

Renesas RA Family Secure Bootloader for RA2 MCU Series

Introduction

MCUboot is a secure bootloader for 32-bit MCUs. It defines a common infrastructure for the bootloader, defines system flash layout on microcontroller systems, and provides a secure bootloader that enables easy software update. MCUboot is operating system and hardware independent and relies on hardware porting layers from the operating system it works with. MCUboot is maintained by Linaro in the GitHub mcu-tools page <u>https://github.com/mcu-tools/mcuboot.</u> There is a /docs folder that holds the documentation for MCUboot in .md file format. This application note refers to those documents wherever possible.

The Renesas Flexible Software Package (FSP) integrates an MCUboot port across the entire RA MCU Family starting from FSP v3.0.0. The Renesas RA2 MCU series is based on the Arm[®] Cortex[®]-M23 core and has limited flash and RAM memory. This application project is created to address the unique challenges and provide guidelines on the optimization of the RA2 MCU bootloader memory size. For the MCUboot cryptographic support for RA2 MCU groups, TinyCrypt (https://github.com/intel/tinycrypt/) is integrated with the FSP MCUboot module to provide a smaller memory footprint compared with Mbed Crypto. Refer to the GitHub folder /tinycrypt/documentation/ for details on the TinyCrypt cryptographic algorithm usage.

This application note guides you through secure bootloader creation using the MCUboot Module with TinyCrypt for enhanced security on the Renesas EK-RA2E1 kit. In addition, examples of how to configure the application project to use the bootloader are provided. The Overwrite, Swap and Direct XIP upgrade modes are discussed and example projects are provided to support these upgrade modes.

For the Renesas RA6 and RA4 MCU Series, Renesas provides an application project *Using MCUboot with Renesas RA MCU Application Project*, which guides you through using MCUboot with RA6 and RA4 MCU groups with Mbed Crypto module. See the References section for information on that application project.

Required Resources

Development Tools and Software

- e² studio IDE v2024-01
- Renesas Flexible Software Package (FSP) v5.2.0
- SEGGER J-link® USB driver v7.94g

The above three software components: the FSP, J-Link USB drivers, and e² studio are bundled in a downloadable platform installer available on the FSP webpage at <u>renesas.com/ra/fsp</u>.

Hardware

- EK-RA2E1 Evaluation Kit for RA2E1 MCU Group (<u>http://www.renesas.com/ra/ek-ra2e1</u>).
- Workstation running Windows[®] 10 and Tera Term console, or similar application.
- One USB device cable (type-A male to micro-B male).

Prerequisites and Intended Audience

This application note assumes that you have some experience with the Renesas e² studio IDE. You should read the entire MCUboot Port section in the *FSP User's Manual* prior to moving forward with this application project. In addition, the application note assumes that you have some knowledge of cryptography. Prior knowledge of Python usage is also helpful.

The intended audience are product developers, product manufacturers, product support, and end users who are involved with designing application systems involving use of a secure bootloader with the Renesas RA2 MCU family.



Using this Application Note

Section 1 presents a general overview of MCUboot and the application upgrade methods supported by MCUboot.

Section 2 describes the general flow of using the FSP MCUboot module to establish bootloader-based application systems.

Section 3 to Section 6 are the walk-throughs of how to create bootloader projects using Overwrite, Swap, and Direct XIP upgrade modes, how to configure the application projects to use the bootloader, and how to boot the primary and secondary images.

Section 7 provides instructions on how to directly run the included example projects without going through Sections 3 to 6. For a quick evaluation of the included example projects, you can go directly to Section 7.

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1. Overview of MCUboot

MCUboot is an open-source project hosted at <u>mcu-tools github project</u>. It is currently managed by the <u>Linaro</u> <u>Community Project</u>.

MCUboot handles the firmware integrity and authenticity check after startup and the firmware switch part of the firmware update process. The operation of switching the firmware from the original image to a new image depends on the image upgrade method. The image upgrade methods are described in section 1.1.2. Downloading the new version of the firmware is out of scope for MCUboot. Typically, downloading the new version of the firmware is provided by the application project itself.

1.1.1 Overview of Application Booting Process

For applications using MCUboot, the MCU memory is separated into MCUboot, Primary App, Secondary App, and the Scratch Area. The following is an example of the single-image MCUboot memory map.



Figure 1. Single Image MCUboot Memory Flash Map

The functionality of MCUboot during booting and updating follows the process below:

- 1. The bootloader is started when the CPU is released from reset.
- 2. If there are images in the Secondary App memory marked as to be updated, the bootloader performs the following actions:
 - A. The bootloader verifies the integrity and authenticity of the Secondary image.
 - B. Upon successful authentication, the bootloader switches to the new image based on the update method selected.
 - C. The bootloader boots the new image.
- 3. If there is no new image in the Secondary App memory region, the bootloader authenticates the Primary applications and boots the Primary image.

The authentication of the application is configurable in terms of the authentication methods and whether the authentication is to be performed with MCUboot. The firmware image can be authenticated by hash (SHA-256) and digital signature validation.

1.1.2 Application Update Strategies

The following update strategies are supported by MCUboot. The Renesas FSP MCUboot Module supports one or more of the following strategies depending on the FSP version. The analysis of pros and cons is based on the MCUboot functionality, not the FSP version specific MCUboot Module functionality. In addition, this application note is not intended to provide all details on the MCUboot application update strategies. We recommend acquiring more details on these update strategies by referring to the MCUboot design page:

https://github.com/mcu-tools/mcuboot/blob/master/docs/design.md



• Overwrite

In the Overwrite update mode, the active firmware image is always executed from the Primary slot, and the Secondary slot is a staging area for new images. Before the new firmware image is executed, the entire contents of the Primary slot are overwritten with the contents of the Secondary slot (the new firmware image).

- Pros:
 - Fail-safe and resistant to power-cut failures.
 - Less memory overhead, with a smaller MCUboot trailer and no Scratch Area.
 - Encrypted image support is available when using external flash.
- Cons:
 - Does not support pre-testing of the new image prior to overwrite.
 - Does not support automatic application fallback mechanism.

Overwrite upgrade mode is supported by Renesas RA FSP v3.0.0 or later. However, encrypted image support using external flash is not currently supported.

• Swap

In the Swap image upgrade mode, the active image is also stored in the Primary slot and is always started by the bootloader. If the bootloader finds a valid image in the Secondary slot that is marked for upgrade, then contents of the Primary slot and the Secondary slot are swapped. The new image then starts from the Primary slot.

- Pros:
 - The bootloader can revert the swapping as a fallback mechanism to recover the previous working firmware version after a faulty update.
 - The application can perform a self-test to mark itself permanent.
 - Fail-safe and resistant to power-cut failures.
 - Encrypted image support is available when using external flash.
- Cons:
 - Need to allocate a Scratch Area.
 - Larger memory overhead, due to a larger image trailer and additional Scratch Area.
 - Larger number of write cycles in the Scratch Area, wearing the Scratch sectors out faster.

Swap upgrade mode is supported by Renesas RA FSP v3.0.0 or later. However, encrypted images using external flash is not supported. Runtime image testing is supported from FSP v3.4.0 or later.

Direct execute-in-place (XIP)

In the direct execute-in-place mode, the active image slot alternates with each firmware update. If this update method is used, then two firmware update images must be generated: one of them is linked to be executed from the Primary slot memory region, and the other is linked to be executed from the Secondary slot.

- Pros:
 - Faster boot time, as there is no overwrite or swap of application images needed.
 - Fail-safe and resistant to power-cut failures.
- Cons:
 - Added application-level complexity to determine which firmware image needs to be downloaded.
 - Encrypted image support is not available.

Direct execute-in-place is supported by Renesas FSP v3.4.0 or later.

• RAM loading firmware update

Like the direct execute-in-place mode, RAM loading firmware update mode selects the newest image by reading the image version numbers in the image headers. However, instead of executing it in place, the newest image is copied to RAM for execution. The load address (the location in RAM where the image is copied to) is stored in the image header. This upgrade method is not typically used in an MCU environment. This image update mode does not support encrypted images. Refer to the <u>MCUboot Design Page</u> for more information on this update strategy.

RAM loading update mode is not supported by the Renesas RA FSP.



2. Architecting an Application with MCUboot Module using FSP for RA2 MCUs

This section provides an overview of the FSP MCUboot Module, the available application image upgrade modes, memory architecture design, and guidelines for mastering the new image. In addition, this section describes how the lightweight TinyCrypt is used in the RA2 bootloader design. We recommend reviewing the MCUboot Port section of the *FSP User's Manual* to understand the build time configurations for MCUboot.

2.1 Secure Booting with TinyCrypt

TinyCrypt is a small-footprint cryptography library targeting constrained devices. Its minimal set of standard cryptographic primitives are designed to provide secure messages, basic encryption, and random number generation, which are all needed to secure the small footprint of IoT devices. For the RA2 bootloader design, SHA256 and ECDSA from TinyCrypt are used to ensure the application image integrity and authenticity. TinyCrypt does not support RSA.

The FSP TinyCrypt port module does not provide any interfaces to the user. Consult the documentation at https://github.com/intel/tinycrypt/blob/master/documentation/tinycrypt.rst for further information on use of the TinyCrypt port. The software only module is available in FSP on all RA devices. Hardware acceleration for AES-128 through FSP TinyCrypt port is provided for the RA2 family.

2.2 Designing Bootloader and the Initial Primary Application Overview

A bootloader is typically designed with the initial primary application. The following are the general guidelines for designing the bootloader and the initial primary application:

- Develop the bootloader and analyze the MCU memory resource allocation needed for the bootloader and the application. The bootloader memory usage is influenced by the application image update mode, signature type, and whether to validate the Primary Image, as well as the cryptographic library used.
- Develop the initial primary application, perform the memory usage analysis, and compare with the bootloader memory allocation for consistency and adjust as needed.
- Determine the bootloader configurations in terms of image authentication and new image update mode. This may result in adjustment of the memory allocated definition in the bootloader project.
- Sign the application image. The signing command is output to the <bootloader project>

 \Debug\<bootloader project>.bld file. The application image can use a BuildVariable to access this .bld file. The IDE tools will use the signing command to sign the application and generate a binary file for downloading to the MCU.
- Test the bootloader and the initial primary application.

The above guidelines are demonstrated in the walk-through sections in this application note.

2.3 Guidelines for Using the MCUboot Module with RA2 Series MCUs

The MCUboot Module is supported on all RA Family MCUs. For the Renesas RA2 Cortex-M23 MCU series, image hashing and image authentication are supported in FSP v3.4.0 and later.

2.3.1 Customizing the RA2 Bootloader

Customizing the bootloader involves the following main aspects:

- Customized method to download the application. This is very application specific and is not discussed in this application project.
- Bootloader size optimization.

Some of the bootloader size optimization actions that can be taken are summarized as follows:

- Disable application image validation to reduce code size.
- Disable image signing to reduce code size.
- Update the linker script to optimize memory usage.
- Disable unused FSP components to reduce code size.
- Compile the bootloader with Optimization for Size (-Os).
- Use pin configurations that initialize fewer peripheral and IO pins.

Details on the operational flow of these optimization are described in section 3.

• Details on the RA2 bootloader memory optimization are introduced in later sections.



2.3.2 Time Usage in an Application Image Update

There are several major factors that can influence how much time an application image update takes. This section will discuss some of the major factors that can influence the time used in an application image update.

First, during an image update, if image verification using ECC or RSA is used, the larger the application image size, the longer it takes to verify the image for a given cryptographic algorithm.

Secondly, the larger the size of the application image, the longer it takes to erase and program the flash during the image upgrade process (for Overwrite and Swap upgrade mode where flash erase and programming are involved). User can reference the MCU Hardware User's manual section Electrical Characteristics to calculate the flash erase and programming time based on the table for code flash characteristics located in the sub section Flash Memory Characteristics.

Thirdly, the upgrade mode itself influences the time used to upgrade an application image. Assuming a new image is already downloaded and programmed to the update slot, the following erase and program events will happen after the MCU comes out from a reset.

For overwrite upgrade mode, the upgrade process involves:

- 2 x erase time (both primary and secondary slot).
- 1 x programming time (primary slot only).

For swap upgrade mode, the upgrade mode involves:

- 2 x erase time (both primary and secondary slot).
- The erase and program time used for erasing and programming the scratch area multiple times (with a total flash area equals the size of the application image on a scratch area size boundary).
- 2 x programming time (both primary and secondary slot).

For Direct XIP mode, the upgrade process does not involve any flash erasing or programming:

• Since the image update in the Direct XIP mode does not involve any flash erasing and programming operation, this is the best upgrade mode in terms reducing the system downtime.

The fourth factor is related to the usage of different signature algorithms. RSA typically takes longer verification times compared with ECC for the same image size. Currently, only ECC is supported for RA2 signature verification.

2.4 Production Recommendations for RA2 MCU

2.4.1 Making the Bootloader Immutable

Refer to the *Renesas RA MCU Family Securing Data at Rest Utilizing the Renesas Security MPU* application project section Permanent Locking of the FAW Region to understand how to make the bootloader immutable. The PC Application to Permanently Lock the FAW section in the same application note describes how to handle flash locking in production mode.

2.4.2 Disabling the Debug and Serial Programming Interface Prior to Deployment

Once the bootloader development is finished, you may want to set up ID Code protection on the Renesas RA2 MCU to lock down the debugger and the serial programming interface.

Refer to the Securing Data at Rest Utilizing the Renesas Security MPU Application Project section Setting up the Security Control for Debugging for the desired settings to control the device lifecycle management of the RA2 MCUs using the ID Code protection method.

3. Creating the Bootloader Project

This section guides you through the creation process of the RA2 bootloader provided in this application project.

The example bootloader that you will create by following this section is provided in the RA2_secure_bootloader.zip. You can follow section 7 to exercise the example bootloader and application projects without going through the creation process in this section.



3.1 Including the MCUboot Module in the Bootloader Project

 Launch e² studio and start to establish a new C/C++ Project. Click File > New > Renesas C/C++ Project > Renesas RA.

<u>F</u> ile	Edit Source Refactor Navigate	Search Project F	Renes	sas <u>V</u> iews <u>R</u> un Renesas Al <u>W</u> indow <u>H</u> elp		
	New	Alt+Shift+N >		Renesas C/C++ Project	>	Renesas Debug
. 7	Open File		6	Makefile Project with Existing Code		Renesas RA
۵,	Open Projects from File System		C	C/C++ Project	1	
	Recent Files	>		Project		
	Close Editor	Ctrl+W	C++	Convert to a C/C++ Project (Adds C/C++ Nature)		
	Close All Editors	Ctrl+Shift+W	63	Source Folder		
	Save	Ctrl+S	<u></u>	Folder		
	Save As		C	Source File		
	Save All	Ctrl+Shift+S		Header File		
	Revert			File from Template		
	Move		C	Class		
	Rename	F2		Example		
-	Refresh	F5		Other Ctrl+	N	

Figure 2. Start a New Project

2. Choose Renesas RA C/C++ Project. Click Next.

New C/C++ Proje Templates for Rene		- D X	
All	Renesas RA C/C++ Project		
C/C++	Create an executable or static library C/C-	+ project for Renesas RA.	
	٢	>	
?	< <u>B</u> ack <u>N</u> ext >	Einish Cancel	

Figure 3. Choose Renesas RA C/C++ Project

3. Provide a project name in the next screen. Select a project name based on the upgrade mode and authentication method. The name will persist in the instructions used in this application note. Table 1 shows the name and intended application image update strategy of each bootloader project. Note that magic number and SHA256 integrity check are included in all of the systems.

Table 1.	Description	of the	Bootloader	Projects
----------	-------------	--------	------------	----------

Name of the project to be used	Intended application update strategy
ra_mcuboot_ra2e1	Overwrite update mode with no signature verification.
<pre>ra_mcuboot_ra2e1_overwrite_with_signature</pre>	Overwrite update mode with signature verification.
ra_mcuboot_ra2e1_swap	Swap update mode with no signature verification. Swap test prior to confirm is not supported.
ra_mcuboot_ra2e1_swap_with_signature	Swap update mode with signature verification, Swap test prior to confirm is supported.
ra_mcuboot_ra2e1_dxip	Direct XIP update mode with signature verification.



Figure 4 is an example of setting the project name to **ra_mcuboot_ra2e1**.

Renesas RA C/C++ Project	×
Renesas RA C/C++ Project Project Name and Location	2
Project name ra_mcuboot_ra2e1 Use default location	
? < Back Next > Finish Cancel	el

Figure 4. Name the Bootloader Project

Click **Next**. If you choose another name for the bootloader, adapt the corresponding instructions in this application note to the project name used.

4. In the next screen, choose EK-RA2E1 for Board and click Next.

Device Selection FSP Version: 5.2.0 ✓ Board: EK-RAZE1 ✓ Device: R7FA2E1A92DFM Core: CM23 ✓ Language: ● C ○ C++	Board Description Evaluation kit for RA2E1 MCU Group Visit <u>https://www.renesas.com/ra/ek-ra2e1</u> to get kit user's manual, quick start guide, errata, design package, example projects, etc.
	Device Details TrustZone No
	Pins 64 Processor Cortex-M23
Toolchains	Debugger
GNU ARM Embedded LLVM Embedded Toolchain for Arm	J-Link ARM ~
13.2.1.arm-13-7 v	

Figure 5. Select the Board

5. Choose Executable for Build Artifact Selection and No RTOS. Click Next.

 Renesas RA C/C ++ Project Renesas RA C/C ++ Project Build Artifact and RTOS Selection 	- • ×
Build Artifact Selection Executable Project builds to an executable file Static Library Project builds to a static library file Executable Using an RA Static Library Project builds to an executable file Project builds to an executable file Project uses an existing RA static library project 	RTOS Selection No RTOS
?	<back next=""> Finish Cancel</back>

Figure 6. Choose to Build Executable and No RTOS



6. Choose **Bare Metal – Minimal** for the Project Template in the next screen and click **Finish** to establish the initial project.



Bare metal FSP project that includes BSP. This project will initialize clocks, pins, stacks, and the C runtime environment.

Figure 7. Choose the Project Template

7. When the following prompt opens, click **Open Perspective**.

Open Associated Perspective?		×
Open the FSP Configuration perspective	2	
Remember my decision	Open Perspective No	

Figure 8. Choose Open the FSP Configuration Perspective

8. The project is now created, and the bootloader project configuration is displayed. Select the **Pins** tab and uncheck **Generate data** for **RA2E1 EK**.

Pin Configuration		Generate Project Content
Select Pin Configuration		🔚 Export to CSV file 🖺 Configure Pin Driver Warnings
RA2E1 EK	✓ Manage configurations	Generate data: g_bsp_pin_cfg

Figure 9. Uncheck Generate data for RA2E1 EK Pin Configuration

Use the pull-down menu to switch from RA2E1 EK to R7FA2E1A92DFM.pincfg for the Select Pin Configuration option, then select the Generate data check box and enter g_bsp_pin_cfg. Note that here we choose to use this configuration, which has fewer peripherals/pins configured, since the bootloader does not use the extra peripheral or GPIO pins configured in the RA2E1 EK configuration. This change also reduces the bootloader memory usage and is highly recommended.

Select Pin Configuration		🔚 Export to CSV file 🗈 Configure Pin Driver Warnings
R7FA2E1A92DFM.pincfg ~	Manage configurations	Generate data: g_bsp_pin_cfg

Figure 10. Select R7FA2E1A92DFM.pincfg and Generate data g_bsp_pin_cfg

Once the project is created, click the Stacks tab on the RA configurator. Add New Stack > Bootloader > MCUboot.

🗟 New Stack > 🚢 Extend Stac	E	
Al	>	
Analog	>	
Audio	>	
Bootloader	> 🕀	MCUboot
CapTouch	> 🕀	MCUboot Image Utilities
Connectivity	>	
	Al Analog Audio Bootloader CapTouch	Analog > Audio > Bootloader > CapTouch >

Figure 11. Add the MCUboot Port



10. Next, configure the General properties of MCUboot.

- For project ra_mcuboot_ra2e1 and ra_mcuboot_ra2e1_overwrite_with_signature, use the settings in Figure 12.
- For project ra_mcuboot_ra2e1_swap and ra_mcuboot_ra2e1_swap_with_signature, update the following properties in Figure 12:
 - Change the **Upgrade Mode** to **Swap**.
 - Set the Downgrade Prevention (Overwrite Only) to Disabled.
- For project **ra_mcuboot_ra2e1_dxip** update the following properties in Figure 12:
 - Change the Upgrade Mode to Direct XIP.
 - Set the Downgrade Prevention (Overwrite Only) to Disabled.

🐑 New Threac	HAL/Common Stacks	🐑 Ne	w Stack > 🏯 Extenc
Remove			
E	I MCUboot		
AL/Commoi ^			
g_ioport I/	(i)		
>			A
			A
🚯 New Object	MCUboot Port for RA (rm_mcuboot	t_port)	MCUboot logging
Remove			
	ć		
BSP Clocks Pine	s Interrupts Event Links Stacks Componen	nts	
ms 📮 Console	🔲 Properties 🔀 🏶 Smart Browser 🤬 S	Smart Manual 🛷 Search	
ot			
Property			Value
✓ Common			
✓ General			
	om mcuboot_config.h		
	ade Mode		Overwrite Only
Valida	ate Primary Image		Enabled
	ngrade Prevention (Overwrite Only)		Enabled
Numb	ber of Images Per Application		1

Figure 12. General Properties for MCUboot

Figure 13 is a more detailed application image format that can be referenced to understand the various MCUboot property definitions.

- The header magic number is used for image validation sanity check (refer to the description of **Validate Primary Image).**
- The image_ok byte is a flag used by the bootloader for swap test mode confirmation (refer to section 6.2 for more details).
- The trailer magic number is written after the image upgrade is finished.



Figure 13. General Configuration for MCUboot Module



The properties configured include:

- **Custom mcuboot_config.h**: The default mcuboot_config.h file contains the MCUboot Module configuration that you select from the RA configurator. You can create a custom version of this file to achieve additional bootloader functionalities available in MCUboot.
- **Upgrade Mode**: This property configures the application image upgrade method. The available options are Overwrite Only, Overwrite Only Fast, Swap, and Direct XIP.
- Validate Primary Image: When Enabled, the bootloader will perform a hash or signature verification, depending on the verification method chosen, in addition to the MCUboot sanity check based on the image header magic number. The header magic number is always checked as part of the sanity checking prior to the integrity checking and the signature verification.

When this property is Disabled, only sanity check is performed based on the MCUboot header magic numbers. It is highly recommended to always enable this property. The additional code used when this property is enabled is less than 30 bytes, while it adds critical security handling to the bootloader. Note that the image magic number is not part of the image validation, it is a reference value that can be used for sanity check during application upgrade debugging process. This image magic number is written to the flash after a successful image upgrade.

- **Number of Images Per Application:** This property allows you to choose one image for Non-TrustZone-based applications and two images for TrustZone-based applications. RA2 MCU groups do not support TrustZone, so this property is set to **1**.
- **Downgrade Prevention (Overwrite Only):** This property applies to Overwrite upgrade mode only. When this property is Enabled, a new firmware with a lower version number will not overwrite the existing application. To see how to set the version number of an image, refer to Figure 52.

11. Configure the Signing Options and Flash Layout of the MCUboot module based on Table 2.

Bootloader Project Name	Screenshots for Detailed Configuration
ra_mcuboot_ra2e1	Figure 14
ra_mcuboot_ra2e1_overwrite_with_signature	Figure 15
ra_mcuboot_ra2e1_swap	Figure 16
ra_mcuboot_ra2e1_swap_with_signature	Figure 17
Ra_mcuboot_ra2e1_dxip	Figure 18

Table 2. Bootloader Configurations

Includes ra_gen src Debug ra_cfg script	-	O Port	 MCUboot Event Links <u>Q Stacks</u> Component
ms 😻 Smart Browser 🛄 Prope	rties ×		
ot			
Property ↓ Common		Value	
> General			
 Signing and Encryption 	Options		
> TrustZone			
Signature Type		None	
Boot Record			
Custom		confirm	
Python		pytnon	-
Encryption Scheme		Encryption Disa	bled
✓ Flash Layout			
> TrustZone			
Bootloader Flash Area	a Size (Bytes)	0x2000	
Image 1 Header Size ((Bytes)	0x100	
Image 1 Flash Area Si	ze (Bytes)	0x2000	
Scratch Flash Area Siz	e (Bytes)	0x0	

Figure 14. Update Configurations for Project ra_mcuboot_ra2e1





Figure 15. Update Configurations for Project ra_mcuboot_ra2e1_overwrite_with_signature

Property	Value
🗸 Common	
> General	
 Signing Options 	
> TrustZone	
Signature Type	None
Boot Record	
Custom	confirm
Python	python
> Debugging	
✓ Flash Layout	
> TrustZone	
Bootloader Flash Area Size (Bytes)	0×3000
Image 1 Header Size (Bytes)	0×100
Image 1 Flash Area Size (Bytes)	0×2000
Scratch Flash Area Size (Bytes)	0×800
> Data Sharing	

Figure 16. Update Configurations for ra_mcuboot_ra2e1_swap

Property	Value
✓ Common	
> General	
 Signing Options 	
> TrustZone	
Signature Type	ECDSA P-256
Boot Record	
Custom	pad
Python	python
> Debugging	
✓ Flash Layout	
> TrustZone	
Bootloader Flash Area Size (Bytes)	0x4000
Image 1 Header Size (Bytes)	0x100
Image 1 Flash Area Size (Bytes)	0x2800
Scratch Flash Area Size (Bytes)	0x800

Figure 17. Update Configurations for ra_mcuboot_ra2e1_swap_with_signature



Property	Value		
✓ Common			
> General			
 Signing and Encryption Options 			
> TrustZone			
Signature Type	None		
Boot Record			
Customconfirm			
Python	python		
Encryption Scheme	Encryption Disabled		
✓ Flash Layout			
> TrustZone			
Bootloader Flash Area Size (Bytes)	0x2000		
Image 1 Header Size (Bytes)	0x100		
Image 1 Flash Area Size (Bytes)	0x2000		
Scratch Flash Area Size (Bytes)	0x0		
> Data Sharing			

Figure 18. Update Configurations for ra_mcuboot_ra2e1_dxip

Explanation of the Above Configurations

For both single-image and two-image configurations, the following properties need to be defined:

- **Bootloader Flash Area**: Size of the flash area allocated for the bootloader with a boundary of 0x800 since 0x800 is the minimum erase size for code flash.
- **Image 1 Header Size**: Size of the flash area allocated for the application header for single-image configuration. For Arm Cortex-M23 MCUs, this should be set to 0x100.
- **Image 1 Flash Area Size**: Size of the flash area allocated for the application image for single-image configuration. This area needs to be equal or larger than the application image with a boundary of 0x800.
- Scratch Flash Area Size: This property is only needed for Swap mode. The Scratch Area must be large enough to store the largest sector that is going to be swapped. For all RA2 MCUs, the Scratch Area should be set up to 0x800 when Swap mode is used.
- **Signature Type** is the signing algorithm selection. Application images using MCUboot must be signed to work with MCUboot. At a minimum, this involves adding a hash and an MCUboot-specific constant value in the image trailer. Note that when using TinyCrypt as the cryptographic support for MCUboot, RSA signature verification is not supported. The choices are:
 - **NONE:** This option is selected for the bootloaders that do not support signature verification as shown in Figure 14 and Figure 16.
 - ECDSA P-256: This option is selected for the example bootloaders that support signature verification included in this application project as shown in Figure 15 and Figure 17.
 - RSA 2048 and RSA 3072: Not supported.
- **Custom:** This property allows you to input any specific arguments for the signing command. By default --confirm is set for this property, which has the following influence on the Secondary image:
 - For Overwrite upgrade mode, the new image will always overwrite the original application image upon successful verification.
 - For Swap upgrade mode, the Primary image slot will be marked as Confirmed after the swap update. No swap happens upon the next reset after the swap update.

If the $\ensuremath{\text{Custom}}$ property is set to $\ensuremath{\text{--pad}}$, the system behavior is:

- For Overwrite upgrade mode, the system behavior is same as when --confirm is set.
- For Swap upgrade mode, the system behavior depends on whether the application has routines to mark the Primary image slot as Confirmed. The details about the system behavior are explained in section 6.2.2.

The Primary image boot behavior is not influenced by the choice between --confirm or --pad.



Properties that vary based on the Upgrade Mode Selection

See Table 3 for the configuration used in the various bootloader projects introduced in this application project:

- Different authentication methods and different Image Upgrade mode use different amounts of flash memory. Select the most suitable configurations based on your specific application project requirement.
- The **Image 1 Flash Area size** is based on a simple blinky project. Adjust this memory configuration based on the specific application project you want to use with the bootloader.
- The Swap upgrade application project uses a larger flash area because the swap test mode is configured in the example project. For details on the swap test mode, refer to section 6.2.2.
- Note that there is no difference in the bootloader flash memory usage whether --confirm or --pad is defined for the Custom property. However, the new image which includes the MCUboot Image Utilities modules will need to allocate about 2kB flash for the added functionality.

Properties	ra_mcuboot_ ra2e1	ra_mcuboot_ra2e1_ove rwrite_with_signature	ra_mcuboot_ ra2e1_swap	ra_mcuboot_ra2 e1_swap_with_ signature	ra_mcuboot_ra2 e1_dxip
Bootloader Flash Area Size	0x2000	0x3800	0x3000	0x4000	0x2000
Image 1 Flash Area Size	0x2000	0x2000	0x2000	0x2800	0x2000
Signature Type	NONE	ECDSA P256	NONE	ECDSA P256	NONE
Custom	confirm	confirm	confirm	pad	confirm

Table 3. Configurations for Different Upgrade Modes

The properties under **TrustZone** are not used for RA2 MCUs since they do not have TrustZone. For other properties shown in this step, refer to the *FSP User's Manual* section on MCUboot port.

12. Next, add the **TinyCrypt** module under **MCUboot Port for RA**. **TinyCrypt (H/W Accelerated)** includes hardware accelerated AES functionality, which is not used in the bootloader, so **TinyCrypt (S/W Only)** is used. The **MbedTLS (Crypto Only)** module has a larger memory footprint compared with **TinyCrypt** and is not used in this bootloader design.



Figure 19. Select TinyCrypt Module

- 13. If the user is creating a bootloader with signature verification support, then the **ASN.1 Parser** stack and the **MCUboot Example Keys** stack will be required. For example, if user wants to recreate the following example bootloaders, user needs to add the **ASN.1 Parser** stack and the **MCUboot Example Keys** stack.
 - o ra_mcuboot_overwrite_with_signature



ra_mcuboot_ra2e1_swap_with_signature

Click on the Add ASN.1 parser stack and select New to add the ASN.1 Parser.



Figure 20. Add the ASN.1 Parser

Click on the Add [Optional] Add Example Keys stack and choose New -> MCUboot Example Keys [NOT FOR PRODUCTION].



Figure 21. Add the Example Image Signing Key

Note that the example key is open to public access from MCUboot port, customers should not use them for production purposes. Customer can follow the procedure in section 3.6.1 to create and use customized signing key.

14. Update the BSP Main Stack size to 0x800.







- 15. Click on Add Required Flash stack and add Flash (r_flash_lp).
- 16. Click on the Flash Driver block and set the Code Flash Programming to Enabled. As Data Flash Programming and Data Flash Background Operation are not used in the bootloader, select Disabled for these two properties to reduce the bootloader memory footprint.

y BSP Clocks Pins Interrupts Event Links Stacks Components lems Console Properties Smart Browser Smart Manual Search O Flash (r_flash_lp) Property Value V Common Parameter Checking Default (BSP) Code Flash Programming Enabled Data Flash Background Operation Support Disabled Value Value	g_ioport I/ ↓ × New Object Remove	<pre> # MCUboot TinyCrypt (S/W Only) </pre> Image: The second secon
O Flash (r_flash_lp) Property Value Common Parameter Checking Default (BSP) Code Flash Programming Enabled Data Flash Programming Data Flash Programming Data Flash Background Operation Support Disabled Module g_flash0 Flash (r_flash_lp) Name g_flash0 	y BSP Clocks Pins Interrupts Event Links Stack	ks Components
Property Value Common Parameter Checking Default (BSP) Code Flash Programming Enabled Data Flash Programming Disabled Data Flash Background Operation Support Disabled Module g_flash0 Flash (r_flash_lp) Name g_flash0	lems 📮 Console 🔲 Properties 🗙 쪶 Smart	Browser 🔑 Smart Manual 🛷 Search
 ✓ Common Parameter Checking Code Flash Programming Data Flash Programming Data Flash Background Operation Support Disabled ✓ Module g_flash0 Flash (r_flash_lp) Name g_flash0 	0 Flash (r_flash_lp)	
V Common Parameter Checking Default (BSP) Code Flash Programming Enabled Data Flash Programming Disabled Data Flash Background Operation Support Disabled V Module g_flash0 Flash (r_flash_lp)	Property	Value
Code Flash Programming Enabled Data Flash Programming Disabled Data Flash Background Operation Support Disabled ✓ Module g_flash0 Flash (r_flash_lp) g_flash0		
Data Flash Programming Disabled Data Flash Background Operation Support Disabled ✓ Module g_flash0 Flash (r_flash_lp) g_flash0	Parameter Checking	Default (BSP)
Data Flash Background Operation Support Disabled Module g_flash0 Flash (r_flash_lp) Name g_flash0	Code Flash Programming	Enabled
 ✓ Module g_flash0 Flash (r_flash_lp) Name g_flash0 	Data Flash Programming	Disabled
Name g_flash0	Data Flash Background Operation Supp	port Disabled
	✓ Module g_flash0 Flash (r_flash_lp)	
Data Flash Background Operation Disabled	Name	g_flash0
	Data Flash Background Operation	Disabled

Figure 23. Enable Code Flash programming

17. Save Configuration.xml and click Generate Project Content. Next, expand the Developer Assistance > HAL/Common > MCUboot > Quick Setup and drag Call Quick Setup to the top of the hal_entry.c of the bootloader project.

Add the following function call to the top of the hal_entry() function: mcuboot_quick_setup();

18. Notice that by default the I/O Port Driver is brought into the project when the project is established. Because the I/O Port Driver is not used in the bootloader project, this stack can be removed to reduce the bootloader project size. Right click on the I/O Port stack and choose Delete.



Figure 24. Remove the I/O Port Stack



After the I/O Port is deleted, remove all sections of code referencing the I/O Port API. For example, remove the two sections of the code in the red boxes in the function R_BSP_WarmStart in hal_entry.c as shown in Figure 25.





3.2 Further Optimizing for the Bootloader Project Size

To further optimize the bootloader project for size, you can put some application code in the gap area between the interrupt vector and the RA2E1 ROM registers. We can use a section (.flash_gap) in the linker script to store some application code in this section.

Note that the bootloader image size optimization methods introduced in this section apply to any application project, regardless of whether a bootloader is used. You can use the methods described in this section to save code space for any RA2 application.



Figure 26. First Flash Sector

Note that there is a section for .mcuboot_sce9_key, which is not used for RA2 MCUs. We can safely comment this section out as shown in Figure 27.



Figure 27. Linker Script Update



Next, you can choose some functions to put in the .flash_gap section in order to reduce the flash usage. What functions to put in the .flash_gap section is your choice.

For all five bootloaders introduced in this application project, the following two functions are put in the gap area. For the $ra_mcuboot_ra2e1_dxip$ bootloader, there is no need to add more functions to the gap area.

- Update function prototype R_BSP_WarmStart shown in Figure 28.
- Add function prototype definition for mcuboot_quick_setup as shown in Figure 28 right before this function's implementation (refer to the sample code for an example).

```
In \src\hal_entry.c:
void R_BSP_WarmStart(bsp_warm_start_event_t event) BSP_PLACE_IN_SECTION(".flash_gap*");
void mcuboot_quick_setup() BSP_PLACE_IN_SECTION(".flash_gap*");
In \ra\mcu-tools\MCUboot\boot\boot\bootutil\include\bootutil\bootutil.h:
fih_ret context_boot_go(struct boot_loader_state *state, struct boot_rsp *rsp)
BSP_PLACE_IN_SECTION(".flash_gap*");
```

Figure 28. Common Functions to Put in the .flash_gap Section

Figure 29 shows the additional function in image.h that is put in the gap area for bootloader ra_mcuboot_ra2e1 in addition to the common functions mentioned in Figure 28.

Figure 29. Functions to Put in the .flash_gap Section for ra_mcuboot_ra2e1

Figure 30 shows the two additional functions in image.h that are put in the gap area for bootloader ra_mcuboot_ra2e1_overwrite_with_signature in addition to the common functions mentioned in Figure 28.

Figure 30. Functions to Put in the .code_in_gap Section for ra_mcuboot_ra2e1_overwrite_with_signature

Figure 31 shows the addition function in image.h that is put in the gap area for ra_mcuboot_ra2e1_swap in addition to the common functions mentioned in Figure 28.





Figure 32 shows the addition function in image.h that is put in the gap area for ra_mcuboot_ra2e1_swap_with_signature in addition to the common functions mentioned in Figure 28.

Figure 32. Functions to Put in the .code_in_gap Section for ra_mcuboot_ra2e1_swap_with_signature

3.3 Compiling the Bootloader Project

When all the above updates are done, change the compiling optimization to **Optimize size (-Os)** and compile the project.

type filter text	Settings 🔶	• 🗘 • 🖇
 Resource Builders C/C++ Build Build Variables Environment 	Configuration: Debug [Active] · Manage Configur	ations
Logging Settings Tool Chain Editor > C/C++ General > MCU Project Natures Project References Renesas QE	 Tool Settings Toolchain P Build Steps Puild Artifact Binary Parsers Processor Target Processor Optimization Warnings Char' is signed (-fsigned-char) Son Construction Settings Son Construction Son Constr	

Figure 33. Optimize Bootloader Size

Depending on which upgrade mode you have selected, Figure 34 - Figure 38 show the compilation results. If you have migrated the projects to a later FSP version, the size may have some minor difference.



Figure 34. Compile the Bootloader ra_mcuboot_ra2e1

Building target: ra_mcuboot_ra2e1_overwrite_with_signature.elf arm-none-eabi-objcopy -0 srec "ra_mcuboot_ra2e1_overwrite_with_signature.elf" "ra_mcuboot_ra2e1_overwrite_with_signature.srec" arm-none-eabi-size --format=berkeley "ra_mcuboot_ra2e1_overwrite_with_signature.elf" text data bss dec hex filename 12628 0 3680 16308 3fb4 ra_mcuboot_ra2e1_overwrite_with_signature.elf 11:21:24 Build Finished. 0 errors, 0 warnings. (took 8s.765ms)

Figure 35. Compile the Bootloader ra_mcuboot_ra2e1_overwrite_with_signature

Building target: ra_mcuboot_ra2e1_swap.elf arm-none-eabi-objcopy -0 srec "ra_mcuboot_ra2e1_swap.elf" "ra_mcuboot_ra2e1_swap.srec" arm-none-eabi-size --format=berkeley "ra_mcuboot_ra2e1_swap.elf" text data bss dec hex filename 11220 0 3732 14952 3a68 ra_mcuboot_ra2e1_swap.elf 11:22:47 Build Finished. 0 errors, 0 warnings. (took 11s.867ms)





arm-none-e	abi-obj	copy -0	srec "ra	_swap_with_signature.elf _mcuboot_ra2e1_swap_with_signature.elf" "ra_mcuboot_ra2e1_swap_with_signature.srec" .ey "ra_mcuboot_ra2e1_swap_with_signature.elf"
text	data	bss	dec	hex filename
16140	0	3756	19896	4db8 ra_mcuboot_ra2e1_swap_with_signature.elf
11:26:01 B	uild Fi	nished.	0 errors,	0 warnings. (took 7s.958ms)

Figure 37. Compile the Bootloader ra_mcuboot_ra2e1_swap_with_signature

Building ta				_dxip.elf _mcuboot_ra2e1_dxip.elf" "ra_mcuboot_ra2e1_dxip.srec"
				ley "ra_mcuboot_ra2e1_dxip.elf"
text	data	bss	dec	hex filename
7172	0	2608	9780	2634 ra_mcuboot_ra2e1_dxip.elf
11:30:59 Bu	ild Fi	nished.	0 errors	, 0 warnings. (took 8s.497ms)

Figure 38. Compile the Bootloader ra_mcuboot_ra2e1_dxip

3.4 Configuring the Python Signing Environment

Signing the application image can be done using a post-build step in e^2 studio using the image signing tool Imgtool.py, which is included with MCUboot. This tool is integrated as a post-build tool in e^2 studio to sign the application image. If this is **NOT** the first time you have used the python script signing tool on your computer, you can skip to section 3.5.

If this is the first time you are using the Python script signing tool on your system, you will need to install the dependencies required for the script to work. Navigate to the <boot_project>\ra\mcu-tools\MCUboot folder in the **Project Explorer**, right click and select **Command Prompt**. This will open a command window with the path set to the $\mcu-tools\MCUboot$ folder.

> @ > @ > @				FSP Version:	
> 🐸 ra > 🐸 sri	c .		New Go Into	>	Flat
			Open in New Window Show In	Alt+Shift+W > cation that blinks an LED. N	
~	mcu-tools	-	Copy Paste	Ctrl+C Ctrl+V	ort Package Common Files Version 5 - Core (M)
€ m € m >	1	Delete Source Move Rename	Delete > F2	port of the second seco	
🔲 Properti		2 2	Import Export		1 8
✓ Info der edit Isst link loc: nar pat	oot_ra2e	ot_ra2e	Build Project	Ctrl+B	
		0	Refresh	F5	
	der edit last	if t	Index Build Targets Resource Configurations	> > >	
	loc nar	u r	Team Compare With Restore from Local History	> >	tions\application_projects\r11a
	\$9 \$9	C/C++ Project Setting Open Change Device Run C/C++ Code Analysis	Command Prompt		
		-	System Explorer Command Prompt		

Figure 39. Open the Command Prompt



We recommend upgrading pip prior to installing the dependencies. Enter the following command to update pip:

python -m pip install --upgrade pip

Next, in the command window, enter the following command line to install all the MCUboot dependencies:

pip3 install --user -r scripts/requirements.txt

This will verify and install any dependencies that are required.

3.5 Review the Signing Command

The signing command for the application image is automatically generated when the bootloader is compiled. In the **Project Explorer**, navigate to the <boot_project>\Debug\<boot_project >.bld file and open this .bld file. The signing command is under the section <image >. For RA2 MCU groups, the entry immediately after <images> is the signing command for the application image.

The application image uses a Build Variable to link with the .bld file. This process is explained in detail in the next section. The signing command is automatically executed when the application image is compiled.

Figure 40. Signing Command (in bold) in the .bld File

3.6 Usage Notes

3.6.1 Using Customized Image Signing Key

In this section, you will generate two sets of ECDSA SECP256R1 keys using the imgtool.py tool included with MCUboot.

The stack MCUboot Example Keys stack imports the example keys included in the MCUboot public port to use in the image signing/verifying. The custom keys generated in this section replace these example keys.

The root_pub_der array is the public key for image verification which is located in $\{bootloader project\}\ra\mcu-tools\MCUboot\sim\mcuboot-sys\csupport\keys.c.$ For ECDSA P-256, the public key for image verification is shown as the following (from keys.c).

0x30,	0x59,	0x30,	0x13,	0x06,	0x07,	0x2a,	0x8
0x48,	0xce,	0x3d,	0x02,	0x01,	0x06,	0x08,	0x2
0x86,	0x48,	0xce,	0x3d,	0x03,	0x01,	0x07,	0x0
0x42,	0x00,	0x04,	0x2a,	0xcb,	0x40,	0x3c,	0xe
0xfe,	0xed,	0x5b,	0xa4,	0x49,	0x95,	0xa1,	0xa
0x1d,	0xae,	0xe8,	0xdb,	0xbe,	0x19,	0x37,	0хс
0x14,	0xfb,	0x2f,	0x24,	0x57,	0x37,	0xe5,	0x9
0x39,	0x88,	0xd9,	0x94,	0xb9,	0xd6,	0x5a,	0xe
0xd7,	0xcd,	0xd5,	0x30,	0x8a,	0xd6,	0xfe,	0x4
0xb2,	0x4a,	0x6a,	0x81,	0x0e,	0xe5,	0xf0,	0x7
0x8b,	0x68,	0x34,	0xcc,	0x3a,	0x6a,	0xfc,	0x5
0x8e,	0xfa,	0xc1,	};				





The matching private key for the public key root_pub_der is root-ec-p256.pem. This example is used in the image signing process in the example bootloaders created in this section.



Figure 42. Example Image Signing Private Key

We will generate a custom private key ecc_sign_private.pem to replace the usage of root-ecp256.pem following the below steps using any of the bootloader example using signature:

1. In the bootloader project, copy keys.c from the MCUboot folder to the \src folder of the bootloader project.



Figure 43. Copy the example Keys.c

2. Open the configurator for the bootloader project, right click on MCUboot Example Keys stack and select **Delete**.



Figure 44. Delete the MCUboot Example Keys Stack



3. Extend the booloader project and navigate to foler \ra\mcu-tools\MCUboot\scripts\. Right click on this folder and select **Command Prompt**.

✓ ₽ ra_mcuboot_ra2e	1 (Deb			
> 🔊 Includes	- [Debi		HAL/Common Stacks	
✓ 😂 ra				
> 😅 arm			+ MCUboot	
> 🗁 board			Webboot	
> 👝 fsp				
✓ ĕ mcu-tools			(i)	
V 🕞 MCUboot				
> 🔁 boot > 🏳 ext			HCUboot Port for RA (rm_r	ncuboot_po
> 🗁 scripts				
> 🍃 sim		New >	1	
B enc-e	C	Go Into	U	
🔒 enc-e				
enc-rs		Open in New Window		g_flash0
enc-rs		Show In Alt+Shift+W >	(S/W Only)	(r_flash_l
▲ root-e ▲ root-r		Copy Ctrl+C	i	1)
e root-n		Paste Ctrl+V		
> 😂 ra_gen	-	Delete Delete		
🗸 🔁 src	•••	Source >		
> C hal entrv.c		Move	ary BSP Clocks Pins Interrupt	s Event Link
🛛 Problems 🏼 🏶 Smart f		Rename F2		
wa wawhaat wa?at	-	Rename F2		
'ra_mcuboot_ra2e1	2	mport		
Resource Property	💪 E	Export		Value
✓ Info	F	Build Project Ctrl+B	·	
deriv	S .	Refresh F5		false
edita				true
last		ndex >		August 1, 2 false
loca	- F	Build Targets >		C:\ra2_boc
nam		Resource Configurations >		scripts
path	1	Team >		/ra_mcubc
		Compare With >		
		Restore from Local Hist Open Command Prompt		
		C/C++ Project Settings Ctrl+Alt+P		
		Renesas C/C++ Project Settings >		
		Run C/C++ Code Analysis		
		System Explorer		
		Command Prompt		
	✓ \	/alidate		
	5	Source >		
		Properties Alt+Enter		

Figure 45. Start Command Prompt under the \MCUboot\scripts Folder

4. Under the command window, execute command:

python imgtool.py keygen -k ecc_sign_private.pem -t ecdsa-p256

- 5. Copy the generated ecc_sign_private.pem to folder \ra_mcuboot_ra2e1\src. This is new image signing key.
- 6. Extract the public key from ecc_sign_private.pem.

Execute command:

python imgtool.py getpub -k ecc_sign_private.pem



\scripts>python imgtool.py getpub -k ecc_sign_private.pem	
/* Autogenerated by imgtool.py, do not edit. */	
const unsigned char ecdsa_pub_key[] = {	
0x30, 0x59, 0x30, 0x13, 0x06, 0x07, 0x2a, 0x86,	
0x48, 0xce, 0x3d, 0x02, 0x01, 0x06, 0x08, 0x2a,	
0x86, 0x48, 0xce, 0x3d, 0x03, 0x01, 0x07, 0x03,	
0x42, 0x00, 0x04, 0x9a, 0x41, 0x49, 0x4c, 0x21,	
0x74, 0x15, 0xe2, 0xfa, 0xb6, 0x93, 0x09, 0xa5,	
0x46, 0xb8, 0x3e, 0xf4, 0x05, 0x7b, 0x76, 0xbe,	
0x39, 0x9b, 0xea, 0x38, 0xf4, 0xf7, 0x09, 0xdd,	
0xca, 0xfb, 0x1f, 0xde, 0x4b, 0xc4, 0xf9, 0x9d,	
0x32, 0x9b, 0xc7, 0x63, 0xb7, 0x09, 0x2e, 0x15,	
0xa1, 0xbf, 0x54, 0xdd, 0xa7, 0xed, 0x6b, 0xd1,	
0xd9, 0x12, 0x2d, 0x87, 0x8e, 0x6b, 0xea, 0xc2,	
0xd1, 0x32, 0xd6,	
const unsigned int ecdsa_pub_key_len = 91;	



- 7. Copy the content of ecdsa_pub_key to keys.c to replarray root_pub_der keys.c. Replace the original root_pub_der content.
- 8. Click Generate Project Content and compile the bootloader project.
- 9. To use the new image signing key, user needs to update the signing key configuration of the application projects.

nvironment			<	
Configuration: Debug [Active]		∨ Manage	Configurations]
Environment variables to set			Add	
Variable CWD	Value C:\ra2_bootloader\r11an0516eu0120-ra2-bootloader\RA2_secure_bootloader_org\overwrite_with_sit	-	JILI	
GCC_VERSION MCUBOOT_IMAGE_SIGNING_KEY MCUBOOT_IMAGE_VERSION	10.3.1 \$(workspace_loc:ra_mcuboot_ra2e1_overwrite_with_signature)/src/ B Edit variable	BU	JILI Edit	×
PATH PWD	C:\Renesas\RA\e2studio_v2022-10_fsp_v4.2.0\toolchains\gcc_arm\c Name: MCUBOOT_IMAGE_SIC		المحدث	Variables
TCINSTALL TC_VERSION	C:Renessi?ARAestudio_v2022-10_fsp_v4.2.0\toolchains\gcc_arm\g 10.3.1.20210824	re}/src/ecc_sign	private.pem	variables
<			ОК	Cancel
 Append variables to native environ Replace native environment with space 				
	_	Restore Defaults	Apply	
		ply and Close	Cancel	

Figure 47. Configure the Application Project to use the Custom Image Signing

Recompile the application projects and following the instructions in section 7 to exercise the system.

3.6.2 Migrating the Bootloader to other FSP versions

When migrating the bootloader project to a new FSP version, the updated contents in the \rac{ra} folder will be overwritten by the extracted new FSP content. Hence, the functions that are put in the gap area need to be reconfigured by updating the corresponding header files described in section 3.2.

The linker script is not automatically updated when user performs Generate Project Content, for applications using MCUboot as bootloader, in most cases, user may not need to update the linker script to boot the new application projects. However, there may be other linker script updates that are related to other application areas or new features related with MCUboot. Therefore, user is recommended to extract the new linker script by deleting the included linker script and apply similar updates to the linker script accordingly section 3.2.

Note that the instructions included in this release only apply to FSP v5.2.0, migration to other versions may need more customization. User needs to review the FSP release note on other potential updates needed.



3.6.3 Migrating from One Upgrade Mode to Another Upgrade Mode

As shown in section 3.2, a different set of functions need to be put in the gap area. The configurations selected in this application can be used as reference.

3.6.4 Use the Memory Usage Window to Select Functions to Put in the Gap Area

After compiling the bootloader project, you can open the **Memory Usage** view to select the functions of suitable size to put in the gap area.

Open the **Memory Usage** view from the e² studio top menu **Windows** tab: **Window > Show View > Other >** C/C++ > Memory Usage > Symbol.

		🛃 Problems 📮 Console 🔲	Properties 🛛 🛞 Smart Br	owser 🛛 💷 Smart Mar	nual 🔰 Memo	br
type filter text				Memo	ory Region Usag	ge
Type Inter text		Section Object Symbol				
. 💫 🗁 General	^	Symbol	Start address	End address	Size (byte)	T
✓ >> C/C++		swap_run	0x0000154C	0x000018BB	880	
😤 C/C++ Index		uECC_verify	0x00002480	0x00002737	696	
C/C++ Projects		context_boot_go	0x0000007C	0×000002FB	640	
		bootutil_img_validate	0x00000BC0	0×00000D97	472	
a 📪 Call Hierarchy		vli_mmod_fast_secp256r1	0x00001C48	0x00001DFB	436	
. 🦻 🌮 FSP Visualization		double_jacobian_default	0x00001FBC	0x00002113	344	
Include Browser		SystemInit	0×000031CC	0×000032EB	288	
Memory Usage		uECC_vli_mmod	0×00001E50	0x00001F67	280	
		uECC_vli_modInv	0×00002170	0x0000227F	272	
🔤 Peripheral Register Calculator		bootutil_verify_sig	0x00000AC4	0x00000BBF	252	
🛒 Problem Details		boot_read_swap_state	0x0000077C	0x00000873	248	

Figure 48. Memory Usage View

4. Using the Bootloader with a New Application or Existing Application

Developing an initial application to use a bootloader starts with developing and testing the application and the bootloader independently. Using the bootloader with an existing application or developing a new application to use the bootloader involves the following common steps:

- Adjust the memory map of the bootloader to allow the application and bootloader to fit the available MCU memory area.
- Configure the application to use the bootloader.
- Sign the application image.
- Developing an application to use a bootloader typically requires the application to have the capability to download a new application. This aspect is not demonstrated in this application project. Customers typically have customized image download method which differs from one customer to another.

This section uses a simple blinky project to demonstrate how to use the bootloader with the blinky application. After the initial blinky project is established, we need to configure the blinky project to the use of the bootloader project generated in the previous section. We also need to sign the blinky project using the signing command generated in the bootloader project. Detailed instructions are provided in this section.

Note: You can also follow section 7 to exercise the example bootloader and application projects without going through the application creation and configuration process to use with the bootloader. This section provides references for users to understand how to customize the project for their specific application.

4.1 Generate the Initial Application Project

Follow the steps below to create a blinky application project as the Initial Application Project. The steps in section 4.1 are identical when generating a blinky project whether the application uses a bootloader or not. Launch e^2 studio and open a Workspace, click **File** > **New** > **C/C++ Project** and select **Renesas RA** and **Renesas RA C/C++** Project.



1. Assign the project name based on Table 4.

Table 4. Name the Initial Application Project

Bootloader project name	Initial application project name
ra_mcuboot_ra2e1	blinky
ra_mcuboot_ra2e1_overwrite_with_signature	blinky_with_signature
ra_mcuboot_ra2e1_swap	blinky_swap
ra_mcuboot_ra2e1_swap_with_signature	blinky_swap_with_signature
ra_mcuboot_ra2e1_dxip	blinky_primary

- 2. Click **Next** and choose **EK-RA2E1** as the **Board** from the drop-down menu. Then click **Next**.
- 3. In the next screen, select **Executable** as the **Build Artifact** and **No RTOS** for the **RTOS Selection**. Then click **Next**.

 Renesas RA C/C++ Project Renesas RA C/C++ Project Build Artifact and RTOS Selection 	×
Build Artifact Selection	RTOS Selection No RTOS
? < Back	Next > Finish Cancel

Figure 49. Choose to Build Executable with No RTOS

4. Select the **Bare Metal - Blinky** as the **Project Template** for the board and click **Finish**. The initial application project is now created.

📴 Renesas RA C/C++ Project 📃	\times
Renesas RA C/C++ Project Project Template Selection	2
Project Template Selection Bare Metal - Blinky Bare metal FSP project that includes BSP and will blink LEDs if available. This project will initialize clocks, pi stacks, and the C runtime environment.	ns,

Figure 50. Choose Bare Metal – Blinky as Project Template

4.2 Configure the Existing Application to Use the Bootloader Project

The steps described in this section can be applied to any other existing application projects to configure the application project using the bootloader. Care should be taken to consider the size the application project. When using the bootloader with a different application project, the **Image 1 Flash Area Size** property should be adjusted accordingly.

Right-click on the application project folder in the **Project Explorer** and select **Properties**. Select the **C/C++ Build > Build Variables**, click **Add** and set the **Variable name** to **BootloaderDataFile** and check the **Apply to all configurations** box. Change the **Type** to **File** and enter the relative path to the .bld files for the bootloader project <boot_project_name>:

- Set \${workspace_loc:<boot_project_name>}/Debug/<boot_project_name>.bld for Value.
- For example, for bootloader project ra_mcuboot_ra2e1 (see Figure 51), Value will be: \${workspace loc:ra mcuboot ra2e1}/Debug/ra mcuboot ra2e1.bld



type filter text	Build Variables	
 Resource Builders C/C++ Build Build Variables Environment 	Configuration: Debug [Active]	✓ Manage Configurations
Logging Settings Tool Chain Editor > C/C++ General > MCU	Name Type Value Image: BootloaderDataFile Variable	× r Edit Delete
Project Natures Project References Renesas QE Run/Debug Settings Task Tags > Validation	Type: File Value: S{workspace_loc:ra_mcuboot_ra2e1}/Debug/ra_mcuboot_	Browse
	OK OK Configuration, such as environment variable value or command line parame builder may use them directly.	Cancel ing external builder eter in form of \${VAR}, internal Restore Defaults Apply

Figure 51. Configure the Build Variable to Use the Bootloader

Click Apply and then Apply and Close.

4.3 Signing the Application Image

Note: If you rebuild the bootloader project after changing any of the signing and signature **Properties** of the MCUboot module, you will need to select **Generate Project Content** again to bring in the updated .bld file.

Each application can have a defined version number. This version number can be used in the overwrite upgrade mode when **Downgrade Prevention** is **Enabled**. This is achieved by defining an Environment Variable: MCUBOOT_IMAGE_VERSION.

For applications that support signature verification, meaning for the applications that will work with bootloader ra_mcuboot_ra2e1_overwrite_with_signature and

ra_mcuboot_ra2e1_swap_with_signature, the signing key can be configured using another Environment Variable: MCUBOOT_IMAGE_SIGNING_KEY.

Figure 52 is an example of setting the above two mentioned Environment Variables for the application project used with bootloader ra_mcuboot_ra2e1_overwrite_with_signature and ra_mcuboot_ra2e1_swap_with_signature.

In this example, the Value of MCUBOOT_IMAGE_SIGNING_KEY is configured to:

\${workspace_loc:ra_mcuboot_ra2e1_overwrite_with_signature}/ra/mcutools/MCUboot/root-ec-p256.pem

If there is no signature verification, then it is not necessary to set the Environment Variable: MCUBOOT_IMAGE_SIGNING_KEY as are the cases for ra_mcuboot_ra2e1 and ra_mcuboot_ra21_swap.



Properties for blinky_wi	th_signature		
type filter text	Environment	4	• => • 8
 Resource Builders C/C++ Build Build Variables Environment 	Configuration: Debug [Active]	✓ Manage Con	figurations
Logging Settings	Environment variables to set		Add
Tool Chain Editor > C/C++ General > MCU	Variable CWD	Value C\ra2_bootloader\demos_11_06\demos\overwrite_with_signature\blinky_with_signature\Debug	Select Edit
Project Natures Project References	MCUBOOT_IMAGE_SIGNING_KEY MCUBOOT_IMAGE_VERSION	S(workspace_loc:ra_mcuboot_ra2e1_overwrite_with_signature)/ra/mcu-tools/MCUboot/root-ec-p256.pem	Delete
Renesas QE Run/Debug Settings	PATH PWD	C:\Renesas\RA\e2studio_v2021-10_fsp_v3.4.0_pure\toolchains\gcc_arm\9_2020q2\bin\;C:\Users\xianghui.wang\.ec C:\ra2_bootloader\demos_11_06\demos\overwrite_with_signature\blinky_with_signature\Debug	Undefine
Task Tags > Validation	TCINSTALL TC_VERSION	C:\Renesas\RA\e2studio_v2021-10_fsp_v3.4.0_pure\toolchains\gcc_arm\9_2020q2\ 9.3.1.20200408	
	<	>	
	 Append variables to native environ Replace native environment with space 		
		Restore Defaults	Apply
(?)	1	Apply and Close	Cancel

Figure 52. Configure the Application Image Version Number and Signing Key

To be able to always recompile the project when the Environment Variables or the linker script are updated, it is recommended add a **Pre-build** step to always delete the .elf file as shown in Figure 53.

```
rm -f ${ProjName}.elf
```

type filter text	Settings		
 Resource Builders C/C++ Build Build Variables Environment 	Configuration: Debug [Active]		
Settings Solution Sol	 Tool Settings Toolchain Build Steps Build Artifact Pre-build steps Command(s): rm -f S{ProjName}.elf 		

Figure 53. Configure the Pre-build Command

Next, you can add the RTT Viewer usage related application code to the primary application project. Unzip RA2_secure_bootloader.zip, open the

RA_secure_bootloader\<boot_project_name>\<Initial application project name>\src folder and copy all files under \src to the \src folder for the newly established project.

At this point, you can click **Generate Project Content** and compile the newly created application project and ensure \debug\<Initial application project name>.bin.signed is generated.

Note: With the blinky_primary of ra_mcuboot_ra2e1_dxip you need to add a configuration

"--defsym=XIP_SECONDARY_SLOT_IMAGE=0" as Figure 54 below:





Figure 54. Configuration of blinky_primary project in DXIP mode

5. Booting the Initial Application Project

5.1 Set Up the Hardware

Connect J10 using a USB micro to B cable from EK-RA2E1 to the development PC to provide power and debug connection using the on-board debugger.

5.2 Configure the Debugger

Open the Debug Configurations: **blinky > Debug As > Debug Configurations**

Optional Step: Set Allow caching of flash contents to No, as shown in Figure 55. Otherwise, the debugging bootloader applications memory window information may show wrong information.

© GDB Simulator Debug; WorkRam Start Image: Start Application WorkRam End Image: Start Start Start Image: Start Star	
wype filter text Mai Debugger Startup Source Common © C/C++ Remote Applic Debug hardware: J-Link ARM Target Device: R7FA2E1A9 © GDB Hardware Debug. GDB Settings Connection Settings Debug Tool Settings © GDB Simulator Debug. Flash Memory Type WorkRam Start Ø Java Applet WorkRam Start Ø Java Application Erase on-chip program flash before download No WorkRam Start Ø Remote Java Application Erase on-chip program flash before download No © Remote Java Application Use CFI-Flash No V	
C C/C ++ Application C/C ++ Remote Applic EASE Script GDB Hardware Debug GDB Struidstor Debug GDB Struidstor Debug GDB Struidstor Debug GDB Struidstor Debug Hash Memory Type WorkRam Stat WorkRam Stat WorkRam End Java Application Launch Group Remote Java Application Grage Start Gob Struidstor Debug WorkRam Stat WorkRam	
© C/C++ Remote Applic Debug hardware: J-Link ARM Target Device: R7FA2E1A9 If EASE Script GDB Hardware Debug; GDB Settings Debug Tool Settings © GDB Andware Debug; GDB Simulator Debug; Flash Memory Type Image: Stript St	
© GDB OpenOCD Debug Flash Memory Type © GDB Simulator Debug: WorkRam Start Ø Java Application Image: Concept of the start 1 Java Application Erase on-chip program flash before download No Q Remote Java Application Use CFI-Flash V or Renesas GDB Hardwar CFI Start 0x0	
C GDB OpenOCD Debug Flash Memory Type Image: GDB Simulator Debug WorkRam Start Image: Java Application Image: GDB OpenOCD Debug Image: Java Application Erase on-chip program flash before download No Image: Remote Java Application Use CFI-Flash Image: Remote Java Application No Image: Remote Java Application VorkRam Start Image: Remote Java Application Use CFI-Flash Image: Remote Java Application No Image: Re	
Co GDB Simulator Debug: WorkRam Start Image: Start Applet WorkRam End Image: Start Start Start Image: Start S	
To Java Application Fase on-chip program flash before download No Erase on-chip program flash before download No Crist Sava Application Use CFI-Flash No CFI Start Ox0	
Grave Oricing programma before download No Case Oricing Pr	e
	~
CFI Start Ox0	~
Cristan dia	~
CFI End UXU	
C blinky Debug_Flat V Semihosting	
C ra_mcuboot_ra2e1 Semihosting breakpoint address	
Renesas Simulator Dek V RTOS	
RTOS Integration in Debug View No 🗸	~
RTOS Debugging - Large Number of Threads. No	~
✓ System	
Allow caching of flash contents No	~
✓ Time Measurement	
Run Break Time Measurement Yes 🗸	~ ~
K → Revert Apple	. h.
Iter matched 15 of 17 items Revert Apple	лу
Debug Clc	lose

Figure 55. Disable Flash Content Caching



Make sure the <initial_application_project_name > Debug_Flat is selected and select the Startup tab.

📴 Debug Configurations				— [X
Create, manage, and run configu	urations				Ť.
Image: Second	Program Binary (blinky.elf)	Common 🖏 Source	Offset (hex)	On connect Yes Edit	
Filter matched 14 of 16 items				Revert Ap	ply
?				Debug	Close

Figure 56. Configure the Primary Project Debug Startup

Click Add... and then Workspace and navigate to the <boot_project_name> and select the <boot_project_name>.elf file from the debug folder. Click OK.

		2
 Image: Second Second	Name: blinky Debugger Startup Source Common Initialization Commands Reset and Delay (seconds): 3 Halt Load image and symbols Filename Load type Offset (hex) On connect Add Filename Edit Edit Edit Edit Remove Move up Move up Move down OK Cancel Set breakpoint at: main	
Filter matched 14 of 16 items	Revert Apply	

Figure 57. Add the Bootloader Project to Debug Configuration

Change the load type of the Program Binaries for the **<initial_application_project_name>** project to **Symbols only** by clicking on the cell for load type and selecting **Symbols only** from the drop-down menu.



Create, manage, and run config	urations				J.
Image: Second Secon	Name: blinky Debug_Flat		ommon Offset (hex)	On connect	
✓ C [®] Renesas GDB Hardware Deb C [®] blinky Debug_Flat C [®] ra_mcuboot_ra2e1 Debug C [®] Renesas Simulator Debuggir	🔽 Program Binary (blinky	Symbols only	0	Yes Yes	Add Edit Remove Move up
< >> Filter matched 14 of 16 items				Rev	vert Apply

Figure 58. Select to Load Symbols Only for the Application Project

Next, configure the Debug Configuration to include the Raw Binary of the signed primary application for download. Click Add... and then Workspace and navigate to the <boot_project_name> and select the <boot_project_name>.bin.signed file from the debug folder. Click OK. Then, change the Load type to Raw Binary. Note that the Offset (hex) setting of the signed primary image is the size of the bootloader (refer to Table 3). Figure 59 is an example of downloading the signed primary image for the overwrite without signature project.

🖹 🖻 闷 🗎 🗶 🖻 🏹 👻	Name: blinky Debug_Flat				
	📄 Main 🕸 Debugger ⊳ Sta	rtup 🔲 Common 🦆	Source		
C/C++ Application	Initialization Commands				
C/C++ Remote Application	Reset and Delay (seconds):	3			
EASE Script	□ Halt				
C GDB Hardware Debugging					
👩 GDB OpenOCD Debugging					~
💽 GDB Simulator Debugging (
🜌 Java Applet					~
🗾 Java Application					
🗊 Java Application 書 Launch Group	Load image and symbols				
			011 - 11 - 2]
🚭 Launch Group	Load image and symbols Filename	Load type	Offset (hex)	On connect	Add
➡ Launch Group ↓ Remote Java Application			Offset (hex)	On connect Yes	
Launch Group Launch Group Remote Java Application ✓ C Renesas GDB Hardware Deb	Filename	Symbols only			Add Edit

Figure 59. Include the Raw Binary of the signed image in the download

Click **Debug**. The debugger should hit the reset handler in the bootloader.





Figure 60. Start the Application Execution

Click **Resume** IP twice to run the project. The bootloader and the primary application project will be programmed and then the primary application project will be booted, the Red, Blue, and Green LEDs on the EK-RA2E1 should now be blinking.

Press up to pause the program. Note that the program counter is in the application image. Click Resume to run again.

Open the JLink RTT Viewer and set up the following configurations.

			1
Connection to J-Link	Serial No		
○ TCP/IP			
O Existing Session			
Specify Target Device			
R7FA2E1A9		~	
Force go on connec	ct		
Script file (optional)			
Target Interface & Spe	eed		
SWD	-	4000 kHz 🔻	
RTT Control Block			
Auto Detection	○ Address	earch Range	
Syntax: <rangestart [<="" td=""><td>ress range(s) the RTT Contro [Hex] > <rangesize>[, <ran 0x1000, 0x2000000 0x1000</ran </rangesize></td><td>ge1Start [Hex] ></td><td></td></rangestart>	ress range(s) the RTT Contro [Hex] > <rangesize>[, <ran 0x1000, 0x2000000 0x1000</ran </rangesize>	ge1Start [Hex] >	
0x20000000 0x8000			
	ОК	Cancel	

Figure 61. Configure the RTT Viewer

Click **OK** and observe the following output on the RTT Viewer. This output shows that the Primary application is being executed and all three LEDs are blinking. The message displayed indicates the upgrade mode and whether the Primary or the Secondary image is running.



Figure 62. RTT Viewer Output from the Primary Application



6. Mastering and Delivering a New Application

This section provides instructions on how to master and deliver a new application that will be loaded into the Secondary image slot.

Note that the example bootloader, the example Primary application as well the example Secondary applications are provided in the RA2_secure_bootloader.zip. You can also follow section 7 to exercise these projects without going through the new application creation and mastering process described in this section if desired.

6.1 Create a New Application

The new application can be created by modifying the existing application. Import the initial project to the same workspace and rename the new project.

Right-click in the white space in the **Project Explorer** area and select **Import**.

		🕲 Import — 🗆 🗙
		Select Choose import wizard.
		Select an import wizard: type filter text
Project Explorer (binky [Debun) S ra_mcubo		 ✓ Evisiting Projects into Workspace CMSIS Pack ✓ Existing Projects into Workspace ✓ File System ✓ Projects from Folder or Archive ✓ Renesas CS+ Project for CA/8K0R/CA/8K0 ✓ Renesas CS+ Project for CC-RX and CC-RL ✓ C/C++ > Enstall > Comph > Exam
	Import Export	

Figure 63. Select Rename and Import the Primary Application

Once the **Import** window opens, name the project and click **Browse** for **Select root directory** as shown in Figure 64.



🕑 Import			
Rename & Impo	-		
Select a directory	to search for existing Eclipse projects.		
Project name:	blinky_new		
🗹 Use default I	location		
Location:	C:\ra2_bootloader\repo_dev\ra_sol	utions\applicati Br	owse
	🗹 Create Directory for Project		
Choose file syste	em: default 🖂		
Import from:			
Select root d	irectory:	∼ Bro	owse
O Select archiv	e file:	Br	owse
Projects:			
Options	onfiguration output folders		
?	< Back Next >	Finish	Cancel
C: PFOIDEN5	> (C:) PC10 > ra2_bootloader > k	2 > RA2_secure_boo	tloader » o
	^		
Name		Date modified	Туре
📙 .meta	data	12/2/2021 2:51 PM	File folder
📙 blinky	,	12/2/2021 2:56 PM	File folder
📙 ra_mo	uboot_ra2e1	12/2/2021 2:53 PM	File folder

Figure 64. Rename the Project

Name the new project based on Table 5.

Table 5. Project Naming

Bootloader Project Name	Initial Application Project Name	New Application Project Name
ra_mcuboot_ra2e1	blinky	blinky_new
<pre>ra_mcuboot_ra2e1_overwrite _with_signature</pre>	blinky_with_signature	blinky_with_signature_new
ra_mcuboot_ra2e1_swap	blinky_swap	blinky_swap_new
ra_mcuboot_ra2e1_swap_with _signature	blinky_swap_with_signatu re	blinky_swap_with_signatur e_new
ra_mcuboot_ra2e1_dxip	blinky_primary	blinky_secondary



Figure 65 is an example screenshot when importing the blinky project as **blinky_new**.

📴 Import	-	
Rename & Import Proj	ect	
Select a directory to searc	h for existing Eclipse projects.	
Project name: blinky_n	ew	
🗹 Use default location		
Location: C:\	ra2_bootloader\K2\RA2_secure_bootloader\ove	Browse
C	reate Directory for Project	
Choose file system: def	ault \vee	
Import from:		
Select root directory:	C:\ra2_bootloader\K2\RA2_secure_bootlc ~	Browse
O Select archive file:		Browse
	ader\K2\RA2_secure_bootloader\overwrite_no_si :\ra2_bootloader\K2\RA2_secure_bootloader\ove	
Options Keep build configura	tion output folders	

Figure 65. Import blinky Project as blinky_new

Click Finish, and the new application project will be created.

Update Existing Application to a New Application

To demonstrate that the application is updated, portions of the code can be updated, for example:

- Update the application to blink one blue LED only.
- Update the RTT Viewer message to show this is the update image.

For simplicity, user can unzip RA2_secure_bootloader.zip, open the \<boot_project_name>\<new application project name>\src folder and copy all files under \src to the newly established project \src folder.

When importing the primary application, the Build Variable and the Environment Variables as well as the Debug configurations are automatically imported. Click **Generate Project Content** and compile the new application. The signed binary for the new application is now created. In this example, blinky_new.bin.signed will be created.

For cleanness of the project, user can delete the .jlink file of the old project under the root of the newly created project structure.

Note: For blinky_secondary of ra_mcuboot_ra2e1_dxip you need to add a configuration

"--defsym=XIP_SECONDARY_SLOT_IMAGE=1" as Figure 66 below:



type filter text	Settings	< → < < 8
 Resource Builders C/C++ Build Build Variables 	Configuration: Debug [Active]	V Manage Configurations
Environment Logging Settings Tool Chain Editor > C/C++ General > MCU	 Tool Settings Toolchain Build Steps Target Processor Optimization Warnings Debugging 	Puild Artifact Binary Parsers Serror Parsers Linker flags (-Xlinker [option]) Set
Project Natures Project References Refactoring History Renesas QE Run/Debug Settings Task Tags > Validation	 Solution Arm Cross Assembler Preprocessor Includes Warnings Miscellaneous Solution Arm Cross C Compiler 	Other objects
	Preprocessor Includes Includes Vernings Miscellaneous Note Clinker	
	 ➢ General ➢ Libraries ➢ Miscellaneous ✓ ➢ GNU Arm Cross Create Flash Image 	Generate map "\$(BuildArtifactFileBaseName).map"
	 	Cross reference (-Xlinkercref) Print link map (-Xlinkerprint-map)

Figure 66. Configuration of blinky_secondary project in DXIP mode

Debug the New Application

To boot the new image, there is no need to update the debug configuration.

However, in most cases, user needs to debug the new application. It is recommended user debug the new application as a primary application, which means to initiate the debug process using the debug configuration of the new application. To debug the new image as a primary image, we need to update the debug configuration of the newly created application to use the signed binary of the blinky_new application rather than the signed binary of the old blinky application.

For example, when using the application projects for the ra_mcuboot_ra2e1, we want to change the debug configuration of the blinky_new project from the imported result shown in Figure 68:

ame: blinky_new Debug_Flat		
] Main 🕸 Debugger 🍺 Startup 🦗 Source 🔲 Common		
Initialization Commands		
Reset and Delay (seconds): 3		
Halt		
Load image and symbols		
Load image and symbols Filename	Load type	Offset (hex)
	Load type Symbols only	Offset (hex)
Filename	Symbols only	Offset (hex)

Figure 67. Debug Configuration of blinky_new initially imported



In the imported configuration, the signed binary of the blinky project is used. We need to change that to the signed binary of blinky_new as shown in Figure 68.

Name: blinky_new Debug_Flat								
📄 Main 🕸 Debugger 🍉 Startup 🦗 Source 🔲 Common								
Initialization Commands								
Reset and Delay (seconds): 3								
Halt								
Load image and symbols								
Load image and symbols Filename	Load type	Offset (hex)	On conne					
	Load type Symbols only	Offset (hex)	On conne Yes					
Filename	Symbols only	Offset (hex)						

Figure 68. Debug Configuration of blinky_new to use for debugging

Note that in order to debug the new image as a primary image, for overwrite and swap mode, we want to set the download address of the signed new image binary to the location of the primary slot. For Direct XIP, we can set the download address of the signed new image binary to the location of the intended slot.

To create a brand-new application when using the overwrite, swap or Direct XIP upgrade mode without importing the previous application, you can follow section 4.2 to configure the application to use the bootloader and section 4.3 to sign the application image.

6.2 Configure the Swap Test Mode

Prior to introducing the swap test mode, it helps to introduce the image_ok byte as part of the application image trailer. The image_ok byte resides in the image trailer area. It is a flag byte that is used in Swap and Direct XIP upgrade modes. This byte is used to determine whether the new image will be swapped or not after the next reset following an image update. Please refer to Figure 13 for the location of the image trailer and the image_ok byte.

When using the Swap update mode, after the new image is loaded to the Secondary slot and authenticated successfully, the old image and the new image are swapped. At the next system reset, the system behavior differs based on whether the image_ok byte which resides in the primary slot is 0x01 or 0xFF.

If the image_ok byte is 0x01, after the next reset, there will be no swapping and hence the new image still stays in the Primary slot and will be booted. If the image_ok byte is 0xFF, after the next reset, the new image and the old image is swapped again and the old image is booted. This is the rollback feature of swap mode.

Setting the image in the Primary slot as Confirmed can be achieved at the new image compile time or runtime. This is explained in section 6.2.1 and 6.2.2.





Figure 69. Swap Test Mode

6.2.1 Confirming the New Application at Compile Time

FSP 3.4.0 or earlier only supports confirming the new image at compile time. FSP 3.5.0 or later supports runtime image confirmation of flat projects.

Confirming the new image (which will be loaded to the primary slot) at compile time requires setting the Custom Signing Options to --confirm as shown in Figure 16. This usage is demonstrated in the example bootloader blinky_swap_new.

6.2.2 Confirming the New Application at Run-time

Confirming the new application at runtime requires the bootloader to use --pad for the Custom signing command as shown in Figure 17. In addition, confirming the new image at runtime requires the **MCUboot Image Utilities** module to be included in the new application image and configure the system to use several files from the bootloader project. The example project demonstrate this feature. This module is included in the example bootloader blinky_swap_with_signature_new.

Open the Secondary application project blinky_swap_with_signature_new, and navigate to the Stacks tab, click **New stack > Bootloader > MCUboot Image Utilities**. Then, configure the properties of **MCUboot Image Utilities** module as shown in Figure 71. Adding this module adds about 2 kB of flash usage in the application.



Figure 70. Include the MCUboot Image Utilities Module

Configure the path of the header files needed.



Renesas RA Family

	Common Stacks	🛃 New Stack > 斗 Extend Sta				
AL/Common g_ioport I/O Port (r_ioport) MCUboot Image Utilities	(r_ioport) Utilities					
 New Object > Remove 	 g_flash0 Flash (r_flash_lp) i 					
BSP Clocks Pins Interrupts Event Links Stacks Components						
ns 📮 Console 🔲 Properties 🗙 🌸 Smart Browser 🔑 Smart Manual 🔗 Search						
t Image Utilities						
Property	Value					
✓ Common						
✓ General						
Bootloader mcuboot_config.h	//ra_mcuboot_ra2e1_swap_with_signature/ra_cfg/mcu-tool	//ra_mcuboot_ra2e1_swap_with_signature/ra_cfg/mcu-tools/include/mcuboot_config/mcuboot_config.h				
Bootloader sysflash.h	//ra_mcuboot_ra2e1_swap_with_signature/ra_cfg/mcu-too	//ra_mcuboot_ra2e1_swap_with_signature/ra_cfg/mcu-tools/include/sysflash/sysflash.h				
Bootloader mcuboot_logging.	h//ra_mcuboot_ra2e1_swap_with_signature/ra_cfg/mcu-tool	ls/include/mcuboot_config/mcuboot_logging.h				

Figure 71. Include the Bootloader Header Files

Next configure the **r_flash_lp** module in the same way as in Figure 23.

In the secondary application project, insert the following function call to activate the confirmation of the application image. This function call can be added at a user chosen location after the desired testing of the application project is finished.

In the included example project, this function is demonstrated in the hal_entry() function located in \swap_with_signature\blinky_swap_with_signature_new\hal_entry.c.

/* Confirm the image in the primary slot.

* This is required after a test update in swap mode.

* This makes the swap permanent, and prevents MCUboot from reverting to the previous image at the next reset.

*/

assert(0 == boot_set_confirmed());

Figure 72. Confirm the Update Image

6.3 Downloading and Booting the New Application

Assume the Primary application blinky is now up and running and the three LEDs are blinking.

For testing purpose, user can click **Pause** and use the **Ancillary Download** button (which is available under the e2studio Debug view) to load the compiled Secondary Application blinky_new.bin.signed Select the new application image and set the download address. The download address depends on the bootloader flash memory allocation.

The download address should be the sum of Bootloader Flash Area Size + Image 1 Flash Area Size based on update mode shown in Table 3. For example, for the overwrite only without signature bootloader ra_mcuboot_ra2e1, the download address should be **0x4000**.



Load Ancillary File		
Select an ancillary file for loading		
File:	&workspace_loc:\blinky_new\Debug blinky_new.bin.signed} Vorkspace File System	
	s raw binary image	
Address:	0x00004000	
	OK Cancel	
	OK Cancel	

Figure 73. Download the Secondary Application Image

Note that for user-created customized applications, the download address needs to be adjusted by referencing the specific flash layout. User can reference Table 3 to learn how to come up the download address.

Notes on using the Load Ancillary File Download

When we use the Load Ancillary File to download a new image during a debug session, the GDB server reconnects with the target, downloads the image, and restarts the debug session as shown in the following Console window output.

 ⇒ 1 2 3 4 5 00000494 6 0000049a 7 8 		
	Console X 🔲 Properties 🌸 Smart Browser 🐺 Smart Manual 🔗 Search	
	: [Renesas GDB Hardware Debugging] [pid: 40]	
	r Renesas targets. on 9.1.0.v20230405-115727 [dd3207d3] (Apr 6 2023 16:06:04)	
Raw o	er with the following options: ptions : C:\Users\a5099044\.eclipse\com.renesas.platform_101687610 version V7.88d - C:\Users\a5099044\.eclipse\com.renesas.platform_1016876100\Debug	
GDBSe	R7FA2E1A9, ARM Target rver endian : little t power from emulator : Off	
	et connection	
Finished targ	d the connected device ID (device ID address not specified). et connection	
GDB: 56755	tion status - OK	
	tion status - OK	
Starting down	load	
SECMPUxxx, wr Finished down		
And the second sec	kpoint set at address 0x494	
	kpoint set at address 0x2dc0 ead memory' has failed with error code. 0xffffffff	
GDB action 'read memory', has failed with error code, 0xffffffff Starting download		
Starting down	load	

Figure 74. GDB Actions when using the Load Ancillary File Button



After the new image is downloaded and the GDB debug session is restarted, user can click **Resume** to allow the system to perform image overwrite and the new image will be booted. Only the blue LED should be blinking now, which indicates the new image is flashed to the Primary slot of the application area.

On the RTT Viewer, information on the secondary application execution is displayed including the upgrade mode, whether signature authentication is supported as well as what LEDs are blinking. Below is an example when blinky_overwrite_with_signature_new is booted.

00> Running the Secondary (New) application with overwrite update mode without signature authentication. 00> Only the blue LED is blinking.

Figure 75. RTT Viewer Output from the New Application

Prior to deployment, a system with bootloader solution would typically need to include an image downloader and programmer in the application (primary and secondary applications), so a new application can be downloaded in the field.

Application project *RA6 Secure Firmware Update using MCUboot and Flash Dual Bank (R11AN0570)* includes an image downloader using XModem over UART interface. User can reference that to create an image downloader.

7. Appendix: Compile and Exercise the Included Example Bootloader and Application Projects

Unzip RA2_secure_bootloader.zip to access the included bootloader and example application projects.



Figure 76. Example Projects Included

7.1 Running the Example Projects with Overwrite Upgrade Mode

7.1.1 Without Signature Verification

Follow the steps below to run the example projects under folder \overwrite_no_signature:

- 1. Import projects to a workspace.
- 2. Open the configuration.xml file from project ra_mcuboot_ra2e1.
- 3. Click Generate Project Content.
- 4. Compile the project ra_mcuboot_ra2e1.
- 5. Open the configuration.xml file from project blinky.
- 6. Click Generate Project Content.
- 7. Compile the blinky project.
- 8. Open the configuration.xml file from project blinky_new.
- 9. Click Generate Project Content.
- 10. Compile the blinky_new project.
- 11. Debug the application from project blinky.
- 12. Resume the program execution twice. All LEDs should be blinking.
- 13. Pause the execution.
- 14. Download the blinky_new.bin.signed using Load Ancillary File to address 0x4000.
- 15. Resume the program execution. The blue LED should be blinking.

7.1.2 With Signature Verification

Follow the steps below to run the example projects under folder \overwrite_with_signature:



- 1. Import projects to a workspace.
- 2. Open the configuration.xml file from project ra_mcuboot_ra2e1_overwrite_with_signature.
- 3. Click Generate Project Content.
- 4. Compile the project ra_mcuboot_ra2e1_overwrite_with_signature.
- 5. Open the configuration.xml file from project blinky_with_signature.
- 6. Click Generate Project Content.
- 7. Compile the blinky_with_signature project.
- 8. Open the configuration.xml file from project blinky_with_signature_new.
- 9. Click Generate Project Content.
- 10. Compile the blinky_with_signature_new project.
- 11. Debug the application from project blinky_with_signature.
- 12. Resume the program execution twice. All LEDs should be blinking.
- 13. Pause the execution.
- 14. Download the blinky_with_signature_new.bin.signed to address 0x5800.
- 15. Resume the program execution, the blue LED should be blinking.

7.2 Running the Example Projects with Swap Upgrade Mode

7.2.1 Without Signature Verification

Follow the steps below to run the example projects under folder \swap_no_signature:

- 1. Import projects to a workspace.
- 2. Open the configuration.xml file from project ra_mcuboot_ra2e1_swap.
- 3. Click Generate Project Content.
- 4. Compile the project ra_mcuboot_ra2e1_swap.
- 5. Open the configuration.xml file from project $blinky_swap$.
- 6. Click Generate Project Content.
- 7. Compile the blinky_swap project.
- 8. Open the configuration.xml file from project blinky_swap_new.
- 9. Click Generate Project Content.
- 10. Compile the blinky_swap_new project.
- 11. Debug the application from project blinky_swap.
- 12. Resume the program execution twice. All LEDs should be blinking.
- 13. Pause the execution.
- 14. Download the blinky_swap_new.bin.signed using the Load Ancillary File to address 0x5000.
- 15. Resume the program execution. The blue LED should be blinking.
- 16. Reset the program execution from e² studio.
- 17. Run the application. The blue LED should be blinking.

7.2.2 With Signature Verification

Follow the steps below to run the example projects under folder $\swap_with_signature$:

- 1. Import projects to a workspace.
- 2. Open the configuration.xml file from project ra_mcuboot_ra2e1_swap_with_signature.
- 3. Click Generate Project Content.
- 4. Compile the project ra_mcuboot_ra2e1_swap_with_signature.
- 5. Open the configuration.xml file from project blinky_swap_with_signature.
- 6. Click Generate Project Content.



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- 7. Compile the blinky_swap_with_signature project.
- 8. Open the configuration.xml file from project blinky_swap_with_signature_new.
- 9. Click Generate Project Content.
- 10. Compile the $blinky_swap_with_signature_new project$.
- 11. Debug the application from project blinky_swap_with_signature.
- 12. Resume the program execution twice. All LEDs should be blinking.
- 13. Pause the execution.
- 14. Download the blinky_swap_with_signature_new.bin.signed using Load Ancillary File to address 0x6800.
- 15. Resume the program execution. The blue LED should be blinking.
- 16. Reset the program execution from e^2 studio.
- 17. Run the application. The blue LED should be blinking.

7.3 Running the Example Project with Direct XIP Upgrade Mode Without Signature

Follow the steps below to run the example projects under folder $\direct_xip_no_signature$:

- 1. Import projects to a workspace.
- 2. Open the configuration.xml file from project ra_mcuboot_ra2e1_dxip.
- 3. Click Generate Project Content.
- 4. Compile the project ra_mcuboot_ra2e1_dxip.
- 5. Open the configuration.xml file from project blinky_primary.
- 6. Click Generate Project Content.
- 7. Compile the blinky_primary.
- 8. Open the configuration.xml file from project blinky_secondary.
- 9. Click Generate Project Content.
- 10. Compile the blinky_secondary.
- 11. Debug the application from project blinky_primary.
- 12. Resume the program execution twice. All LEDs should be blinking.
- 13. Pause the execution.
- 14. Download the blinky_secondary.bin.signed using Load Ancillary File to address 0x4000.
- 15. Resume the program execution. The blue LED should be blinking.
- 16. Reset the program execution from e^2 studio.
- 17. Run the application. The blue LED should be blinking.

8. References

- 1. Renesas RA Family MCU Securing Data at Rest using Security MPU Application Project (R11AN0416)
- 2. RA6 Secure Bootloader Using MCUboot and Internal Code Flash Application Project (R11AN0497)

9. Website and Support

Visit the following URLs to learn about the RA family of microcontrollers, download tools and documentation, and get support:

EK-RA2E1 Resources RA Product Information Flexible Software Package (FSP) RA Product Support Forum Renesas Support renesas.com/ra/ek-ra2e1 renesas.com/ra renesas.com/ra/fsp renesas.com/ra/forum renesas.com/support



Revision History

	Description		ion	
Rev.	Date	Page	Summary	
1.00	Jul.26.21	-	First release document	
1.10	Dec.09.21	-	Update to add swap mode and signature verification support	
1.2.0	Apr.07.23	-	Update to FSP v4.2.0. Add Direct XIP mode and use new e ² studio features	
1.3.0	Sep.07.23	-	Update to usage mode based on FSP v4.5.0. Correct project recreation missing steps.	
1.4.0	May.01.24	-	Update to FSP v5.2.0. Update functions to put in the flash gap section.	



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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