RX Family

AES Library Firmware Integration Technology

R20AN0044EJ0107
Rev.1.07
Oct.31.2022

Introduction

This application note explains information for implementing the RX Family AES library (hereafter referred to as the AES FIT library) using Firmware Integration Technology (FIT). The AES FIT library is the software library incorporated in the RX series and includes the data encryption/decryption functions that use the AES encryption technology. Also, it is designed in dedicated efficient processing with the RX microcontroller.

And AES FIT library package also includes GCM driver functionality for Galois/Counter Mode (GCM).

Please refer to the User's Manual(R20UW0068JJ0200) to know how to use this software library.

Target Device

RX Family

When applying this application note to other microcontrollers, please modify it according to the specifications of the microcontroller and evaluate it thoroughly.

Target Compiler

Renesas Electronics C/C++ Compiler Package for RX Family

GCC for Renesas RX

IAR Embedded Workbench for Renesas RX

For detailed information on the compiler's system requirements, please refer to Section "4.1 Confirmed Operation Environment".

Related Documents

Firmware Integration Technology User’s Manual (R01AN1833)

Board Support Package Module Using Firmware Integration Technology (R01AN1685)

Adding Firmware Integration Technology Modules to Projects (R01AN1723)

Adding Firmware Integration Technology Modules to CS+ Projects (R01AN1826)

Renesas e2studio Smart Configurator User's Guide (R20AN0451)

Contents

1. Overview

1.1 AES FIT Library

This library is used as an API to be embedded in a project. See "2.9 Adding the FIT Module to Your Project " for details on how to incorporate this library.

1.2 AES FIT Library Overview

Please refer to the user's manual (R20UW0068JJ0200) stored in the package.

1.3 API Function

AES Library for the RX supports the following functions.

For details on each API function, please refer to the user's manual (R20UW0068JJ0200).

Table 1-1 AES Library API Function

API	Outline
R_Aes_128_Keysch	AES 128-bit Key Schedule
R_Aes_128_Ecbenc	AES 128-bit Encryption Function (ECB Mode)
R_Aes_128_Ecbdec	AES 128-bit Decryption Function (ECB Mode)
R_Aes_128_Cbcenc	AES 128-bit Encryption Function (CBC Mode)
R_Aes_128_Cbcdec	AES 128-bit Decryption Function (CBC Mode)
R_Aes_256_Keysch	AES 256-bit Key Schedule
R_Aes_256_Ecbenc	AES 256-bit Encryption Function (ECB Mode)
R_Aes_256_Ecbdec	AES 256-bit Decryption Function (ECB Mode)
R_Aes_256_Cbcenc	AES 256-bit Encryption Function (CBC Mode)
R_Aes_256_Cbcdec	AES 256-bit Decryption Function (CBC Mode)

GCM Library for the RX supports the following functions.

Table 1-2 GCM Library API Function

API	Outline
R_gcm_enc	GCM Encryption Function
R_gcm_dec	GCM Decryption Function
R_gcm_enc_start	GCM Start Encryption Function
R_gcm_dec_start	GCM Start Decryption Function
R_gcm_repeat	GCM Repeat Function

1.4 Version Information

In the AES Library, the version information is stored as a character string in the R_aes_version variable. This variable can be accessed by the following extern declaration. In addition, the data stored in the product's library is as follows.

```
extern const mw_version_t R_aes_version;
```

In the GCM Library, the version information is stored as a character string in the R_gcm_version variable. This variable can be accessed by the following extern declaration. In addition, the data stored in the product's library is as follows.

```
extern const mw_version_t R_gcm_version;
```

1.5 The Structure of AES FIT Library

1.5.1 Application Note Structure

This product includes the files listed in Table 1-3 Structure of Product Files below.

Table 1-3 Structure of Product Files

File / Directory(bold) Names	Description
r20an0044jj0107-rx-aes.pdf	AES FIT Library Application Note (Japanese)
r20an0044ej0107-rx-aes.pdf	AES FIT Library Application Note (English)
r20uw0068jj0200-aes.pdf	AES FIT Library User's manual (Japanese)
r20uw0068ej0200-aes.pdf	AES FIT Library User's manual (English)
FITDemos	FIT Module Demo Program folder
aes_demo_65n_2m	AES FIT Module Demo Program
FITModules	FIT Module folder
r_aes_rx_v1.07.zip	AES FIT Module
r_aes_rx_v1.07.xml	AES FIT Module XML file
r_aes_rx_v1.07_extend.mdf	AES FIT Module MDF file

1.5.2 File Structure

The folder to which the content of r_aes_rx_v1.07.zip is extracted will contain the files listed in Table 1-4 File Structure below.

Table 1-4 File Structure

File / Directory(bold) Names	Description
r_aes_rx	FIT Module folder
doc	Document folder
en	Document folder (English)
r20an0044ej0107-rx-aes.pdf	AES FIT Library Application Note (English)
r20uw0068ej0200-aes.pdf	AES FIT Library User's manual (English)
ja	Document folder (Japanese)
r20an0044jj0107-rx-aes.pdf	AES FIT Library Application Note (Japanese)
r20uw0068jj0200-aes.pdf	AES FIT Library User's manual (Japanese)
ref	Reference folder
r_aes_config_reference.h	Configure reference file
src	Source code folder
aes	AES source code folder
aes128Ecb_small.c	128-bit ECB mode AES API function definition
aes128Cbc_small.c	128-bit CBC mode AES API function definition
aes256Ecb_small.c	256-bit ECB mode AES API function definition
aes256Cbc_small.c	256-bit CBC mode AES API function definition
aes128Ecb_big.c	128-bit ECB mode AES API function definition
aes128Cbc_big.c	128-bit CBC mode AES API function definition
aes256Ecb_big.c	256-bit ECB mode AES API function definition
aes256Cbc_big.c	256-bit CBC mode AES API function definition
aes128.h	128-bit CBC mode AES core
aes256.h	256-bit CBC mode AES core

r_aesEcb.h	ECB mode AES core
r_aes_version.c	AES version file
r_aesSbox.h	Definition of SBOX table for AES
r_aes_development.h	AES library function name definition macro header file
r_aes.h	AES library function name definition header file
gcm	GCM source code folder
r_gcm.c	GCM Library source
r_gcm_version.c	GCM version file
r_gcm.h	GCM library header file
r_gcm_driver.c	GCM driver file
r_mw_version.h	Version data header file
r_stdint.h	typedef header file
r_aes_rx_if.h	AES library header file
readme.txt	Readme file
r_config	Config file folder
r_aes_config.h	Config file (default)

2. API Information

2.1 Hardware Requirements

There are no hardware requirements.

2.2 Software Requirements

There are no software requirements.

2.3 Limitations

There are no software limitations.

2.4 Supported Toolchain

This driver has been confirmed to work with the toolchain listed in “4.1 Confirmed Operation Environment”.

2.5 Header Files

All API calls and their supporting interface definitions are in r_aes_rx_if.h.

2.6 Integer Types

This project uses ANSI C99. These types are defined in stdint.h.

2.7 How to Use Library Functions

2.7.1 Execution Performance vs. Code Size

The AES library for RX has two approaches: one is to emphasize execution performance (faster) by optimizing the program code size (hereinafter referred to as "execution performance-oriented"), and the other is to emphasize the program code size (smaller) rather than improving execution performance (hereinafter referred to as "code size-oriented").

The configuration options for this module are set in r_aes_config.h.

The table below describes the option names and setting values.

Configuration option in r_aes_config.h	
Definition	**Description**
#define AES_CFG_BUILD_OPTION ※The default value is "0": "emphasis on execution performance" will be set.	You can choose to " execution performance-oriented" or "code size-oriented". 0 : SPEED (emphasis on execution performance) 1 : SIZE (emphasis on code size)

The following macro definitions are enabled by the above option settings.

Macro	Select Implementation
__COMPILE_EMPHASIS_SPEED__	compile with emphasis on execution performance
__COMPILE_EMPHASIS_SIZE__	compile with emphasis on code size

2.8 AES Library ROM / RAM / Stack Size / Performance

The various sizes and processing cycles when building with the following optimization options are described for reference.

CCRX: Level2 performs whole module optimization GCC: -O2 IAR: High (size)

2.8.1 ROM/RAM Size

API	Little or Big Endian	Implement	ROM size [byte]			RAM size [byte]		
			CCRX	GCC	IAR	CCRX	GCC	IAR
R_Aes_128_Keysch	Little	execution performance-oriented	221	248	238	0	0	0
		code size-oriented	170	256	174			
R_Aes_128_Ecbenc	Little	execution performance-oriented	2389	2848	2420	0	0	0
		code size-oriented	331	1160	578			
R_Aes_128_Ecbdec	Little	execution performance-oriented	2535	3184	2535	0	0	0
		code size-oriented	481	1808	1280			
R_Aes_128_Cbcenc	Little	execution performance-oriented	454	544	525	0	0	0
		code size-oriented	240	552	238	0	0	0
R_Aes_128_Cbcdec	Little	execution performance-oriented	558	688	614	0	0	0
		code size-oriented	308	688	298			
R_Aes_256_Keysch	Little	execution performance-oriented	469	560	499	0	0	0
		code size-oriented	405	576	411			
R_Aes_256_Ecbenc	Little	execution performance-oriented	3201	3832	3234	0	0	0
		code size-oriented	411	1368	648			
R_Aes_256_Ecbdec	Little	execution performance-oriented	3347	4232	3347	0	0	0
		code size-oriented	562	2096	1350			
R_Aes_256_Cbcenc	Little	execution performance-oriented	454	544	525	0	0	0
		code size-oriented	240	552	238	0	0	0
R_Aes_256_Cbcdec	Little	execution performance-oriented	558	688	614	0	0	0
		code size-oriented	308	688	298			
R_gcm_enc	Little	-	487	576	443	0	0	0
R_gcm_dec	Little	-	512	614	465	0	0	0
R_gcm_enc_start	Little	-	103	181	100	0	0	0
R_gcm_dec_start	Little	-	103	181	100	0	0	0
R_gcm_repeat	Little	-	989	1592	851	0	0	0

Note 1: All the value when the sample program is executed. If the user changes the implementation of the user-defined function, the stack size will change.

Note 2: Since each CBC mode enc/dec function calls an ECB mode enc/dec function, the total ROM size of the two functions is required (for example, the R_Aes_128_Cbcenc function calls the R_Aes_128_Ecbenc function, the total ROM size of both functions is required when the R_Aes_128_Cbcenc function is used).

Note 3: "-" means execution performance-oriented and code size-oriented, and there is no change in the code.

2.8.2 Stack Size

API	Little or Big Endian	Implement	Stack Size [byte]		
			CCRX	GCC	IAR
R_Aes_128_Keysch	Little	execution performance-oriented	28	32	24
		code size-oriented	12	32	12
R_Aes_128_Ecbenc	Little	execution performance-oriented	84	108	72
		code size-oriented	104	108	56
R_Aes_128_Ecbdec	Little	execution performance-oriented	276	464	244
		code size-oriented	276	308	228
R_Aes_128_Cbcenc	Little	execution performance-oriented	68	112	60
		code size-oriented	80	116	60
R_Aes_128_Cbcdec	Little	execution performance-oriented	96	136	76
		code size-oriented	108	136	76
R_Aes_256_Keysch	Little	execution performance-oriented	32	32	24
		code size-oriented	16	36	16
R_Aes_256_Ecbenc	Little	execution performance-oriented	84	120	72
		code size-oriented	120	104	56
R_Aes_256_Ecbdec	Little	execution performance-oriented	340	592	308
		code size-oriented	356	376	292
R_Aes_256_Cbcenc	Little	execution performance-oriented	68	112	60
		code size-oriented	80	116	60
R_Aes_256_Cbcdec	Little	execution performance-oriented	96	136	76
		code size-oriented	108	136	76
R_gcm_enc	Little	-	260	252	232
R_gcm_dec	Little	-	232	256	232
R_gcm_enc_start	Little	-	24	60	28
R_gcm_dec_start	Little	-	24	60	28
R_gcm_repeat	Little	-	176	192	64

Note1: "-" means execution performance-oriented and code size-oriented, and there is no change in the code.

2.8.3 Performance

The performance of AES library.

The measurement condition is CC-RX and optimization level 2. The implement is execution performance oriented.

API	Little/Big Endian	Performance (Cycle)		
		1 block	2 block	3 block
R_Aes_128_Keysch	Little	752		
	Big	768		
R_Aes_256_Keysch	Little	1060		
	Big	908		
R_Aes_128_Ecbenc	Little	1692	3274	4858
	Big	1704	3292	4882
R_Aes_128_Ecbdec	Little	3116	4564	6012
	Big	3224	4670	6116
R_Aes_128_Cbcenc	Little	1920	3656	5548
	Big	1930	3666	5404
R_Aes_128_Cbcdec	Little	3448	6684	10068
	Big	3554	7044	10388
R_Aes_256_Ecbenc	Little	2244	4386	6528
	Big	2248	4390	6530
R_Aes_256_Ecbdec	Little	4294	6412	8222
	Big	4296	6260	8224
R_Aes_256_Cbcenc	Little	2476	4768	7060
	Big	2478	4760	7042
R_Aes_256_Cbcdec	Little	4622	9036	13602
	Big	4626	9040	13602

The performance of GCM library.

The measurement condition is CC-RX and optimization level 2. The implement is execution performance oriented.

API	Little/Big Endian	Key Type	Performance (Cycle)
R_gcm_enc	Little	128 bit	51288
		256 bit	197262
	Big	128 bit	51826
		256 bit	198228
R_gcm_dec	Little	128 bit	52040
		256 bit	197892
	Big	128 bit	52460
		256 bit	197738

Note 1. These values are calculated using atag = 16 byte, ivec = 12 byte, add = 1 block.
2. This processing speed may fluctuate with inputting data (plain text/cipher text).

2.9 Adding the FIT Module to Your Project

This module must be added to each project in which it is used. Renesas recommends the method using the Smart Configurator described in (1) or (3) below. However, the Smart Configurator only supports some RX devices. Please use the methods of (2) or (4) for RX devices that are not supported by the Smart Configurator.

(1) Adding the FIT module to your project using the Smart Configurator in e2 studio

By using the Smart Configurator in e2 studio, the FIT module is automatically added to your project.

Refer to “Renesas e2 studio Smart Configurator User Guide (R20AN0451)” for details.

(2) Adding the FIT module to your project using the FIT Configurator in e2 studio

By using the FIT Configurator in e2 studio, the FIT module is automatically added to your project.

Refer to “Adding Firmware Integration Technology Modules to Projects (R01AN1723)” for details.

(3) Adding the FIT module to your project using the Smart Configurator in CS+

By using the Smart Configurator Standalone version in CS+, the FIT module is automatically added to your project. Refer to “Renesas e2 studio Smart Configurator User Guide (R20AN0451)” for details.

(4) Adding the FIT module to your project in CS+

In CS+, please manually add the FIT module to your project. Refer to “Adding Firmware Integration Technology Modules to CS+ Projects (R01AN1826)” for details.

3. Demo project

The demo project is a stand-alone program. The demo projects include function main() that utilizes the FIT module and its dependent modules (e.g. r_bsp). This FIT module includes the following demo projects.

3.1 aes_demo_65n_2m

aes_demo_65n_2m shows how to use the AES library API. This demo project uses the AES128-CBC, AES128-ECB, AES256-CBC, AES256-ECB, AES128-GCM, and AES256-GCM algorithms for encryption and decryption.

3.2 Add the Demo to Workspace

The demo projects are found in the FITDemos subdirectory of the distribution file for this application note. To add a demo project to a workspace,

- Select "File" -> "Import".
- In the "Import" dialog, select "Existing Project to Workspace" under "General" and click the "Next" button.
- In the "Import" dialog, select the "Select archive file" radio button.
- Click the "Browse" button to open the FITDemos subdirectory.
- Select the desired demo zip file, then click “Finish”.

The above process will add the demo project to the workspace.

4. Appendix

4.1 Confirmed Operation Environment

This section describes confirmed operation environment for the AES FIT Library.

Table 4-1 Confirmed Operation Environment (Rev. 1.07)

Item	Contents
Integrated Development Environment	Renesas Electronics e2 studio Version 2022-01 IAR Embedded Workbench for Renesas RX 4.20.3
C compiler	Renesas Electronics C/C++ Compiler Package for RX Family V3.04.00 Compiler option: The following option is added to the default settings of the integrated development environment. -lang = c99
	GCC for Renesas RX 8.3.0.202104 Compiler option: The following option is added to the default settings of the integrated development environment. -std=gnu99 Linker option: The following user defined option should be added to the default settings of the integrated development environment, if “Optimize size (-Os)” is used: -Wl,--no-gc-sections This is to work around a GCC linker issue whereby the linker erroneously discards interrupt functions declared in FIT peripheral module
	IAR C/C++ Compiler for Renesas RX version 4.20.3 Compiler option: The default settings of the integrated development environment
Endian	Big endian/little endian
Revision of the module	Rev.1.07
Board used	Target Board for RX65N Target Board for RX130 Renesas Envision Kit for RX72N

5. Reference documents

Related Technical Updates

This module reflects the content of the following technical updates.

None

Website and Support

Renesas Electronics Website
http://www.renesas.com/

Inquiries
http://www.renesas.com/contact/

Revision History

Rev.	Date	Description	
		Page	Summary
1.07	2022.10.31	-	Updated the confirmed operation environment
1.06	2022.08.10	-	With the fixed of FIT, the title was corrected, and FIT-related information was added. The library format has been changed from Lib. format to C source.
1.04	2013.05.30	-	Version notation has been corrected to V.1.04. Updated User's Manual from rev 1.05 to rev 1.08. Added GCM description to Introduction
1.03	2012.12.27	-	Fixed GCM Samplecode. 1)Tested NIST test vector CAVS10.1. http://csrc.nist.gov/groups/STM/cavp/ 2)Changed using standerd data types. Fixed Library version information. Updated User's Manual from rev 1.03 to rev 1.05.
1.02	2012.04.16	-	Add RX200 series support The source code of GCM was collected to the sample. Add cycles.
1.01	2011.05.06	-	Added GCM Library
1.00	2011.02.18	-	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.

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(Rev.5.0-1 October 2020)

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