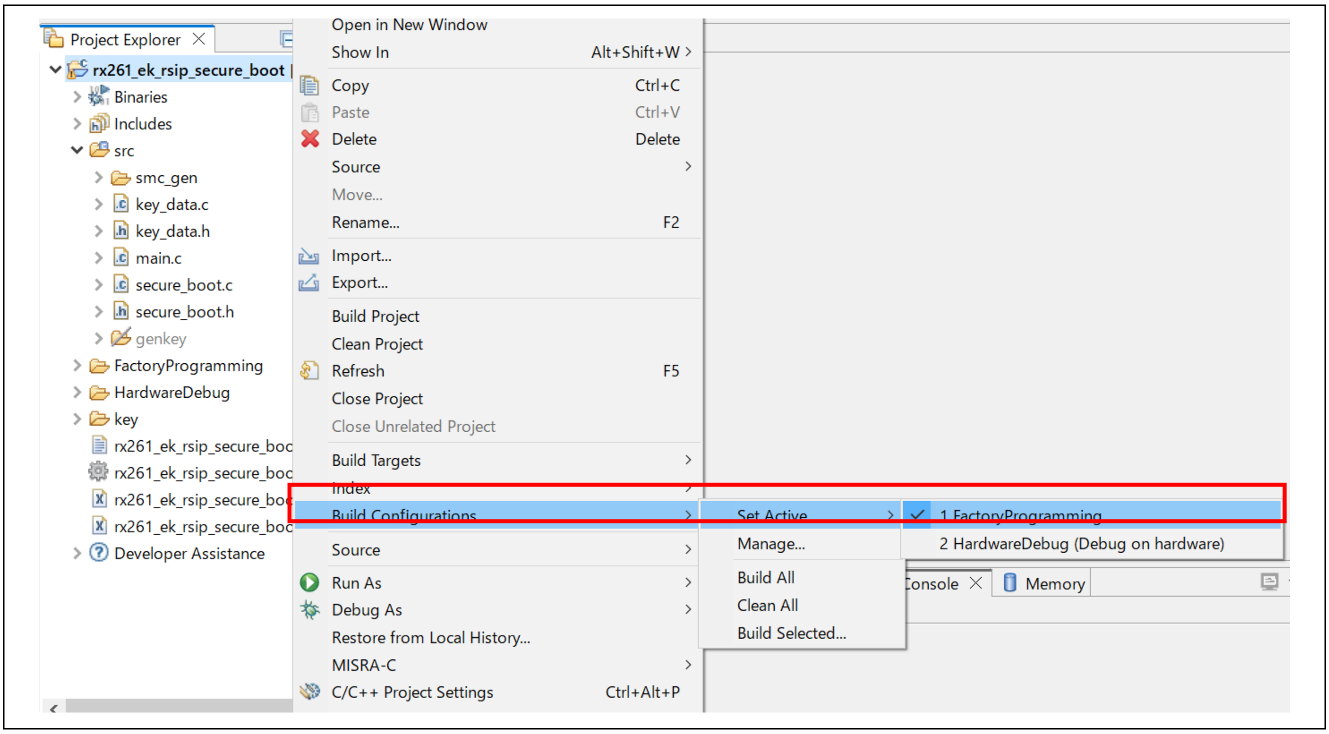


Figure 6.23 Changing Build Configuration to Factory Programming

After changing the **Build Configuration** setting to **Factory Programming**, build the secure bootloader project.

A definition of the build macro FACTORY_PROGRAMMING has been added from **Build Configuration**: **HardwareDebug**. Also, the section information is different.

(3) Building the Firmware Update Project

Build the project with the same operation of 6.2.3.1, Execution Example of Two-Step Setup (3).

(4) Encrypting the Firmware Update Program

- Command line version
  Run the following command.

  > skmt.exe /enctsip /mode "factory" /ver "2" /prg "{$skmt_loc}\..\rx261_ek_rsip_user_program\Release\rx261_ek_rsip_user_program.mot" /prg_sb "{$skmt_loc}\FactoryProgramming\rx261_ek_rsip_secure_boot.mot " /enckey "0123456789abcdef0123456789abcdef" /startaddr "FFFB8300" /endaddr "FFFEFFFF" /destaddr "FFFB8300" /filetype "mot" /output ""{$skmt_loc}\userprog.mot"

  For {$skmt_loc}, substitute the path of the secure bootloader project folder.

  The setting values of **/stardaddr**, **/endaddr**, and **/destaddr** differ depending on the MCU. Refer to the table below when entering values.

Table 6-11 Specifying address for Each MCU

MCU	Parameter		Address
	GUI	CLI	
RX261	Start address	/startaddr	FFFB8300
	End address	/endaddr	FFFEFFFF
	Encrypted image output address	/destaddr	FFFB8300

- Standalone version
  Enter the following values.
  - **Output Image**
    Select **Secure Update**.
  - **Firmware Image**
    Motorola S format file output by update project (rx261_ek_rsip_user_program.mot)
  - **Encrypted Address Range** tab
    The values differ depending on the MCU. Refer to Table 6-11 and select the appropriate values to match the MCU.
  - **IV** tab
    Select **Use specified value** and enter **“55aa55aa55aa55aa55aa55aa55aa55aa”**.
  - **RSU Header** tab
    RSU header Ver: 1

— **Output**
Format: Binary
File: userprog.mot

To use the above settings, you can load the Security Key Management Tool settings file rx261_SecureUpdate.skmt included in the sample.

The file rx261_SecureUpdate.skmt is in xml format and can be edited as text. For **{$skmt_loc}** in rx261_SecureUpdate.skmt, substitute the path of the secure bootloader project folder.

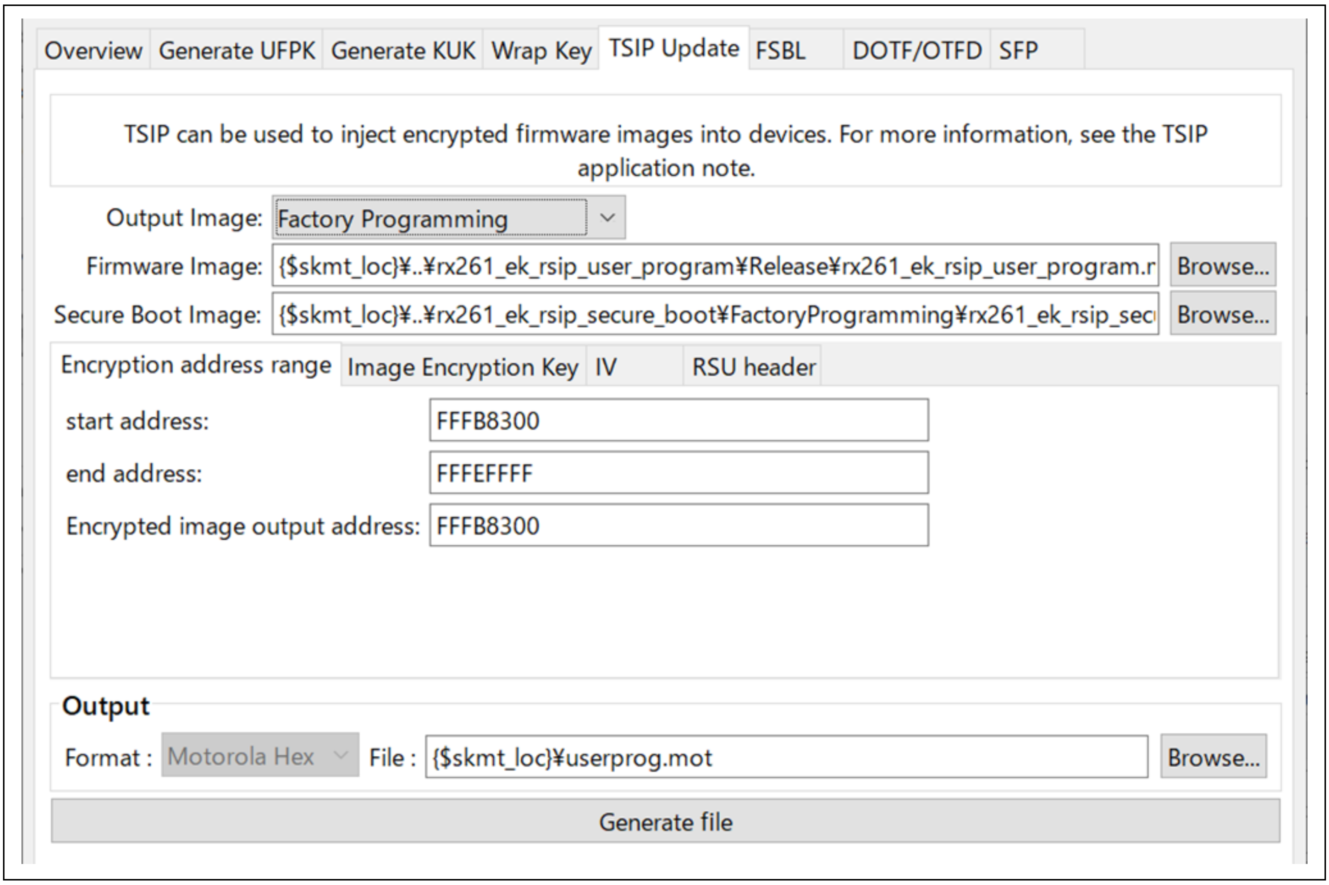


Figure 6.24 Generating an Encrypted File (TSIP UPDATE Tab)

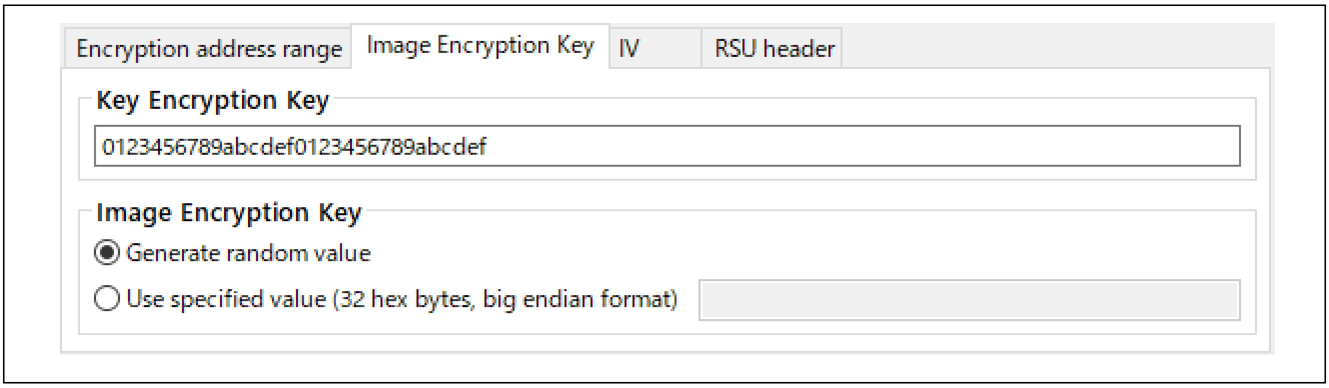


Figure 6.25 Generating an Encrypted File (TSIP UPDATE Tab – Image Encryption Key Tab)

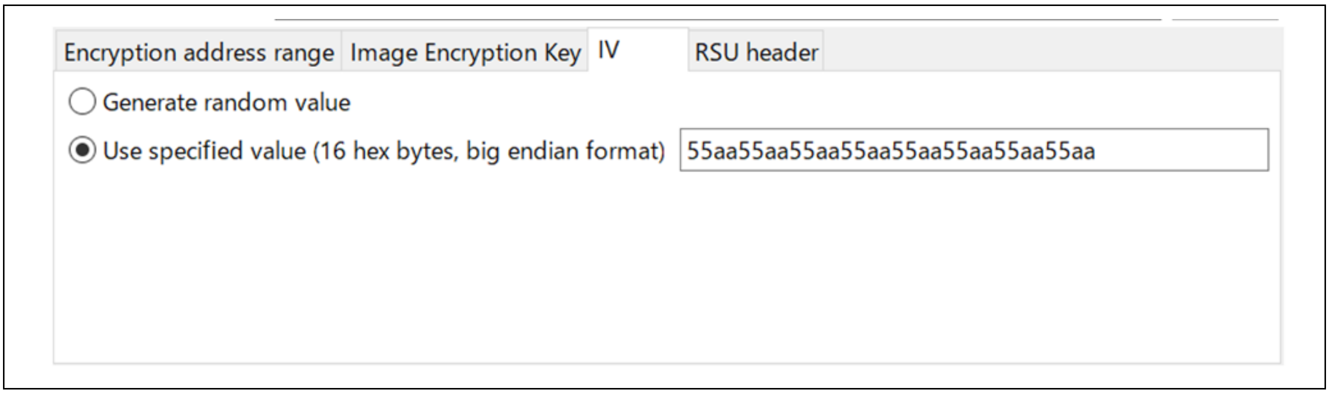


Figure 6.26 Generating an Encrypted File (TSIP UPDATE Tab – IV Tab)

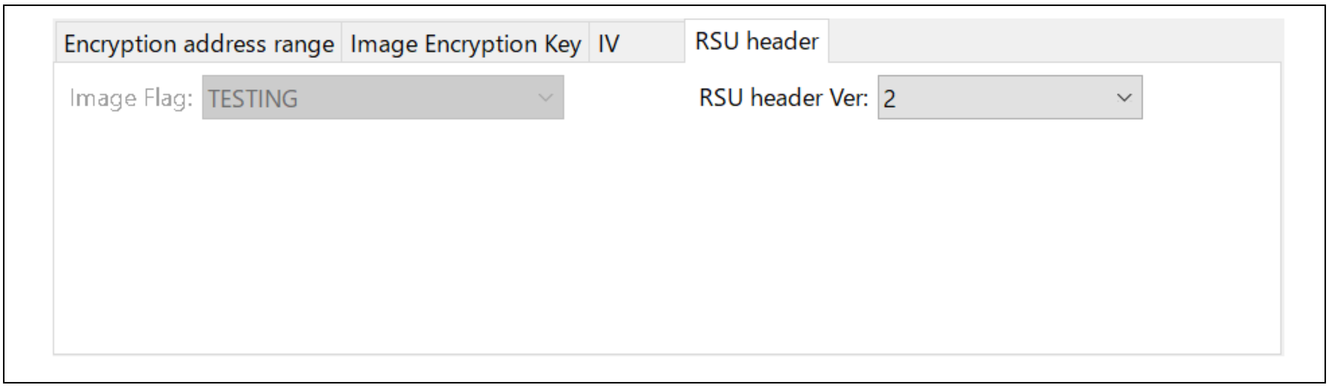


Figure 6.27 Generating an Encrypted File (TSIP UPDATE Tab – RSU Header Tab)

Use Renesas Flash Programmer to write the Motorola S format file (default file name: userprog.mot) containing the encrypted user program and plaintext secure bootloader to the device.

(5) Starting the Terminal Emulator (Tera Term)

Make connections as shown in the applicable connection diagram in 6.2.1, Demo Project Setup, and launch Tera Term before writing the data using Renesas Flash Programmer.

(6) Writing Data Using Renesas Flash Programmer

Start Renesas Flash Programmer and create a project. After creating the project, click the **Tool Details** button on the **Connection Settings** tab. Then select the **Reset Settings** tab and set **Reset signal at Disconnection** to **Reset Pin as Hi-Z**.

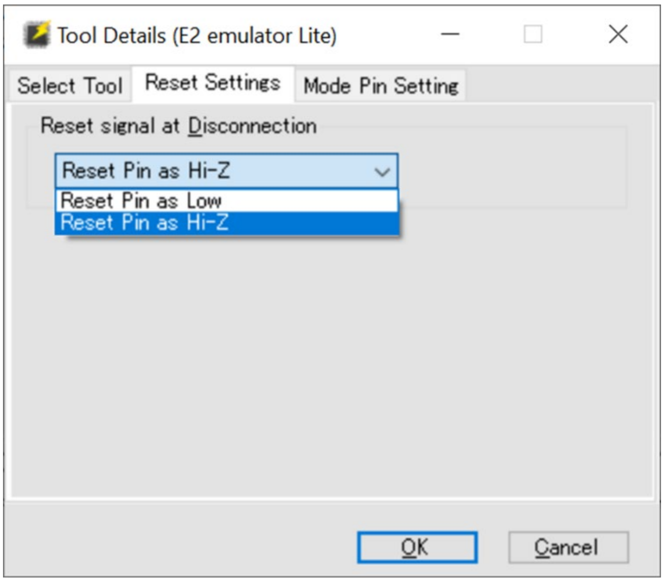


Figure 6.28 Renesas Flash Programmer Reset Settings Tab

If the data was successfully written to the device using Renesas Flash Programmer, the secure bootloader program runs on the device, decrypts the encrypted user program, and then runs the user program.

If the operation is successful, similar to the following is displayed.

```
HELLO!! this is boot program. ~
$ I was built in Oct  2 2024, 14:10:22.
Checking flash ROM status.
status = STATE_INJECT_KEY
========== generate user key index phase ==========
generate aes128 user program mac key index: OK
========== install user key index phase ==========
erase data flash(main)...OK
write data flash(main)...OK
erase data flash(mirror)...OK
write data flash(mirror)...OK
data flash setting OK.
Checking flash ROM status.
status = STATE_GET_IMAGE
```

Figure 6.29 Log Output when Using Renesas Flash Programmer to Write Encrypted Firmware Update Program

After starting the device, the device executes the secure bootloader program and decrypt the encrypted firmware update program. Then, firmware update program is executed. In addition, decryption of the encrypted firmware update program is executed only in the first starting after writing the inclusive setup program.

If the operation is successful, similar to the following is displayed.

```
erase data flash(main)...OK
write data flash(main)...OK
erase data flash(mirror)...OK
write data flash(mirror)...OK
data flash setting OK.
Checking flash ROM status.
status = STATE_ACTIVATE_IMAGE
erase secure boot erase area...OK
update data flash
erase data flash(main)...OK
write data flash(main)...OK
erase data flash(mirror)...OK
write data flash(mirror)...OK
data flash setting OK.
activating image ... OK
software reset...
HELLO!! this is boot program. ~
$ I was built in Oct  2 2024, 14:10:22.
Checking flash ROM status.
status = STATE_EXEC_IMAGE

==== BootLoader [with buffer] ====
secure boot sequence: success.
execute image ...
HELLO!! this is user program. ~
$ I was built in Oct  2 2024, 14:13:48.
Version ver 1.00.
rsip@rx261
$
```

Figure 6.30 Log Output of First Starting after Inclusive Setup Program is Written

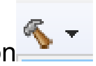
(7) Firmware Update Operation

For firmware update operation, refer to 6.2.3.1, Execution Example of Two-Step Setup (8).

6.2.4 Debugging Firmware Update Project

Since the firmware update project is started via Secure Boot, the reset vector (RESETVECT) of the project is placed at 0xFFF7FFFC. For this reason, the firmware update project cannot be debugged as is. To debug the firmware update project, switch the debugging configuration to the HardwareDebugg.

- How to switch debugger connection configuration:

1.Press ▼ next to e²studio menu build button 
Select [HardwareDebug (Debug on hardware)] to start the build.

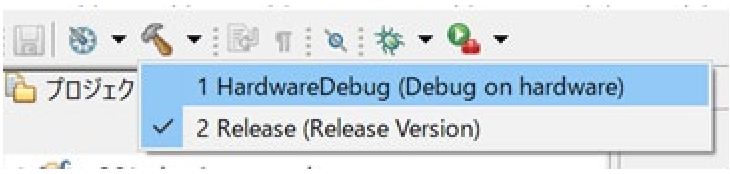


Figure 6.31 e²studio project menu

2. Once the build is complete, debugging with the debugger becomes possible.

Difference between "Release" configuration for release and "HardwareDebug" configuration for debugging
The addresses of the reset vector (RESETVECT) and interrupt vector (EXCEPTVECT) at build time are different between the "Release" and "HardwareDebug" configurations.

Table 6-12 User program project Vector setting address for each configuration

Symbol	Release	HardwareDebug
RESETVECT	0xFFFEFFFC	0xFFFFFFFC
EXCEPTVECT	0xFFFEFF80	0xFFFFFF80

6.2.5 Notes on Transition from Secure Bootloader Project to Firmware Update Project

When the transition from the secure bootloader program to the firmware update program takes place, the peripheral function settings of the secure bootloader program are inherited by the application. Therefore, in the secure bootloader project of the demo project is implemented as follows.

The API functions of the FIT modules (SCI, flash, TSIP, and USB) used by the secure bootloader program are closed when the bootloader terminates. All other settings are returned to their initial values when Smart Configurator is used.

If the user modifies the secure bootloader sample program for their own use, the peripheral function settings configured in the secure bootloader program are inherited by the application. It is therefore recommended either that the peripheral function settings be initialized before the transition from the secure bootloader program to the user program, or that common peripheral function settings be used for the application and the secure bootloader.

In other words, it is necessary to also consider the implementation of the secure bootloader program when creating applications.

7. Appendix

7.1 Confirmed Operation Environment

The operation of the driver has been confirmed in the following environment.

Table 7-1 Confirmed Operation Environment

Item	Description
Integrated development environment	Renesas Electronics e² studio 2024-07 IAR Embedded Workbench for Renesas RX 5.10.01
C compiler	Renesas Electronics C/C++ Compiler for RX Family (CC-RX) V3.06.00 Compile options: The following option has been added to the default settings of the integrated development environment. -lang = c99
	GCC for Renesas RX 8.3.0.202311 Compile options: The following option has been added to the default settings of the integrated development environment. -std = gnu99
	IAR C/C++ Compiler for Renesas RX version 5.10.01 Compiler options: Default settings of the integrated development environment
Endian order	Big-endian or little-endian
Module version	Ver. 1.00
Board used	Renesas Evaluation Kit for RX261 (product No.: RTK5EK2610Sxxxxxxx)

7.2 Troubleshooting

(1) Q: I added the FIT module to my project, but when I build it I get the error "Could not open source file 'platform.h'."

A: The FIT module may not have been added to the project properly. Refer to the documents listed below to confirm the method for adding FIT modules:

- Using CS+
  Application Note: Adding Firmware Integration Technology Modules to CS+ Projects (R01AN1826)
- Using e^2 studio
  Application Note: Adding Firmware Integration Technology Modules to Projects (R01AN1723)

When using the FIT module, the board support package FIT module (BSP module) must also be added to the project. Refer to the application note "RX Family: Board Support Package Module Using Firmware Integration Technology" (R01AN1685) for instructions for adding the BSP module.

(2) Q: I want to use the FIT Demos e^2 studio sample project on CS+.

A: Visit the following webpage for instructions:
Porting from the e^2 studio to CS+
> Convert an Existing Project to Create a New Project With CS+
https://www.renesas.com/jp/ja/products/software-tools/tools/migration-tools/migration-e2studio-to-csplus.html

Note: In step 5, the [Q0268002] dialog box may appear if the box next to "Backup the project composition files after conversion" is checked. If you click the **Yes** button in the [Q0268002] dialog box, you must then re-input the compiler include path.

8. Reference Documents

User's Manual: Hardware
(The latest version can be downloaded from the Renesas Electronics website.)

Technical Updates/Technical News
(The latest information can be downloaded from the Renesas Electronics website.)

User's Manual: Development Environment
RX Family CC-RX Compiler User's Manual (R20UT3248)
(The latest version can be downloaded from the Renesas Electronics website.)

Revision History

Rev.	Date	Description	
		Page	**Summary**
1.00	Oct. 15, 2024	—	First edition issued

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

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Contact information

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