RL78 Family

AES Library: Introduction Guide

Introduction

This document explains AES Library for the RL78 Family (hereafter referred to as "AES Library") that depends on MCUs. The AES Library is the software library incorporated in the RL78 Family and includes the data encryption/decryption functions that use the AES encryption technology. Also it is designed in dedicated algorithm and fully-tuned up by assembly language.

And AES Library package also has GCM Library corresponds “Galois/Counter Mode (GCM)”.

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

Target Device

RL78/G14(S3 core), RL78/G23(S3 core),

This software can be used for all RL78 Family MCUs that belongs into S2 core or S3 core.

This software cannot be used for small memory RL78 Family MCUs for example RL78/G10.

For memory usage for this software, please refer to the ROM/RAM/Stack size section in this document.

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Contents

1. Structure of This Product

This product includes the following data.

Table 1 AES Library Product Files (1/2)

Name	Description
sample program (r20an0151xx0201-rl78-aes)	
workspace <DIR>	
Document (doc) <DIR>	
English (en)	
r20uw0068ej0201-aes.pdf	User's manual
r20an0151ej0201-rl78-aes.pdf	Introduction Guide (this document)
Japanese (ja)	
r20uw0068jj0201-aes.pdf	User's manual
r20an0151jj0201-rl78-aes.pdf	Introduction Guide
libsrc <DIR>	Driver storage folder
aes <DIR>	AES Library
src <DIR>	AES Library source
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
include <DIR>	AES library header
r_aes.h	AES library header file
r_mw_version.h	Version data header file
r_stdint.h	typedef header file
gcm <DIR>	GCM Library
src <DIR>	GCM Library source
r_gcm.c	GCM Library source
r_gcm_version.c	GCM version file
include <DIR>	GCM library header
r_gcm.h	GCM library header file
r_stdint.h	typedef header file
r_mw_version.h	Version data header file

Table 2 AES Library Product Files (2/2)

Name	Description
sample program (r20an0151xx0201-rl78_aes)	
workspace <DIR>	
CS+ <DIR>	CS+ project folder
aes_rl78_sim_sample <DIR>	G23 sample project folder
src <DIR>	program storage folder
main.c	sample main
main.h	sample main header
r_gcm_driver.c	sample GCM Driver
r_gcm_driver.h	sample GCM Driver header
r_sample_aes128.c	sample AES128
r_sample_aes256.c	sample AES256
r_sample_gcm_dec.c	sample GCM mode(decode)
r_sample_gcm_enc.c	sample GCM mode(encode)
r_test_data.c	sample test data
r_test_data.h	sample test data header
libsrc <DIR>	link to libsrc
smc_gen <DIR>	Smart configurator auto-generated folder
general	Common header file / source file storage folder
r_bsp	Initialization code register definition storage folder
r_config	Driver initialization config header storage folder
e^2 studio <DIR>	e^2 studio project folder
CCRL	sample project for CCRL
aes_rl78_sim_sample <DIR>	sample project for G23
LLVM	sample project for LLVM
aes_rl78_sim_sample <DIR>	sample project for G23
IAR	IAR project folder
aes_rl78_sim_sample <DIR>	sample project for G23

2. Product Specifications

2.1 API Function

AES library, GCM library supports the following library API functions.

All pointer-type arguments have the __near type qualifier, and the data to be pointed to must be in the near area.

Table 3 Library Functions (API) of AES Library

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)

Table 4 Library Functions (API) of GCM Library

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

2.2 API How to use library functions

When using the library function, it is necessary to specify the file to be built as follows according to the API to be used.

Table 5 Build target file corresponding to each API

API	Build target file
R_Aes_128_Keysch R_Aes_128_Ecbenc R_Aes_128_Ecbdec	aes128Ecb_small.c, aes128Ecb_big.c, r_aes_version.c
R_Aes_256_Keysch R_Aes_256_Ecbenc R_Aes_256_Ecbdec	aes256Ecb_small.c, aes256Ecb_big.c, r_ aes_version.c
R_Aes_128_Keysch R_Aes_128_Cbcenc R_Aes_128_Cbcdec	aes128Cbc_small.c, aes128Cbc_big.c, r_ aes_version.c
R_Aes_256_Keysch R_Aes_256_Cbcenc R_Aes_256_Cbcdec	aes256Cbc_small.c, aes256Cbc_big.c, r_ aes_version.c
R_gcm_enc R_gcm_dec R_gcm_enc_start R_gcm_dec_start R_gcm_repeat	r_gcm.c r_gcm_version.c

3. CC-RL

3.1 Development environment

Please use the same or a later version of the toolchain listed below:

- Integrated Development Environment:
  CS+ for CC V8.05.00
  e^2 studio 2021-04 (21.4.0)
- C compiler:
  CC-RL V1.09.00

3.2 ROM / RAM / Stack Size / Performance

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

Compiler options

-cpu=S3 -memory_model=medium –Odefault

Link options

-NOOPtimize

Table 6 ROM, RAM, and Stack Size of AES Library

API	ROM (*1) (*2)	RAM	Stack
R_Aes_128_Keysch	17,871	0	26
R_Aes_128_Ecbenc			96
R_Aes_128_Ecbdec			282
R_Aes_128_Cbcenc			156
R_Aes_128_Cbcdec			368
R_Aes_256_Keysch			32
R_Aes_256_Ecbenc			96
R_Aes_256_Ecbdec			346
R_Aes_256_Cbcenc			156
R_Aes_256_Cbcdec			432

(*1) A value in case all the APIs is used. This value changes with the number of APIs to be used.

The ROM, RAM, and stack size of GCM Library functions (API) are shown below (Unit = byte):

Table 7 ROM, RAM, and Stack Size of GCM Library

API	ROM	RAM	Stack (*1)
R_gcm_enc	5,381	0	662
R_gcm_dec			658
R_gcm_enc_start			38
R_gcm_dec_start			38
R_gcm_repeat			596

(*1) This is the value when combined with the AES library including the driver part.

Table 8 AES Library Performance

API	time [us] @ system clock = 32MHz	
	1 block	3 blocks
R_Aes_128_Keysch	100	
R_Aes_128_Ecbenc	200	200
R_Aes_128_Ecbdec	500	500
R_Aes_128_Cbcenc	200	200
R_Aes_128_Cbcdec	500	500
R_Aes_256_Keysch	110	
R_Aes_256_Ecbenc	300	300
R_Aes_256_Ecbdec	700	700
R_Aes_256_Cbcenc	300	300
R_Aes_256_Cbcdec	700	700

Table 9 GCM Library Performance

API	Key Type	time [ms] @ system clock = 32MHz	
		1 block	3 blocks
R_gcm_enc	128 bit	5.0	8.3
	256 bit	15.2	18.7
R_gcm_dec	128 bit	5.0	8.2
	256 bit	5.3	8.8

Notes: 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).
3. Performance of R_gcm_enc_start() and R_gcm_repeat() combination is same as R_gcm_enc().
4. Performance of R_gcm_dec_start() and R_gcm_repeat() combination is same as R_gcm_dec().

4. IAR Embedded Workbench

4.1 Development environment

Please use the same or a later version of the toolchain listed below:

- Integrated Development Environment:
  IAR Embedded Workbench for Renesas RL78 version 4.21.1

- C compiler:
  IAR C/C++ Compiler for Renesas RL78 : 4.20.1.2260 (4.20.1.2260)

4.2 ROM / RAM / Stack Size / Performance

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

Compiler options

--core=S3 --code_model=far --data_model=near --near_const_location=rom0 -e -Oh

--calling_convention=v2

Table 10 ROM, RAM, and Stack Size of AES Library

API	ROM (*1)	RAM	Stack
R_Aes_128_Keysch	18,879	0	48
R_Aes_128_Ecbenc			136
R_Aes_128_Ecbdec			330
R_Aes_128_Cbcenc			210
R_Aes_128_Cbcdec			420
R_Aes_256_Keysch			48
R_Aes_256_Ecbenc			136
R_Aes_256_Ecbdec			394
R_Aes_256_Cbcenc			210
R_Aes_256_Cbcdec			484

(*1) A value in case all the APIs is used. This value changes with the number of APIs to be used.

The ROM, RAM, and stack size of GCM Library functions (API) are shown below (Unit = byte):

Table 11 ROM, RAM, and Stack Size of GCM Library

API	ROM	RAM	Stack (*1)
R_gcm_enc	8,110	0	806
R_gcm_dec			808
R_gcm_enc_start			18
R_gcm_dec_start			18
R_gcm_repeat			666

(*1) This is the value when combined with the AES library including the driver part.

Table 12 AES Library Performance

API	time [us] @ system clock = 32MHz	
	1 block	3 blocks
R_Aes_128_Keysch	300	
R_Aes_128_Ecbenc	1,400	1,400
R_Aes_128_Ecbdec	2,700	2,700
R_Aes_128_Cbcenc	1,500	1,500
R_Aes_128_Cbcdec	2,800	2,800
R_Aes_256_Keysch	300	
R_Aes_256_Ecbenc	1,900	1,900
R_Aes_256_Ecbdec	3,800	3,800
R_Aes_256_Cbcenc	2,000	2,000
R_Aes_256_Cbcdec	3,900	3,900

There is difference in performance for each library (Device, Code model, Data model settings)

Table 13 GCM Library Performance

API	Key Type	time [ms] @ system clock = 32MHz	
		1 block	3 blocks
R_gcm_enc	128bit	10.7	17.9
	256bit	28.2	36.5
R_gcm_dec	128bit	10.8	17.8
	256bit	12.7	21.1

Notes: 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).
3. Performance of R_gcm_enc_start() and R_gcm_repeat() combination is same as R_gcm_enc().
4. Performance of R_gcm_dec_start() and R_gcm_repeat() combination is same as R_gcm_dec().

5. LLVM

5.1 Development environment

Please use the same or a later version of the toolchain listed below:

- Integrated Development Environment:
  e2 studio 2022-01 (22.1.0)

- C compiler:
  LLVM for Renesas RL78 10.0.0.202203

5.2 ROM / RAM / Stack Size / Performance

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

Compiler options

CPU Type : S3-core

Optimization Level : Optimize size (-Os)

Table 14 ROM, RAM, and Stack Size of AES Library

API	ROM (*1)	RAM	Stack
R_Aes_128_Keysch	21,273	0	58
R_Aes_128_Ecbenc			82
R_Aes_128_Ecbdec			276
R_Aes_128_Cbcenc			160
R_Aes_128_Cbcdec			398
R_Aes_256_Keysch			58
R_Aes_256_Ecbenc			82
R_Aes_256_Ecbdec			340
R_Aes_256_Cbcenc			160
R_Aes_256_Cbcdec			462

(*1) A value in case all the APIs is used. This value changes with the number of APIs to be used.

The ROM, RAM, and stack size of GCM Library functions (API) are shown below (Unit = byte):

Table 15 ROM, RAM, and Stack Size of GCM Library

API	ROM	RAM	Stack (*1)
R_gcm_enc	10,185	0	670
R_gcm_dec			670
R_gcm_enc_start			38
R_gcm_dec_start			38
R_gcm_repeat			502

(*1) This is the value when combined with the AES library including the driver part.

Table 16 AES Library Performance

API	time [us] @ system clock = 32MHz	
	1 block	3 blocks
R_Aes_128_Keysch	190	
R_Aes_128_Ecbenc	620	1,840
R_Aes_128_Ecbdec	1,140	2,450
R_Aes_128_Cbcenc	650	1,930
R_Aes_128_Cbcdec	1,190	3,520
R_Aes_256_Keysch	240	
R_Aes_256_Ecbenc	860	2,590
R_Aes_256_Ecbdec	1,860	3,670
R_Aes_256_Cbcenc	900	2,670
R_Aes_256_Cbcdec	1,890	5,650

Table 17 GCM Library Performance

API	Key Type	time [ms] @ system clock = 32MHz	
		1 block	3 blocks
R_gcm_enc	128bit	9.9	16.4
	256bit	10.9	17.8
R_gcm_dec	128bit	10.0	16.5
	256bit	10.9	18.0

Notes: 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).
3. Performance of R_gcm_enc_start() and R_gcm_repeat() combination is same as R_gcm_enc().
4. Performance of R_gcm_dec_start() and R_gcm_repeat() combination is same as R_gcm_dec().

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Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Mar 31, 2012	—	First edition issued
1.01	Nov 30, 2012	—	Add Function of AES-192 and AES-256.
1.02	Mar 29, 2013	—	Added GCM Library.
1.03	Apr 19, 2013	—	Update 5. ROM / RAM / Stack Size 7. Performance 8. Version Information
1.04	Apr 20, 2013	—	Update 8. Version Information
1.05	Apr 23, 2013	2	Update File name of document in Table 1.
1.06	Aug 30, 2013	—	Updated “Structure of This Product” section for package version V.1.04 Release 01. CubeSuite+ version info to section.3, Added IAR version info to section.4. Changed 3.7. Notes section, because additional of libraries for each model. Added 5. Software Update Information section.
1.07	Dec 01, 2015	—	Updated “Structure of This Product” section, “Software Update Information”section, “Performance” and etc for package version V.1.05 Release 00. Added 4. CS+ for CC section.
2.00	Apr 21, 2021	—	The product configuration, software update history, library performance, etc. have been updated according to the package version V.1.06 Release 00.
2.01	Jun 30, 2022	—	Supported LLVM.

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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