

## Renesas RA Family

### Arm® DSP Examples

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#### Introduction

This application note describes the use of ARM® CMSIS-DSP example projects that are ported to Renesas Arm® Cortex-M33 and Cortex-M23 core based MCUs with digital signal processing (DSP) extension, and Floating Point Unit (FPU). This application note will discuss the steps to import, configure, build, and execute these DSP examples and measure their performances.

All information regarding to Arm CMSIS-DSP can be found at the following link:

[https://arm-software.github.io/CMSIS\\_5/DSP/html/group\\_groupExamples.html](https://arm-software.github.io/CMSIS_5/DSP/html/group_groupExamples.html)

#### Target Devices

This application note focuses on RA6M4 MCU. However, it also applies to any Arm Cortex-M33 and Cortex-M23 core based Renesas MCUs. It includes M23 RA2 devices and M33 RA4 and RA6 devices.

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## 1. Arm® CMSIS-DSP Library in Renesas Flexible Software Package (FSPv5.0.0 or above)

The CMSIS DSP software library is a suite of common signal processing functions for use on Cortex-M and Cortex-A processor-based devices.

The library is divided into several functions, each covering a specific category.

- Basic math functions
- Fast math functions
- Complex math functions
- Filtering functions
- Matrix functions
- Transform functions
- Motor control functions
- Statistical functions
- Support functions
- Interpolation functions
- Support Vector Machine (SVM) functions
- Bayes classifier functions
- Distance functions

The library generally has separate functions for operating on 8-bit integers, 16-bit integers, 32-bit integers and 32-bit floating-point values. It is ported to FSP and can be easily included into your project by using **New Stack** in the **Stacks** tab in FSP configurator, as shown in Figure 1.

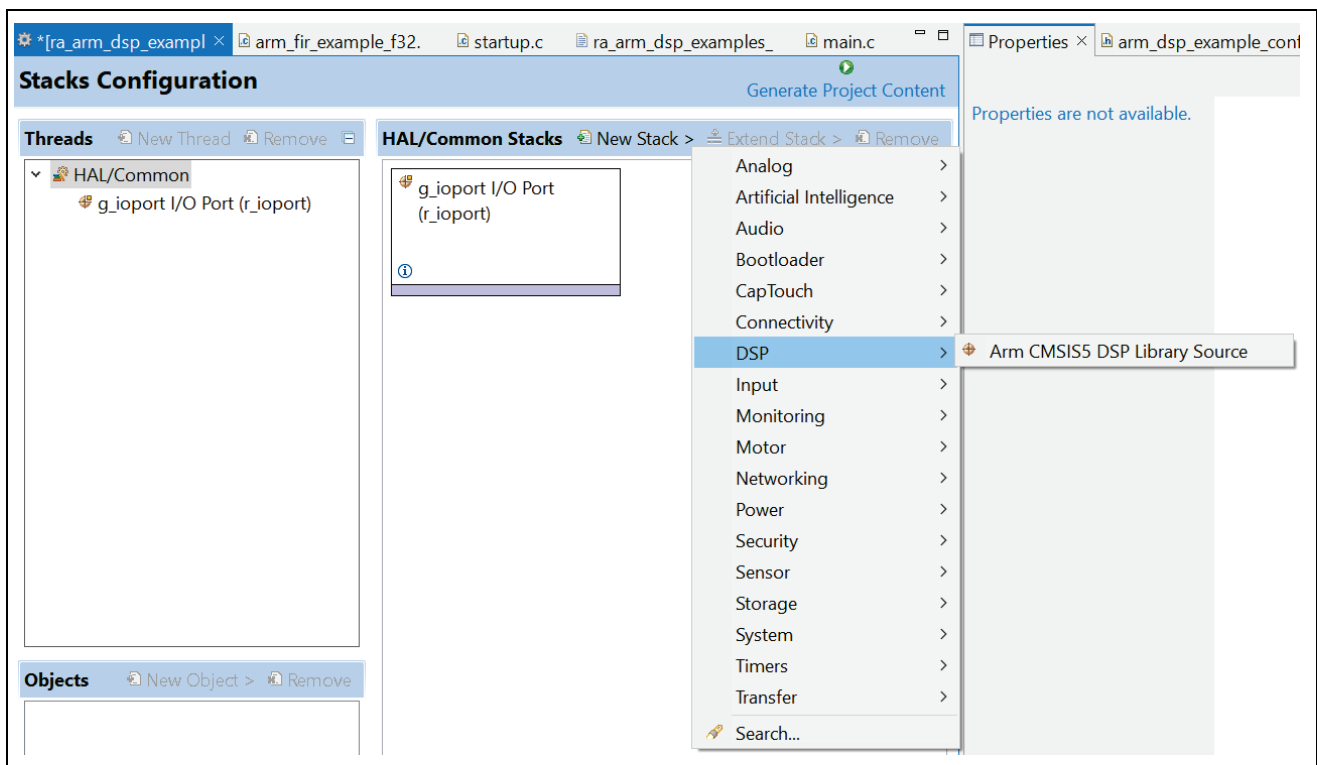
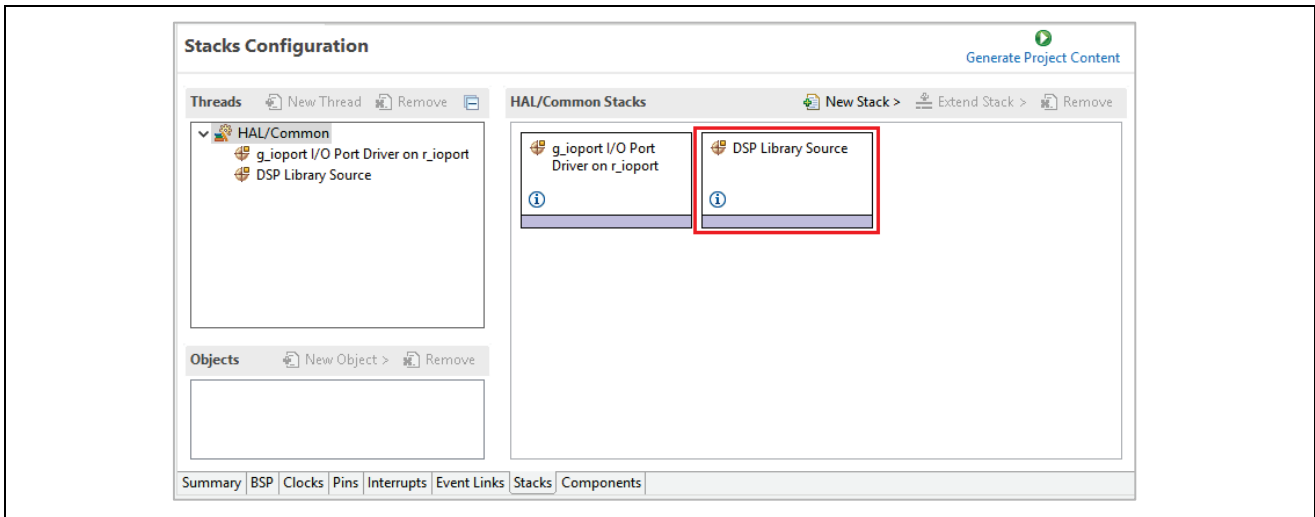


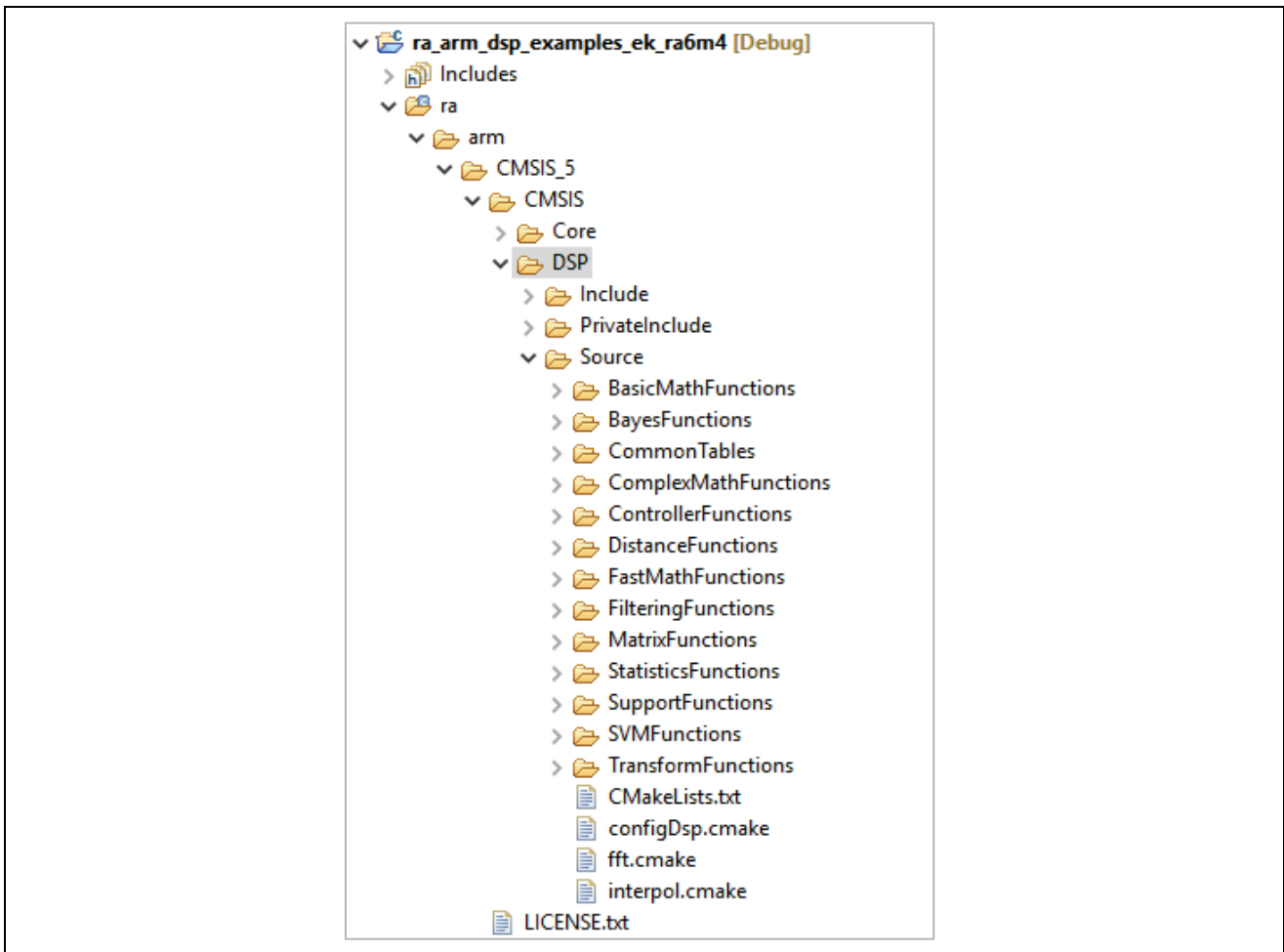
Figure 1. Adding CMSIS-DSP Library Source in FSP Configurator Using New Stack Feature



**Figure 2. Adding CMSIS-DSP Source Library in FSP Configurator**

Pressing **Generate Project Content** will generate the CMSIS-DSP library in your project.

Header and source files are created as shown in Figure 3.



**Figure 3. CMSIS-DSP Library Source in Example Project**

## 2. Arm CMSIS-DSP Examples

Original Arm CMSIS-DSP examples are ported to the e<sup>2</sup> studio/FSP environment in a single project form. This example project includes multiple CMSIS-DSP examples. Below is the list of examples supported by this example project.

- Sin Cos example
- Signal Convergence example
- Linear Interpolate example
- Graphic Audio Equalizer example
- Lowpass Filter example
- Frequency Bin example
- Dot Product example
- Convolution example
- Variance example
- Matrix example
- Class Marks example
- Bayes example
- SVM example

Details of the example project import can be found [here](#).

Details of the above examples can be found [here](#).

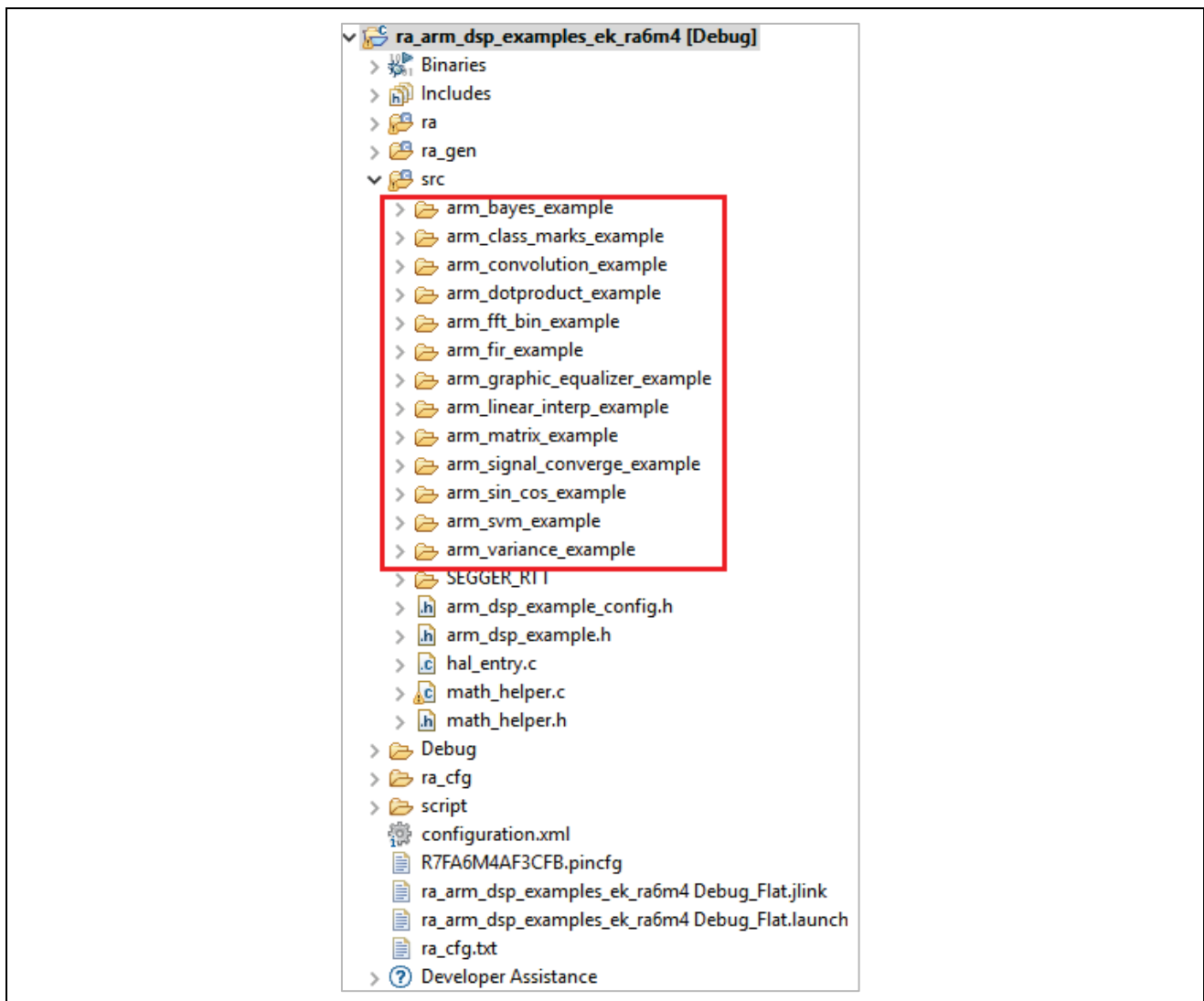


Figure 4. Example Project are Imported to e<sup>2</sup> studio Including Multiple CMSIS-DSP Examples

Each CMSIS-DSP example is enabled using its macro definition in arm\_dsp\_example\_config.h.

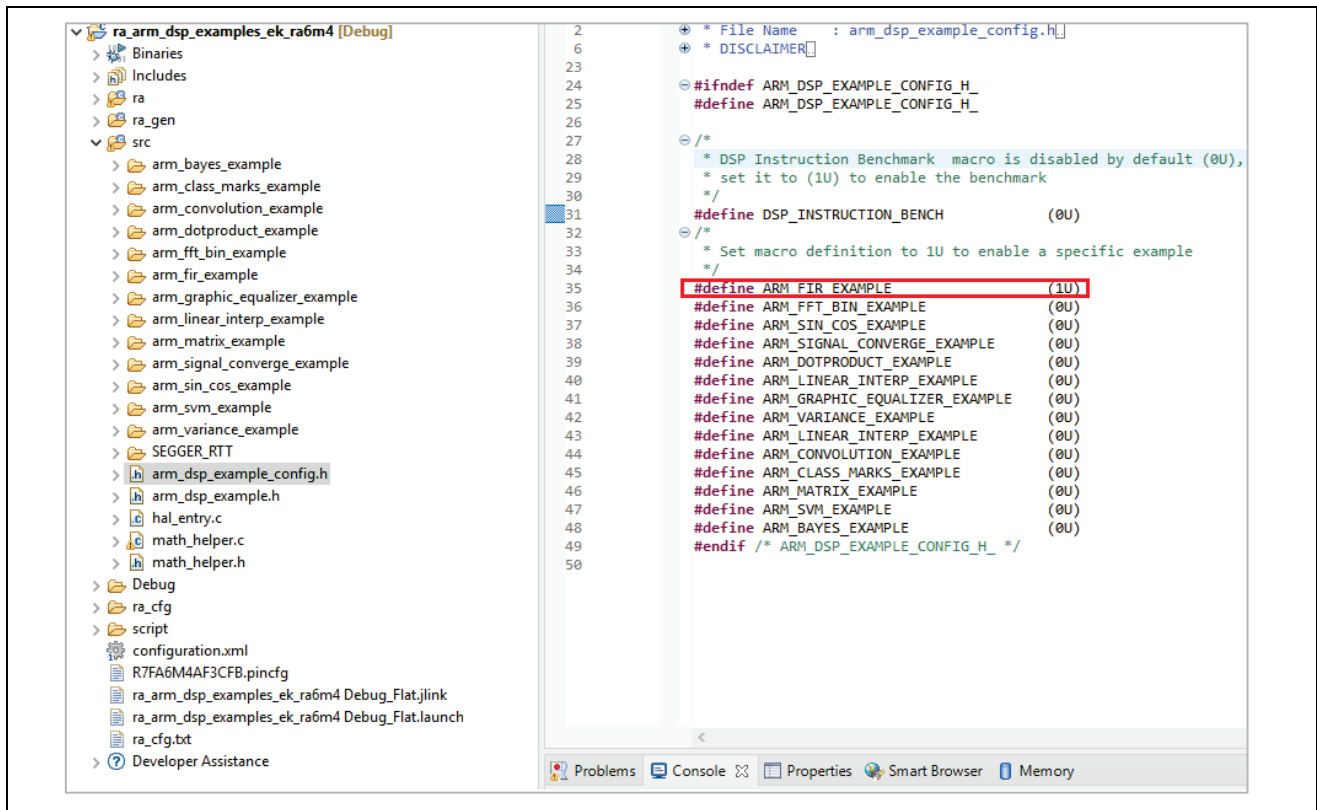



Figure 5. arm\_dsp\_example\_config.h

## 2.1 Build and Run CMSIS\_DSP Example

After importing the example project, enable the example project that you wish to run in arm\_dsp\_example\_config.h.

You now can build, download, and run the project. The following screenshots show an example of running the Lowpass Filter example.

After downloading and running the project, wait for a few seconds and hit the **Suspend** button  to stop project execution.

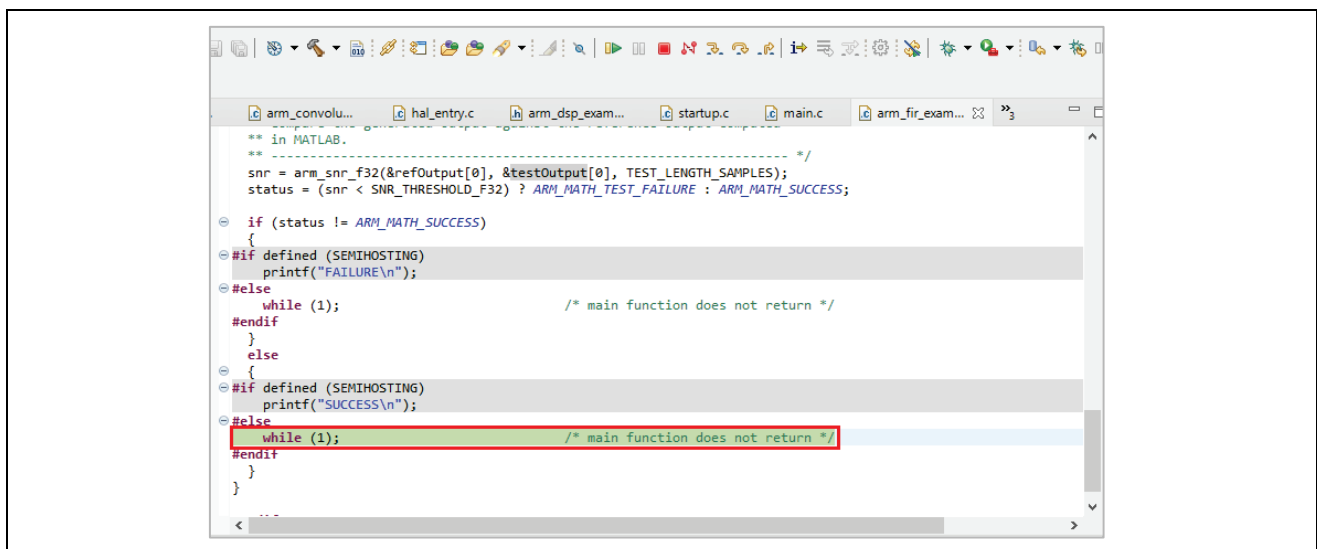


Figure 6. Lowpass Filter example Ran Successfully and Stopped at “SUCCESS” while (1)

The waveforms of input and output buffers can be used to visually verify the result. Add testOutput buffer to the **Memory** tab as shown in Figure 7, then add a new **Fixed Floating Point** rendering for the same buffer.

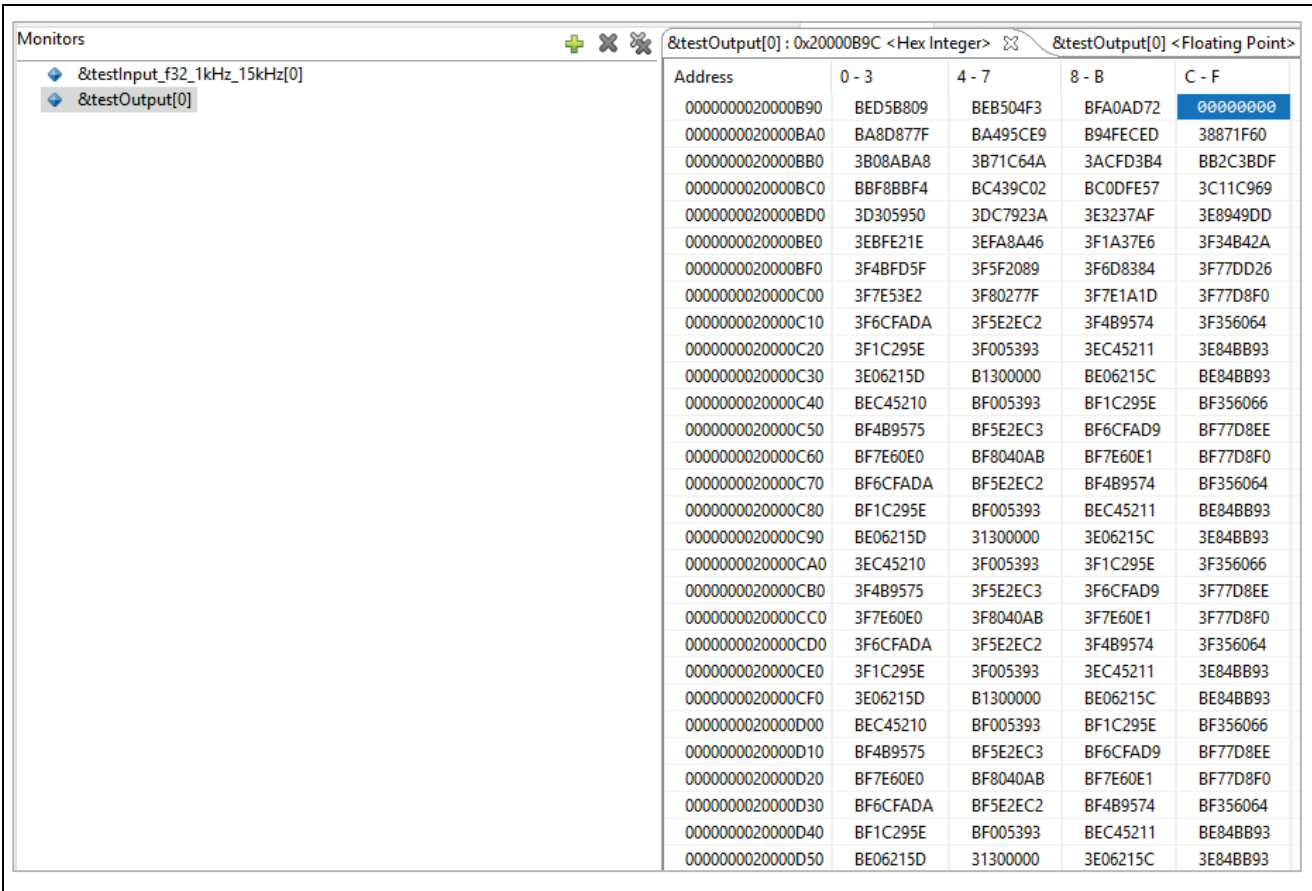


Figure 7. testInput\_f32\_1kHz\_15kHz Buffer of Lowpass Filter Example

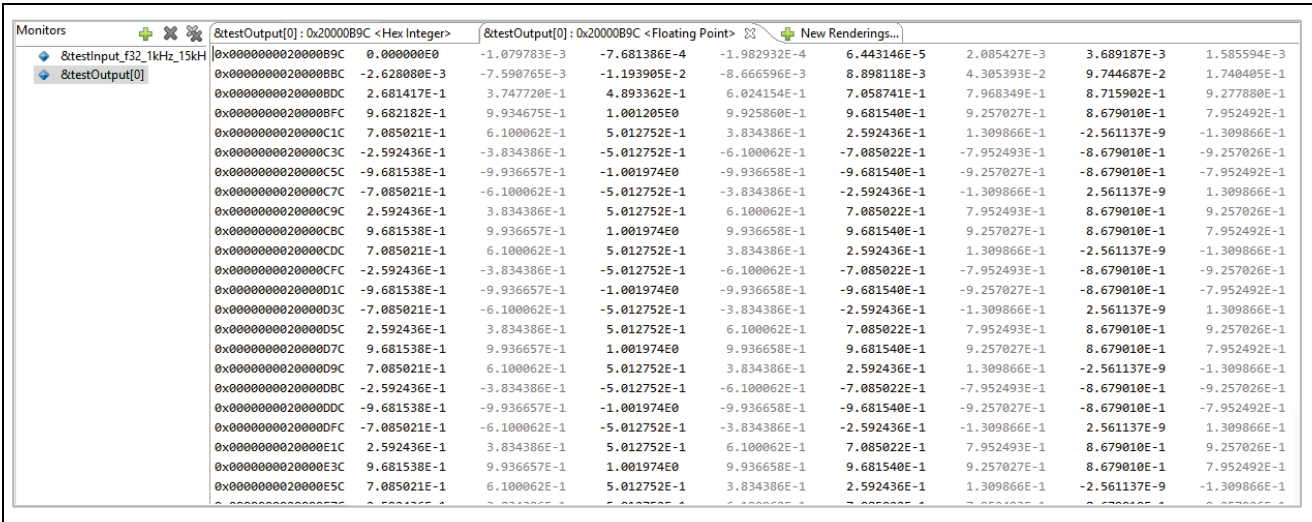


Figure 8. testOutput Buffer in Floating Point format of Lowpass Filter Example

The testInput and testOutput buffers can be visually shown using plotting software such as MATLAB. You can copy floating point data from **Floating Point Rendering** tab by selecting the memory area and using **Copy to Clipboard** to copy. You need to manually edit the data to be able to use it with plotting tools.

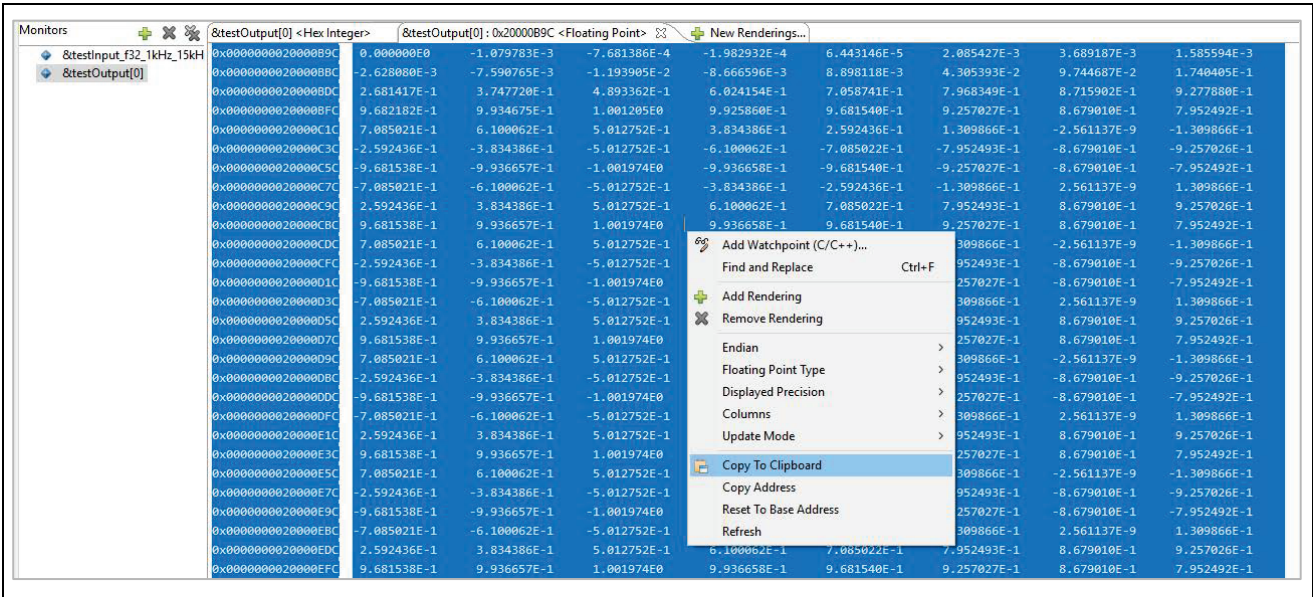


Figure 9. Copy testOutput Buffer to Clipboard

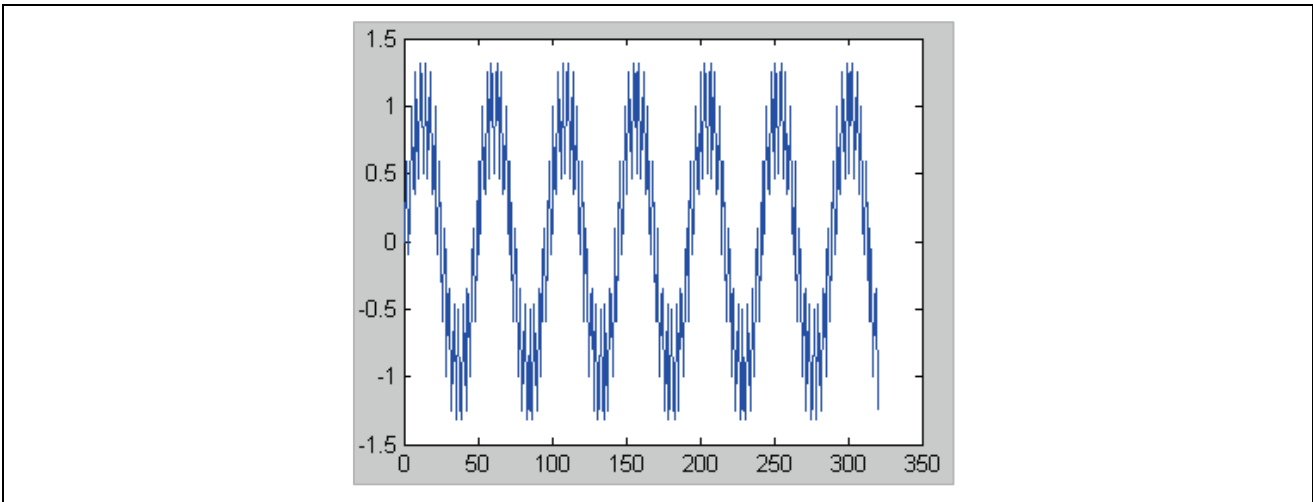


Figure 10. Waveform of Input Buffer of Lowpass Filter Example

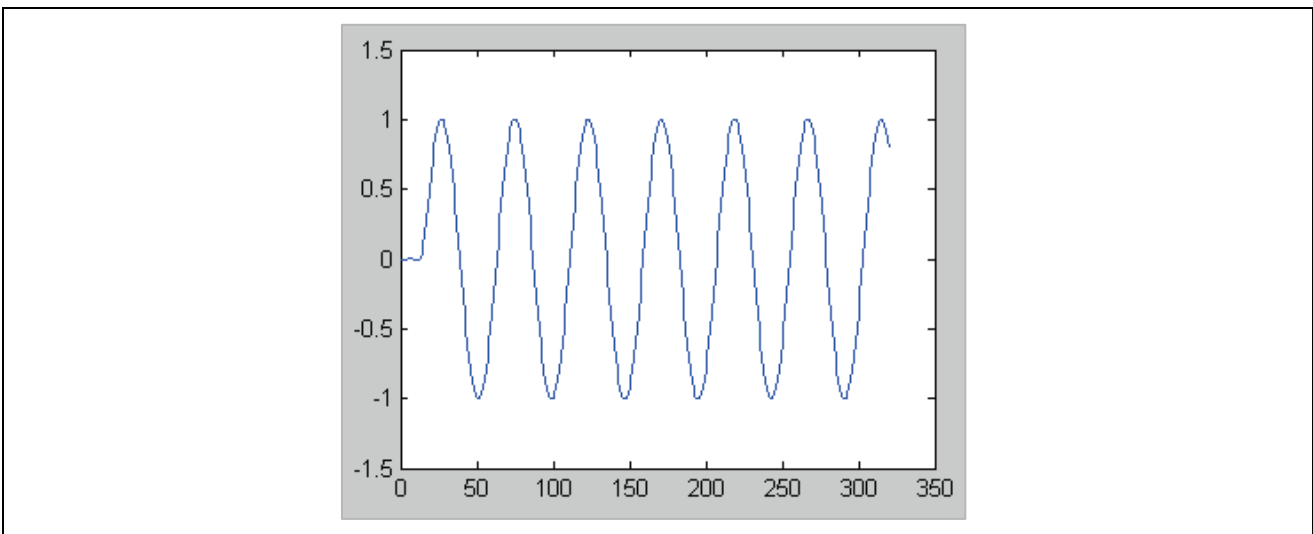


Figure 11. Waveform of Output Buffer of Lowpass Filter Example

### 2.2 Project Settings

The following settings are needed to get the best performance from Cortex-M33 core with DSP extension.

Parameter	Default	Setting	Notes
-mfloat-abi	hard	hard	MCU has hardware support
-mfpu	fpv5-sp-d16	fpv5-sp-d16	MCU supports this version
semihosting-enable	false	false	Not use semihosting
-march	Toolchain default	armv8-m.main+dsp	MCU has DSP support
Optimization	-O2	-O3	Optimize most
BSP/Heap Size	0x0	0x200	Heap size
Miscellaneous	false	Use float with nano printf	GNU ARM Cross Linker

The following settings are needed to get the best performance from Cortex-M23 core with DSP extension.

Parameter	Default	Setting	Notes
-mfloat-abi	hard	hard	MCU has hardware support
-mfpu	Toolchain default	Toolchain default	Toolchain default
semihosting-enable	false	false	Not use semihosting
-march	Toolchain default	Toolchain default	MCU has DSP support
Optimization	-O2	-O2	Optimize more
BSP/Heap Size	0x0	0x100	Heap size
Miscellaneous	false	Use float with nano printf	GNU ARM Cross Linker

## 3. Performance Measurement

### 3.1 Enable Performance Measurement

The DSP\_INSTRUCTION\_BENCH macro in arm\_dsp\_example\_config.h is used to enable example code to measure performance of the arm\_fir\_f32 function in the arm\_fir\_example\_f32 example. Set DSP\_INSTRUCTION\_BENCH to 1U to enable this performance measurement. Set it to 0U to disable the measurement. Refer to section 3.2 for more details.

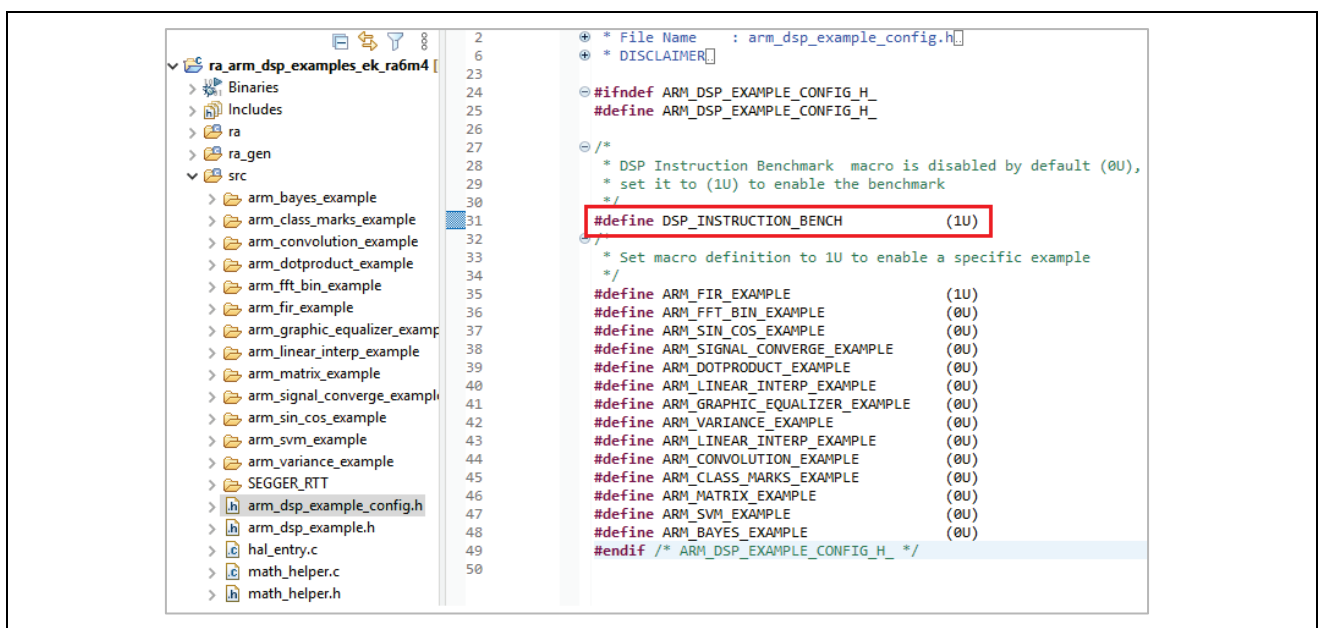


Figure 12. Enable Performance Measurement in arm\_dsp\_example\_config.h



## 3.2 Adding Supporting Code to Measure DWT Cycle

Store the DWT counter (DWT->CYCCNT) before and after calling the DSP function.

```

- #if DSP_INSTRUCTION_BENCH //Performance Benchmark
  uint32_t ts_0 = 0;
  uint32_t ts_1 = 0;
  uint32_t dwt_cycle = 0;
  ts_0 = DWT->CYCCNT;
  R_LED_LED415ON();
- #endif
- /* -----
  ** Call the FIR process function for every blockSize samples
  ** ----- */
- for(i=0; i < numBlocks; i++)
  {
    arm_fir_f32(&S, inputF32 + (i * blockSize), outputF32 + (i * blockSize), blockSize);
  }
- #if DSP_INSTRUCTION_BENCH //Performance Benchmark
  ts_1 = DWT->CYCCNT;
  R_LED_LED415OFF();
- #endif

```

**Figure 13. Store DWT Before and After Calling DSP Functions**

The execution time of a specific DSP function call can be calculated based on DWT cycle and MCU system clock frequency (ICLK) using the following formula.

$$\text{Time} = \text{DWT cycle} \times (1/\text{ICLK})$$

**Note:** DWT cycles are the count of MCU execution cycles. ICLK is the system clock of the MCU, which is set to 200 MHz in this application project for EK-RA6M4.

```

- #if DSP_INSTRUCTION_BENCH //Performance Benchmark
  /* Calculate DW cycles */
  dwt_cycle = ts_1 > ts_0? ts_1 - ts_0 : ~(ts_0 - ts_1);
  APP_PRINT("DWT Clock Cycle: %d\n", dwt_cycle);
- #endif

```

**Figure 14. Calculate DWT Cycle**

### 3.2.1 Adding LED function Code to Measure DSP Processing Interval

The LED1 on the RA EK kits can be probed to measure the time taken to complete the signal processing operations. The LED1 is turned on before starting DSP operations and turned off after. This simple analysis technique is useful when DWT timer is not available with the CPU or preferred for measurement. Refer to `arm_fir_example_f32.c` for an example of this implementation, as shown in Figure 15.

```

- #if DSP_INSTRUCTION_BENCH //Performance Benchmark
  uint32_t ts_0 = 0;
  uint32_t ts_1 = 0;
  uint32_t dwt_cycle = 0;
  ts_0 = DWT->CYCCNT;
  R_LED_LED415ON();
- #endif
- /* -----
  ** Call the FIR process function for every blockSize samples
  ** ----- */
- for(i=0; i < numBlocks; i++)
  {
    arm_fir_f32(&S, inputF32 + (i * blockSize), outputF32 + (i * blockSize), blockSize);
  }
- #if DSP_INSTRUCTION_BENCH //Performance Benchmark
  ts_1 = DWT->CYCCNT;
  R_LED_LED415OFF();
- #endif

```

**Figure 15. Setting Points of LED Light Start and End for Timing Measurement**

- Using a digital oscilloscope and probe on the anode of the LED1 of EK-RA2E1 or EK-RA6M4, trigger the signal “High to Low”.

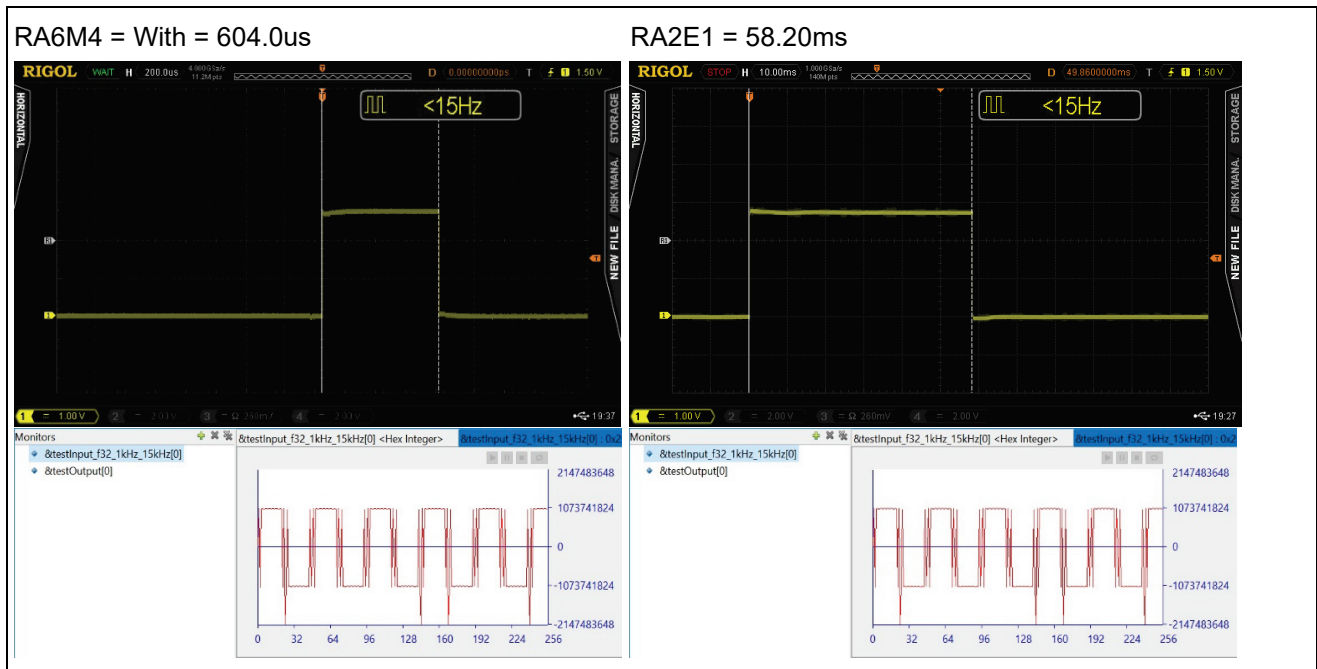


Figure 16. Timing measurement of EK-RA6M4 and EK-RA2E1

### 3.3 Printing Example Status

Example status and DWT cycle will be sent to SEGGER J-Link RTT Viewer. You can connect to SEGGER RTT Viewer using the following steps.

Launch SEGGER RTT Viewer V7.92j or greater from Windows Start Menu.

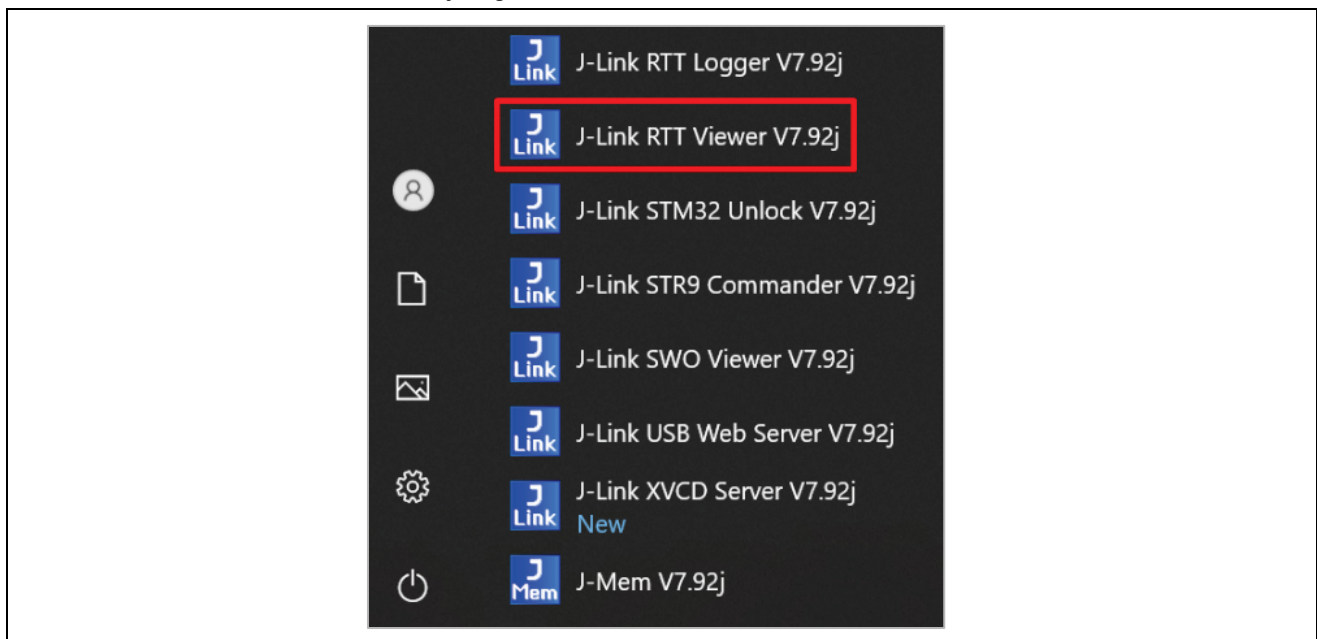


Figure 17. Launch J-Link RTT Viewer

**Note:** For communication between J-Link RTT Viewer and CM33 MCUs such as EK-RA6M4, users need to select **Address** option of RTT Control Block and enter the memories address shown in Figure 18. This address can be obtained from “ra\_arm\_dsp\_example\_ra6m4” under **Debug > ra\_arm\_dsp\_example\_ra6m4.map**. You search for “\_SEGGER\_RTT”. Every single **arm\_dsp\_example** will generate a new control block memory address.

.bss.firStateF32	0x20000c08	0xf0	./src/arm_fir_example/arm_fir_example_f32.o
.bss.testOutput	0x20000cf8	0x500	./src/arm_fir_example/arm_fir_example_f32.o
.bss._acDownBuffer	0x200011f8	0x10	./src/SEGGER_RTT/SEGGER_RTT.o
.bss._acUpBuffer	0x20001208	0x400	./src/SEGGER_RTT/SEGGER_RTT.o
.bss._SEGGER_RTT	0x20001608	0xa8	./src/SEGGER_RTT/SEGGER_RTT.o
	0x20001608		_SEGGER_RTT
.bss.g_ioport_ctrl	0x200016b0	0x8	./ra_gen/common_data.o
	0x200016b0		g_ioport_ctrl

Figure 18. J-Link RTT Viewer Control Block Address

Configure the SEGGER RTT Viewer.

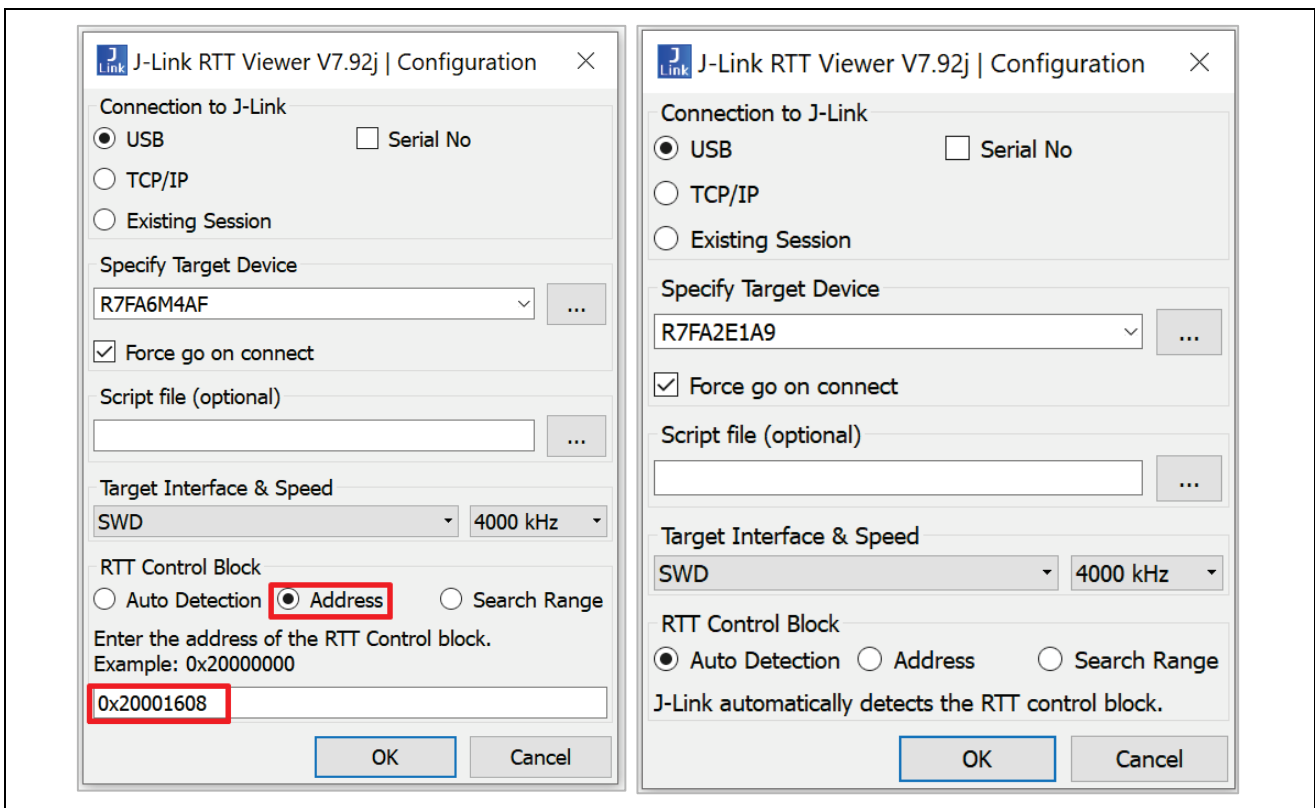


Figure 19. RTT Viewer Settings for EK-RA6M4 and EK-RA2E1

A typical example status output is shown below.

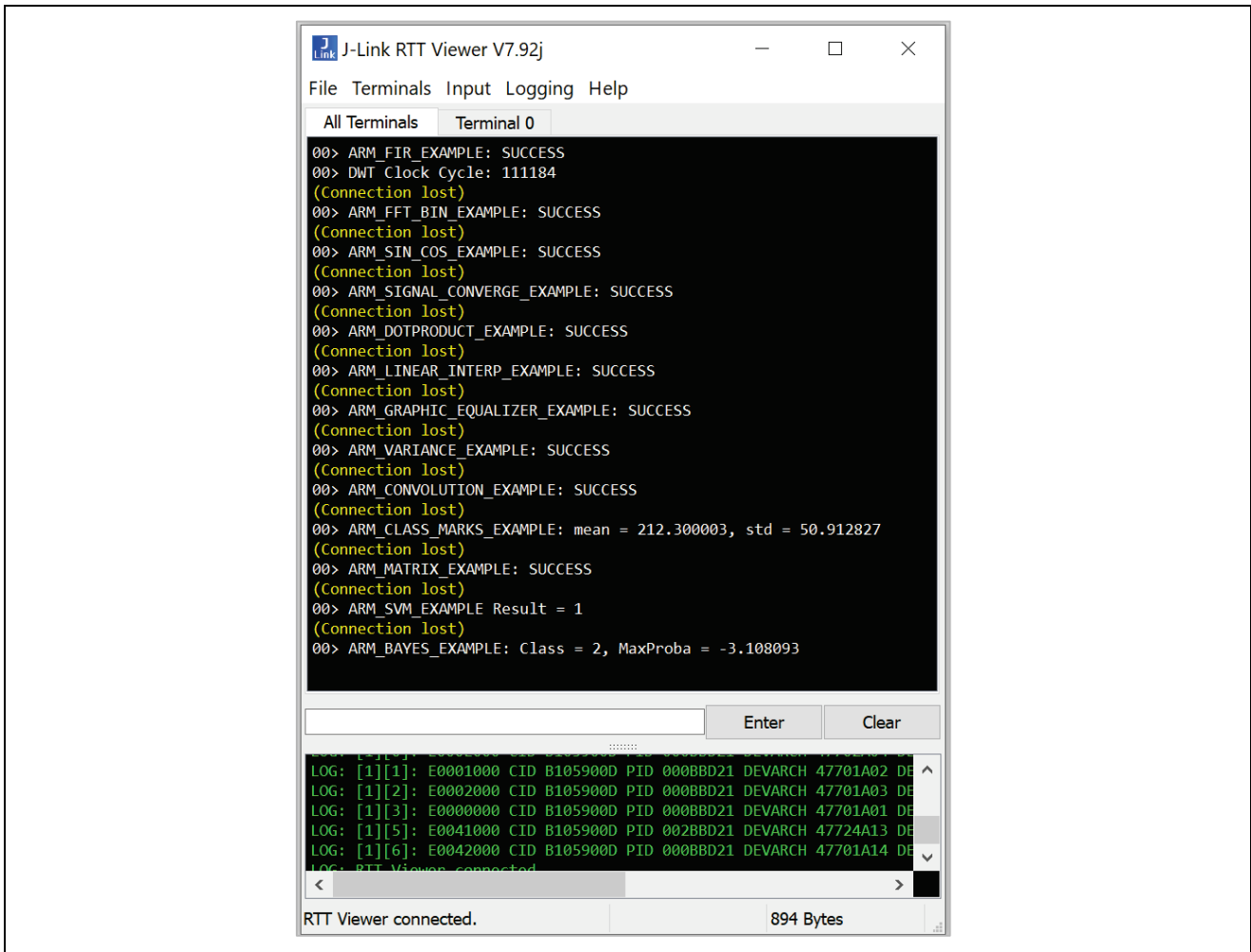


Figure 20. J-Link RTT Viewer Output

#### 4. Website and Support

Visit the following URLs to learn about key elements of the RA family, download components and related documentation, and get support:

RA Product Information	<a href="https://renesas.com/ra">renesas.com/ra</a>
RA Product Support Forum	<a href="https://renesas.com/ra/forum">renesas.com/ra/forum</a>
RA Flexible Software Package	<a href="https://renesas.com/FSP">renesas.com/FSP</a>
Renesas Support	<a href="https://renesas.com/support">renesas.com/support</a>

**Revision History**

Rev.	Date	Description	
		Page	Summary
1.00	May.17.21	—	First release document
1.10	March.21.23	— —	Added support and configuration for RA2 series MCU(s). Updated RA6M4 source code project and properties configuration
1.20	Feb.23.24	—	Update to FSP v5.0.0

## 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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