RL78 Family

FFT Library: Deployment Guide

Introduction

This document provides information for deploying FFT Library. Fast Fourier transform (FFT) is an algorithm that executes the discrete Fourier transform at high speed. The implementation developed in 1965 by James Cooley and John Tukey, now widely known as FFT, has contributed to the rapid advancement of digital signal processing applications.

The FFT library is provided in a version that has been tuned at the assembly language level to enable efficient processing on Renesas MCUs.

Target Devices

RL78/G13, RL78/G14, RL78/G23, RL78/G15

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

Contents

1. Product Configuration

The product comprises the following items.

1. FFT Library V. 1.03 Release 00
2. FFT Library V. 1.03 Release 00: Deployment Guide (r20an0150ej0107_rl78_fft.pdf)
   Product No.: R0M7800LF0010RRC

The product comprises the files listed in Table 1.1.

Table 1.1 FFT Library Configuration

	Description
r20an0150ej0107_rl78_fft.pdf	Deployment guide (this document)
Workspace (workspace)	
Documents (doc)	
English (en)	
r20uw0099ej0102_fft.pdf	User's Manual
r20an0150ej0107_rl78_fft.pdf	Deployment guide (this document)
Japanese (ja)	
r20uw0099jj0102_fft.pdf	User's Manual
r20an0150jj0107_rl78_fft.pdf	Deployment guide
CS+, e²studio for CC (CS+, e²studio for CC)	
FFT library (sample/<sample program folder>lib)	
libfft_rl78g13.lib	FFT library for RL78/G13 (assembler version), version 1.01
libfft_rl78g14.lib	FFT library for RL78/G14 and RL78/G23 (assembler version), version 1.01
libfft_rl78_S2_NOMDA.lib	FFT library for RL78/G15 (assembler version), version 1.03
r_fft_int16.h	FFT library header file
r_stdint.h	Type definition header file
Sample program (sample)	
rl78g14_fft_ccrl_CS+	Sample CS+ for CC project (RL78/G14 and RL78/G23)
rl78g14_fft_ccrl_e2studio	Sample e²studio for CC project (RL78/G14 and RL78/G23)
rl78g15_fft_ccrl_CS+	Sample CS+ for CC project (RL78/G15)
rl78g14_fft_ccrl_e2studio	Sample e²studio for CC project (RL78/G15)
IAR Embedded Workbench (IAR)	
FFT library (sample/<sample program folder>lib)	
libfft_rl78g14.a	FFT library for RL78/G14 and RL78/G23 (assembler version), version 1.01
libfft_rl78_S2_NOMDA.a	FFT library for RL78/G15 (assembler version), version 1.03
r_fft_int16.h	FFT library header file
r_stdint.h	Type definition header file
Sample program (sample)	
rl78g14_fft_iar	Sample IAR Embedded Workbench project (RL78/G14 and RL78/G23)
rl78g15_fft_iar	Sample IAR Embedded Workbench project (RL78/G15)
e²studio for LLVM	
FFT library (sample\<sample-program-folder>\lib)	
libfft_rl78.a	FFT library for RL78/G23 (assembler version) version 1.01
libfft_rl78_S2_NOMDA.a	FFT library for RL78/G15 (assembler version) version 1.03
r_fft_int16.h	FFT library header file
r_stdint.h	Type definition header file
Sample program (sample)	
rl78g14_fft_llvm_e2tudio	Sample e²studio for LLVM project (RL78/G23)
rl78g15_fft_llvm_e2tudio	Sample e²studio for LLVM project (RL78/G15)

2. Library Functions

The FFT library supports the following library functions (APIs).

API	Description
R_rfft64_int16	16-bit fixed-point real-number FFT (64 points)
R_rfft128_int16	16-bit fixed-point real-number FFT (128 points)
R_rfft256_int16	16-bit fixed-point real-number FFT (256 points)

3. CS+, e²studio for CC

3.1 Limitations

The FFT library for the RL78/G13 uses the MCU's on-chip multiplier and divider/multiply-accumulator for multiply-accumulate operations. Therefore, it is necessary to ensure that the register values listed below are not changed within interrupt handlers implemented by the user. For information on the multiplier and divider/multiply-accumulator and related registers, refer to chapter 14, Multiplier and Divider/Multiply-Accumulator, in RL78/G13 User's Manual: Hardware.

Registers

- Multiplication/division data register A (L) (MDAL)
- Multiplication/division data register A (H) (MDAH)
- Multiplication/division data register B (L) (MDBL)
- Multiplication/division data register B (H) (MDBH)
- Multiplication/division data register C (L) (MDCL)
- Multiplication/division data register C (H) (MDCH)

Control register

- Multiplication/division control register (MDUC)

3.2 Compiler Options

The library files are generated using the following compile options.

[Compile options]

FFT library for RL78/G13, RL78/G14 and RL78/G23:

```
-asmopt=-mirror_source=common -memory_model=medium
```

FFT library for RL78/G15:

```
-asmopt=-mirror_source=0 -memory_model=medium
-cpu=S2 -Odefault
```

3.3 Development Environment

The Renesas development environment consists of the items listed below.

Make sure to use the latest versions available when developing user applications.

[Software tools]

FFT library for RL78/G13, RL78/G14 and RL78/G23:

- Integrated development environment
  CS+ for CC V8.06.00
- C compiler
  CC-RL V1.10
- Debugger
  RL78 simulator

FFT library for RL78/G15:

- Integrated development environment
  CS+ for CC V8.08.00
  e^{2}studio Version: 2022-10(22.10.0)
- C compiler
  CC-RL V1.11.00
- Debugger
  E2 Lite emulator

3.4 ROM, RAM, and Stack Sizes

The ROM, RAM, and stack sizes of the various FFT library APIs are listed below (unit: bytes).

FFT library for RL78/G13:

API	ROM	RAM	Stack
R_rfft64_int16	1,260	0	68
R_rfft128_int16	1,512	0	68
R_rfft256_int16	2,018	0	68

FFT library for RL78/G14 and RL78/G23:

API	ROM	RAM	Stack
R_rfft64_int16	1,224	0	68
R_rfft128_int16	1,476	0	68
R_rfft256_int16	1,982	0	68

FFT library for RL78/G15:

API	ROM	RAM	Stack
R_rfft64_int16	1,358	0	82
R_rfft128_int16	1,610	0	82

3.5 Section Information

The sections (segments) used by the various FFT library APIs are listed in the table below.

FFT library for RL78/G13, RL78/G14 and RL78/G23:

Section Name	Description	Section Attribute
.textf	Program	.CSEG TEXTF
.const	Constant data	.CSEG CONST

FFT library for RL78/G15:

Section Name	Description	Section Attribute
.text	Program	SECTION=.text
.const	Constant data	SECTION=.const

3.6 Library Performance

The processing times when calling the various library functions (APIs) are listed below.

FFT library for RL78/G13:

API	Time (System Clock = 32 MHz)
R_rfft64_int16	Approx. 0.4 ms
R_rfft128_int16	Approx. 0.9 ms
R_rfft256_int16	Approx. 1.9 ms

FFT library for RL78/G14 and RL78/G23:

API	Time (System Clock = 32 MHz)
R_rfft64_int16	Approx. 0.3 ms
R_rfft128_int16	Approx. 0.7 ms
R_rfft256_int16	Approx. 1.6 ms

Measured using the execution time measurement function of the integrated development environment (CS+)

FFT library for RL78/G15:

API	Time (System Clock = 16 MHz)
R_rfft64_int16	Approx. 29.3 ms
R_rfft128_int16	Approx. 73.1 ms

Measured using the execution time measurement function of the integrated development environment (e^2studio)

3.7 Version Information

The version information for the library is stored as a character string in the r_fft_a_version variable. This variable can be accessed by means of the following extern declaration.

```
extern const char r_fft_a_version[];
```

The data stored in the libraries comprising the current product is shown below.

FFT library for RL78/G13:

```
const char r_fft_a_version[] =
“FFT Library version 1.01 for RL78 Family (RL78G13) (Dec  7 2015, 17:30:04)”;
```

FFT library for RL78/G14 and RL78/G23:

```
const char r_fft_a_version[] =
“FFT Library version 1.01 for RL78 Family (RL78G14) (Dec  7 2015, 17:29:42)”;
```

FFT library for RL78/G15:

```
const char r_fft_a_version[] =
“FFT Library version 1.03 for RL78 Family”;
```

4. IAR Embedded Workbench

4.1 Compiler Options

The library files are generated using the following compile options.

[Compile options]

FFT library for RL78/G14 and RL78/G23:

```
__FAR_MODEL__  __NEAR_DATA_MODEL__
NDEBUG  __RL78__  __TARGET__=RL78G14
```

FFT library for RL78/G15:

```
__NEAR_MODEL__  __NEAR_DATA_MODEL__
NDEBUG  __RL78__  __TARGET__=RL78G15
```

4.2 Development Environment

The Renesas development environment consists of the items listed below.

Make sure to use the latest versions available when developing user applications.

[Software tools]

- Integrated development environment
  IAR Embedded Workbench for Renesas RL78 4.21.1
- C compiler
  IAR C/C++ Compiler for Renesas RL78 4.21.1.2409
- Debugger
  IAR C-SPY Debugger Kernel 8.5.2.7561

4.3 ROM, RAM, and Stack Sizes

The ROM, RAM, and stack sizes of the various FFT library APIs are listed below (unit: bytes).

FFT library for RL78/G14 and RL78/G23:

API	ROM	RAM	Stack
R_rfft64_int16	1,226	0	68
R_rfft128_int16	1,478	0	68
R_rfft256_int16	1,984	0	68

FFT library for RL78/G15:

API	ROM	RAM	Stack
R_rfft64_int16	1,350	0	82
R_rfft128_int16	1,602	0	82

4.4 Section Information

The sections (segments) used by the various FFT library APIs are listed in the table below.

FFT library for RL78/G14 and RL78/G23:

Section Name	Description
.textf	Program
.const	Constant data

4.5 Library Performance

The processing times when calling the various library functions (APIs) are listed below.

FFT library for RL78/G14 and RL78/G23:

API	Time (System Clock = 32 MHz)
R_rfft64_int16	Approx. 0.2 ms
R_rfft128_int16	Approx. 0.6 ms
R_rfft256_int16	Approx. 1.5 ms

Measured using the execution time measurement function of the integrated development environment (IAR Embedded Workbench for Renesas RL78))

FFT library for RL78/G15:

API	Time (System Clock = 16 MHz)
R_rfft64_int16	Approx. 18.3 ms
R_rfft128_int16	Approx. 44.4 ms

Measured using the execution time measurement function of the integrated development environment (IAR Embedded Workbench for Renesas RL78))

4.6 Version Information

The version information for the library is stored as a character string in the r_fft_a_version variable. This variable can be accessed by means of the following extern declaration.

```
extern const char r_fft_a_version[];
```

The data stored in the libraries comprising the current product is shown below.

FFT library for RL78/G14 and RL78/G23:

```
const char r_fft_a_version[] =
“FFT Library version 1.01 for RL78 Family (RL78G14) (Sep  7 2021, 13:40:39)”;
```

FFT library for RL78/G15:

```
const char r_fft_a_version[] =
“FFT Library version 1.03 for RL78 Family”;
```

5. e²studio for LLVM

5.1 Compiler Options

The library files were generated by using the following compile options.

[Compile options]

```
FFT library for RL78/G23:CPU Type: S3-core
Optimization: None(-O0)
```

FFT library for RL78/G15:

```
CPU Type: S2-core
Optimization: None(-O0)
```

5.2 Development Environment

The Renesas development environment consists of the items listed below.

Make sure to use the latest versions available when developing user applications.

[Software tools]

FFT library for RL78/G23:

- Integrated development environment
  e²studio (version 2022-04 (22.4.0))
- C compiler
  LLVM V10.0.0.202203
- Debugger
  E2 Lite emulator

FFT library for RL78/G15:

- Integrated development environment
  e²studio (version 2022-10 (22.10.0))
- C compiler
  LLVM V10.0.0.202207
- Debugger
  E2 Lite emulator

5.3 ROM, RAM, and Stack Sizes

The ROM, RAM, and stack sizes of the various FFT APIs are listed below (unit: bytes).

FFT library for RL78/G23:

API	ROM	RAM	Stack
R_rfft64_int16	1224	0	68
R_rfft128_int16	1476	0	68
R_rfft256_int16	1982	0	68

FFT library for RL78/G15:

API	ROM	RAM	Stack
R_rfft64_int16	1346	0	82
R_rfft128_int16	1854	0	82

5.4 Section Information

The sections (segments) used by the various FFT library APIs are listed in the table below.

Section Name	Description
.text	Program
.rodata	Constant data

5.5 Library Performance

The processing times when calling the various library functions (APIs) are listed below.

FFT library for RL78/G23:

API	Time (System Clock = 32 MHz)
R_rfft64_int16	Approx. 0.3 ms
R_rfft128_int16	Approx. 0.7 ms
R_rfft256_int16	Approx. 1.6 ms

FFT library for RL78/G15:

API	Time (System Clock = 16 MHz)
R_rfft64_int16	Approx. 29.2 ms
R_rfft128_int16	Approx. 73.2 ms

Measured using the execution time measurement function of the integrated development environment (e2studio)

5.6 Version Information

The version information for the library is stored as a character string in the r_fft_a_version variable. This variable can be accessed by means of the following extern declaration.

```
extern const char r_fft_a_version[];
```

The data stored in the libraries comprising the current product is shown below.

FFT library for RL78/G23:

```
const char r_fft_a_version[] =
“FFT Library version 1.01 for RL78 Family”;
```

FFT library for RL78/G15:

```
const char r_fft_a_version[] =
“FFT Library version 1.03 for RL78 Family”;
```

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Mar. 31, 2012	—	First edition issued
1.01	Apr.1, 2014	—	Updated product configuration to match package version V. 1.00 Release 01. Added support for IAR Embedded Workbench.
1.02	Apr.1, 2015	2	Updated product configuration to match package version V. 1.00 Release 02.
1.03	Oct. 1, 2015	—	Changed CubeSuite+ to CS+ for CA and CX. Added support for CS+ for CC.
1.04	Apr. 13, 2021	—	Added RL78/G23 to CS+ for CC. Deleted IAR.
1.05	Oct. 25, 2021	P6 P8-P10	Remove CS + for CA, CX Updated the processing time of FFT library for RL78/G14 and RL78/G23 Add IAR
1.06	Jun. 27, 2022	P3 P11-P13	Added "e^{2}studio for LLVM" in "Table 1.1 FFT Library Configuration". Added chapter "5. e^{2}studio for LLVM".
1.07	Sep. 26, 2022	—	Added RL78/G15

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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