

Renesas RA Family

RA4 Quick Design Guide

Introduction

This document answers common questions and points out subtleties of the RA4 MCU that might be missed unless the hardware manual was extensively reviewed. The document is not intended to be a replacement for the hardware manual. It is intended to supplement the manual by highlighting some key items most engineers will need to start their own design. It also discusses some design decisions from an application point of view.

Target Device

RA4 MCU Series

Contents

1. Power Supplies.....	4
1.1 References	5
2. Emulator Support.....	6
2.1 SWD Interface	7
2.2 JTAG Interface	8
2.3 Serial Programming Interface using SCI.....	9
2.4 Serial Programming Interface using SCI: Devices with Arm® TrustZone® Support	10
2.5 Multiple Emulator Interface.....	11
2.6 Software Setups for Emulator Connections	12
2.6.1 SWD and JTAG Interfaces	12
2.6.2 Trace Port.....	12
3. MCU Operating Modes	13
3.1 RA4E2 MCU Operating Modes	14
4. Option Setting Memory	14
4.1 Option Setting Memory Registers	17
5. Clock Circuits.....	17
5.1 Reset Conditions	18
5.2 Clock Frequency Requirements.....	18
5.2.1 Requirements for USB Communications	19
5.2.2 Requirements for Programming and Erasing ROM or Data Flash.....	19
5.3 Lowering Clock Generation Circuit (CGC) Power Consumption.....	19
5.4 Writing the System Clock Control Registers	19
5.5 Clock Setup Example	20
5.6 HOCO Accuracy	21
5.7 Flash Interface Clock.....	21
5.8 Board Design.....	21

5.9	External Crystal Resonator Selection.....	21
5.10	External Clock Input	22
6.	Reset Requirements and the Reset Circuit.....	22
6.1	Pin Reset	23
6.2	Power-On Reset	23
6.3	VBATT-Selected Voltage Power-On Reset.....	23
6.4	Independent Watchdog Timer Reset.....	24
6.5	Watchdog Timer Reset.....	24
6.6	Voltage-Monitoring Resets	24
6.7	Deep Software Standby Reset.....	24
6.8	Software Reset	24
6.9	Other Resets	24
6.10	Determination of Cold/Warm Start	24
6.11	Determining the Reset Source	25
7.	TrustZone® Support	25
7.1	Implementation of Arm® TrustZone Technology	25
7.2	Emulator Support for TrustZone®	27
7.2.1	Device Lifecycle Management	28
7.2.2	ID Authentication	28
8.	Memory	29
8.1	SRAM	30
8.2	Standby SRAM.....	30
8.3	Peripheral I/O Registers	31
8.4	On-Chip Flash Memory	31
8.4.1	Background Operation	32
8.4.2	ID Code Protection	32
8.4.3	Flash Block Protection.....	32
8.4.4	Memory Protection Unit.....	32
8.5	Restriction on Endian	33
9.	Register Write Protection.....	33
10.	I/O Port Configuration	34
10.1	Multifunction Pin Selection Design Strategies.....	34
10.2	Setting Up and Using a Pin as GPIO	35
10.2.1	Internal Pull-Ups	36
10.2.2	Open-Drain Output	36
10.2.3	Drive Capacity	36
10.3	Setting Up and Using Port Peripheral Functions.....	37
10.4	Setting Up and Using IRQ Pins	38

10.5	Unused Pins	39
10.6	Nonexistent Pins.....	40
10.7	Electrical Characteristics	40
11.	Module Stop Function.....	40
12.	Interrupt Control Unit	40
13.	Low Power Consumption.....	42
14.	Buses	45
14.1	Bus Error Monitoring.....	46
14.1.1	Bus Error Types.....	46
14.1.2	Operations When a Bus Error Occurs.....	46
15.	General Layout Practices.....	47
15.1	Digital Domain vs. Analog Domain.....	47
15.2	High Speed Signal Design Considerations	47
15.3	Signal Group Selections	48
16.	References	48
	Revision History.....	50

1. Power Supplies

The RA family has digital power supplies and analog power supplies. The power supplies use the following pins.

Table 1. Digital Power Supplies

Symbol	Name	Description
VCC	Power supply	Power supply pin. Connect to the system power supply. Connect this pin to VSS via a 0.1 μ F capacitor placed close to the VCC pin.
VSS	Ground	Ground.
VCL	Power supply	Connect this pin to VSS via a capacitor close to the VCL pin. The value depends upon the specific MCU group.
VCL0	Power supply	Connect this pin to VSS via a 0.1 μ F capacitor close to the VCL0 pin.
VBATT ²	Backup power	Backup power pin. Supplies power to RTC and sub-clock oscillator in the absence of VCC. When VBATT pin is not used, connect to VCC or VSS.
VCC_USB ¹	USB FS power supply	USB Full-speed power supply pin. Connect this pin to VCC. Connect this pin to VSS_USB via a 0.1 μ F capacitor placed close to the VCC_USB pin.
VSS_USB	USB FS ground	USB Full-speed ground pin. Connect this pin to VSS.

Note 1: For RA4M1, VCC_USB can be either input or output. As input, it is the supply voltage for the USB transceiver. As output, it is the voltage out from the USB LDO Regulator, and needs an external capacitor. When the USB LDO Regulator is not used, connect to VCC. When the regulator is used, connect to VSS through a 1.0 μ F capacitor.

Note 2: Not included on RA4E2.

Table 2. Analog Power Supplies

Symbol	Name	Description
AVCC0	Analog power supply	Analog voltage supply pin for the respective modules. Connect this pin to the same voltage as the VCC pin.
AVSS0	Analog ground	Analog ground for the respective modules. Connect this pin to the same voltage as the VSS pin.
VREFH0 ^{*1}	12-bit ADC high reference voltage	Reference voltage input pin for the 12-bit A/D. Connect this pin to AVCC0 if the 12-bit A/D converter is not used.
VREFL0 ^{*1}	12-bit ADC low reference voltage	Analog reference ground pin for the 12-bit A/D converter. Connect this pin to VSS if the 12-bit A/D converter is not used.
VREFH	12-bit ADC and DAC analog supply	Reference voltage input pin for the 12-bit A/D converter, unit 1 (if present) and the D/A converter. Connect this pin to AVCC0 if these features are not used.
VREFL	12-bit ADC and DAC analog ground	Reference ground pin for the 12-bit A/D converter, unit 1 (if present) and the D/A converter. Connect this pin to VSS if these features are not used.

Note 1. For RA4M1, this applies to the 14-bit ADC.

1.1 References

Further information regarding the power supply for the RA MCU Group can be found in the following documents:

- R01UH0887 RA4M1 Group, *RA4M1 Group User's Manual: Hardware*
- R01UH0892 RA4M2 Group, *RA4M2 Group User's Manual: Hardware*
- R01UH0893 RA4M3 Group, *RA4M3 Group User's Manual: Hardware*
- R01UH0929 RA4E1 Group, *RA4E1 Group User's Manual: Hardware*
- R01UH0996 RA4E2 Group, *RA4E2 Group User's Manual: Hardware*

Chapter numbers may vary between Arm® Cortex®-M4 and Arm® Cortex®-M33 devices.

The **Overview** chapter lists power pins in each package with recommended bypass capacitors.

The **Resets** chapter discusses the Power-On Reset and how to differentiate this from other reset sources.

The **Low Voltage Detection** chapter provides details on the Low-Voltage Detection Circuit that can be used to monitor the power supply. The **Option-Setting Memory** chapter additionally describes how to enable Low-Voltage Detection 0 Circuit automatically at startup.

The **Battery Backup Function** chapter shows how to provide battery backup to the RTC and sub-clock oscillator.

If you plan to use the on-chip Analog to Digital Converters (ADC) or the Digital to Analog Converter (DAC), see *12-Bit A/D Converter (ADC12)* or *14-Bit A/D Converter (ADC14)* and *12-Bit D/A Converter (DAC12)* for details on how to provide filtered power supplies for these peripherals.

Table 3. RA4 MCU Groups, User's Manual: Hardware

Chapter Name	Description
Overview	Lists power pins in each package with notes on termination and bypassing.
Resets	Discusses the Power-on Reset and how to differentiate this from other reset sources.
Voltage Detection Circuit	Provides details on the Low-Voltage Detection Circuit that can be used to monitor the power supply.
Low Power Modes	Using low power modes may allow you to reduce the voltage of the power supply. See this chapter for details on how operating modes affect power supply requirements.
Battery Backup Function	Shows how to provide battery backup to the RTC and sub-clock oscillator

Chapter Name	Description
12-Bit A/D Converter 14-Bit A/D Converter 12-Bit D/A Converter	If you plan to use the on-chip A/D or D/A converters, these chapters give details on how to provide filtered power supplies for these peripherals.
Clock Generation Circuit	Provides detailed descriptions on how to configure and use the available clocks, including PCB design recommendations.

2. Emulator Support

RA4 MCU devices have an emulator interface that supports both debugging using SWD or JTAG communication, and serial programming using SCI communication. This emulator makes it easy to switch between debugging and serial programming.

Some RA4 MCU devices, such as RA4E2, do not support JTAG or TRACE functions. For these devices, the SWD interface must be used for debugging.

The SWD or JTAG emulator interface should be connected to an Arm®-standard 10-pin or 20-pin socket. MD, TXD, and RXD pins are added for serial programming using SCI communication.

The serial programming interface must be used to program the Arm® TrustZone® IDAU boundary register settings. For devices that support TrustZone, it is recommended to connect P300/SWCLK/TCK and P201/MD pins using a wired-OR circuit on the board to use both debugging and serial programming.

To comply with the Arm® specification, pull up resistors are required on the JTAG, SWD and SCI signals. Without the correct pull up resistors, the interface may not function correctly. However, RA4 MCU devices have internal pull up resistors that are enabled by default for these signals. When the internal pull up resistors are enabled, no external resistors are required on these signals.

Emulator support is useful for product development and prototyping, but may not be needed once a design moves to production. If emulator support is no longer needed for a design, make sure to configure the ports according to the *Handling of Unused Pins* section of the related MCU Hardware User's Manual. See also section 10.5 in this document.

2.1 SWD Interface

The following diagram shows the typical connectivity of the debug interface when using Serial Wire Debug (SWD).

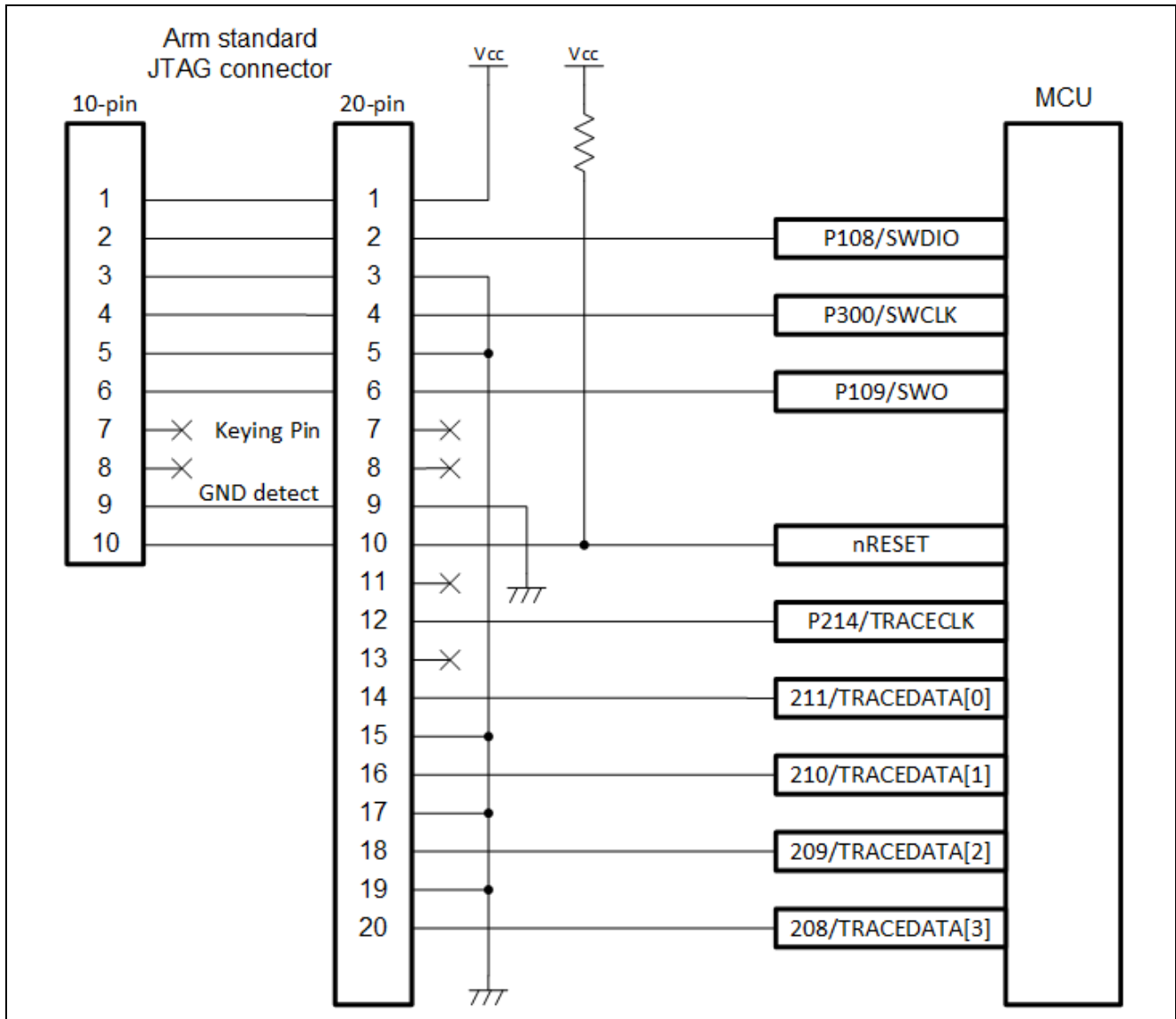


Figure 1. SWD Interface Connections

- Note:
1. The output of the reset circuit of the user system must be open collector.
 2. Arm® Cortex®-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins.
 3. Some RA4 Arm® Cortex®-M33 devices, such as RA4E2, do not support the SWO, TRACECLK or TRACEDATA[n] pins.

2.2 JTAG Interface

The following diagram shows the typical connectivity of the debug interface when using an Arm®-standard JTAG debug interface.

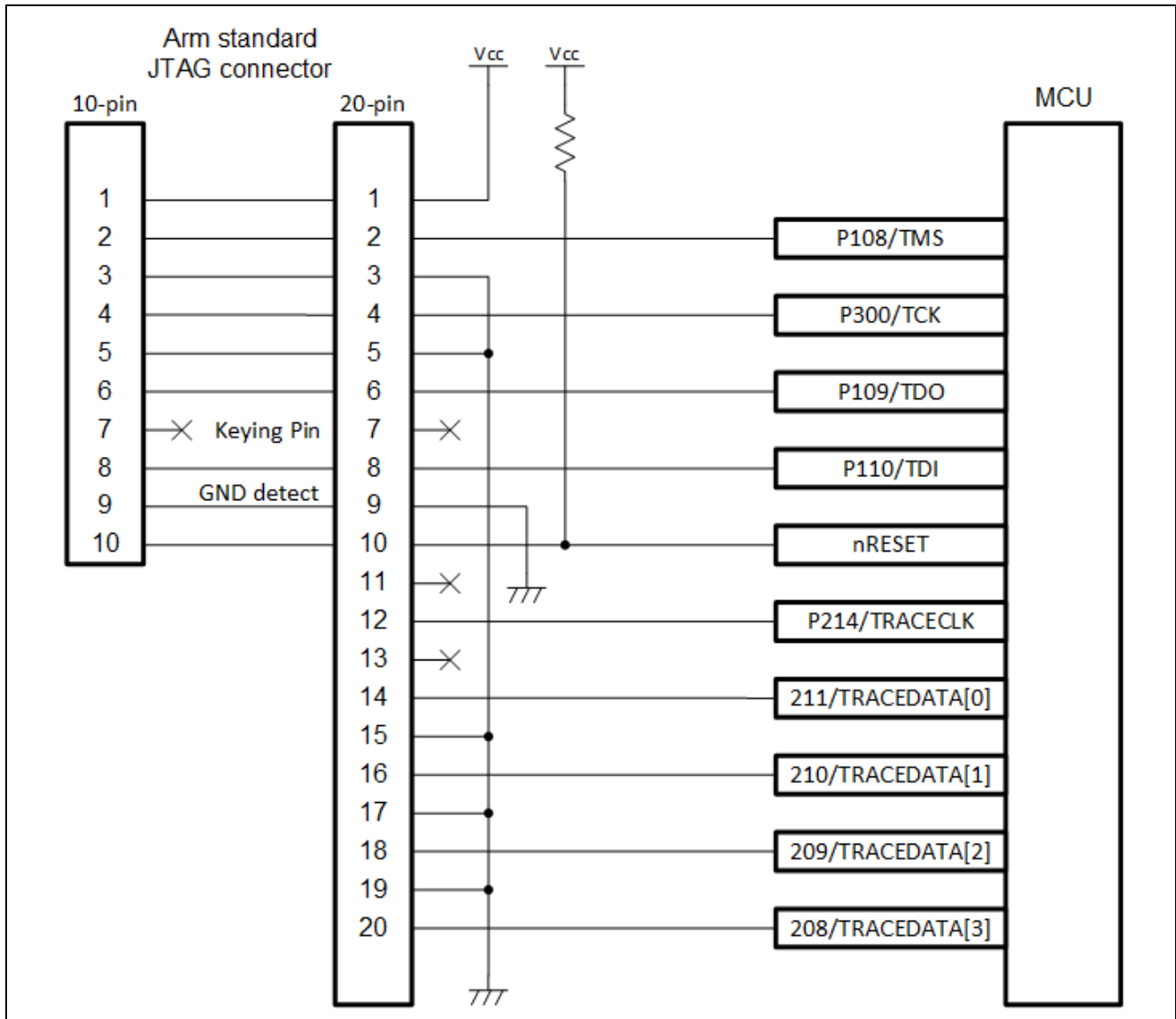


Figure 2. JTAG Interface Connections

- Note:
1. The output of the reset circuit of the user system must be open collector.
 2. Arm Cortex®-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins.

2.3 Serial Programming Interface using SCI

The following diagram shows the typical connectivity of the serial programming interface using SCI.

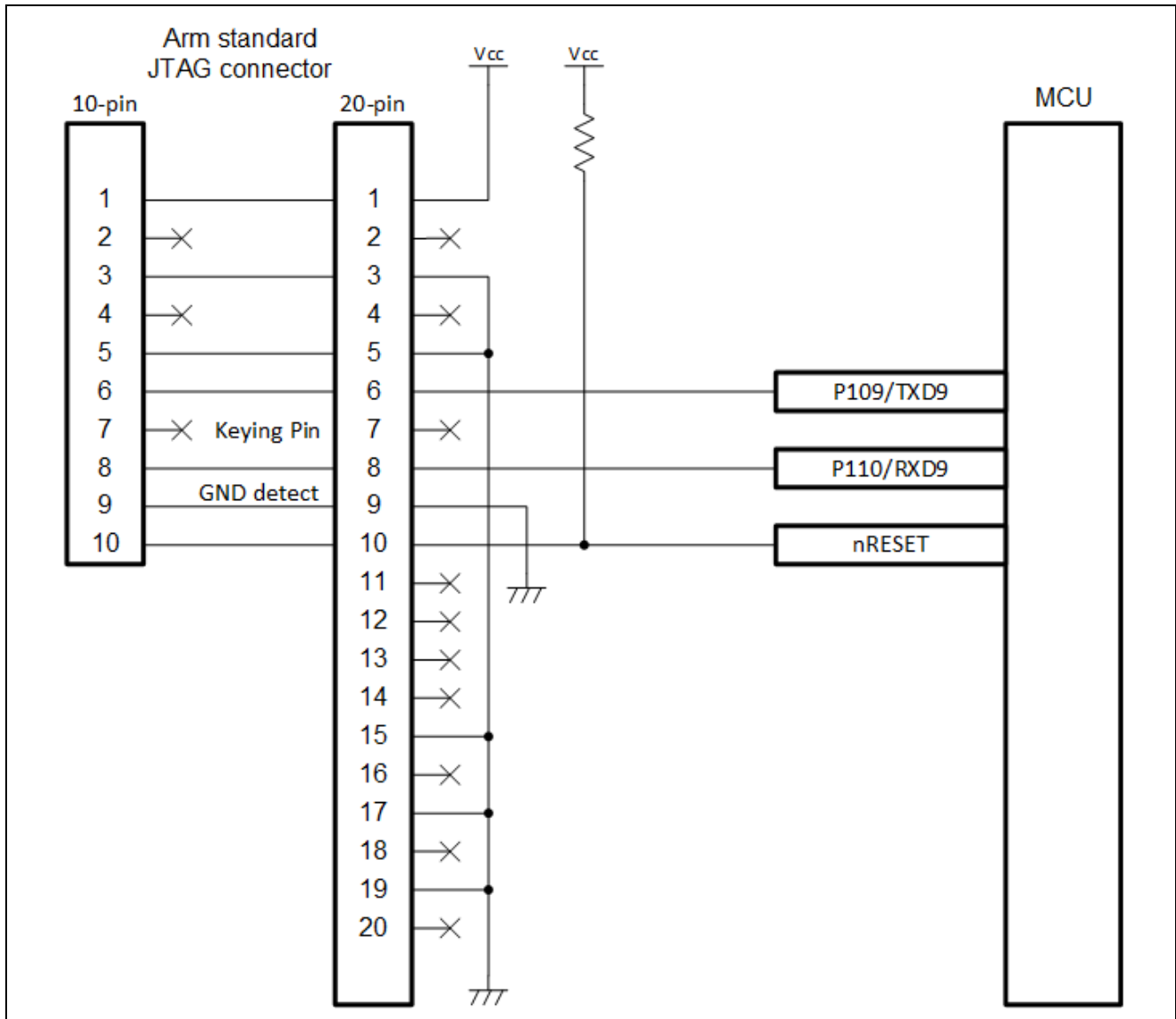


Figure 3. Serial Programming Interface using SCI Connections

- Note:
1. The output of the reset circuit of the user system must be open collector.
 2. The MD pin is not part of the Serial Programming Interface using SCI. However, the MD pin must be set to low to enable serial programming mode.

2.4 Serial Programming Interface using SCI: Devices with Arm® TrustZone® Support

The following diagram shows the typical connectivity of the serial programming interface using SCI for devices that include TrustZone support. Note the additional connection of P201/MD, which enables the programming of the Arm TrustZone IDAU boundary register settings.

RA4E2 MCU devices are an exception to this requirement. For these devices, the IDAU boundary registers are set at runtime via the application. See the Security Design with Arm® TrustZone® - IP Protection document R11AN0467EU for more information.

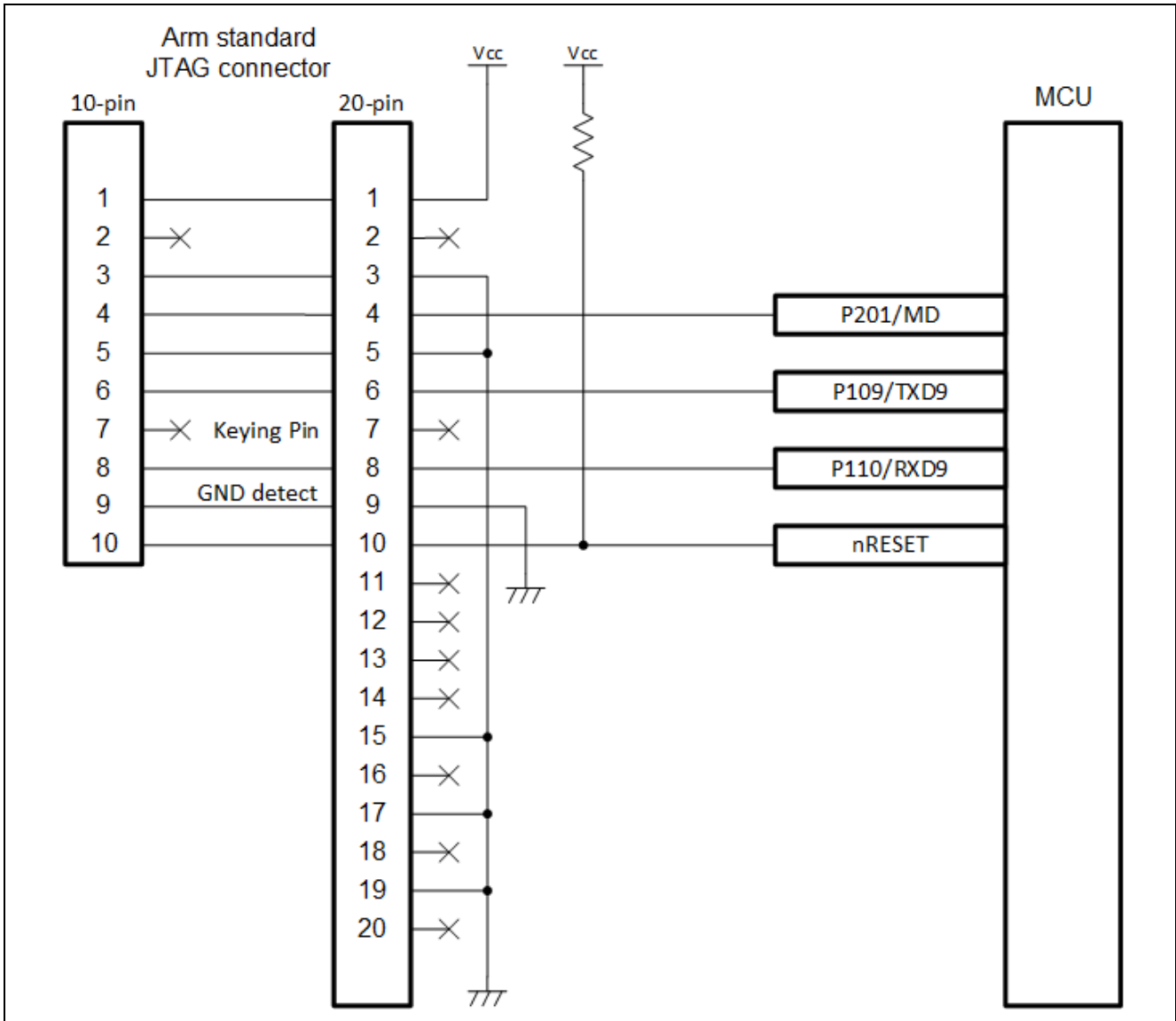


Figure 4. Serial Programming Interface using SCI: Devices with TrustZone Support Connections

- Notes:
1. The output of the reset circuit of the user system must be open collector.
 2. P201/MD must be connected to the Arm-standard JTAG connector pin 4 to support programming the Arm TrustZone IDAU boundary register settings.

2.5 Multiple Emulator Interface

The following diagram shows the typical connectivity of the debug interface to support multiple emulator types, including SWD, JTAG, SCI Serial Programming, and Arm® TrustZone® support.

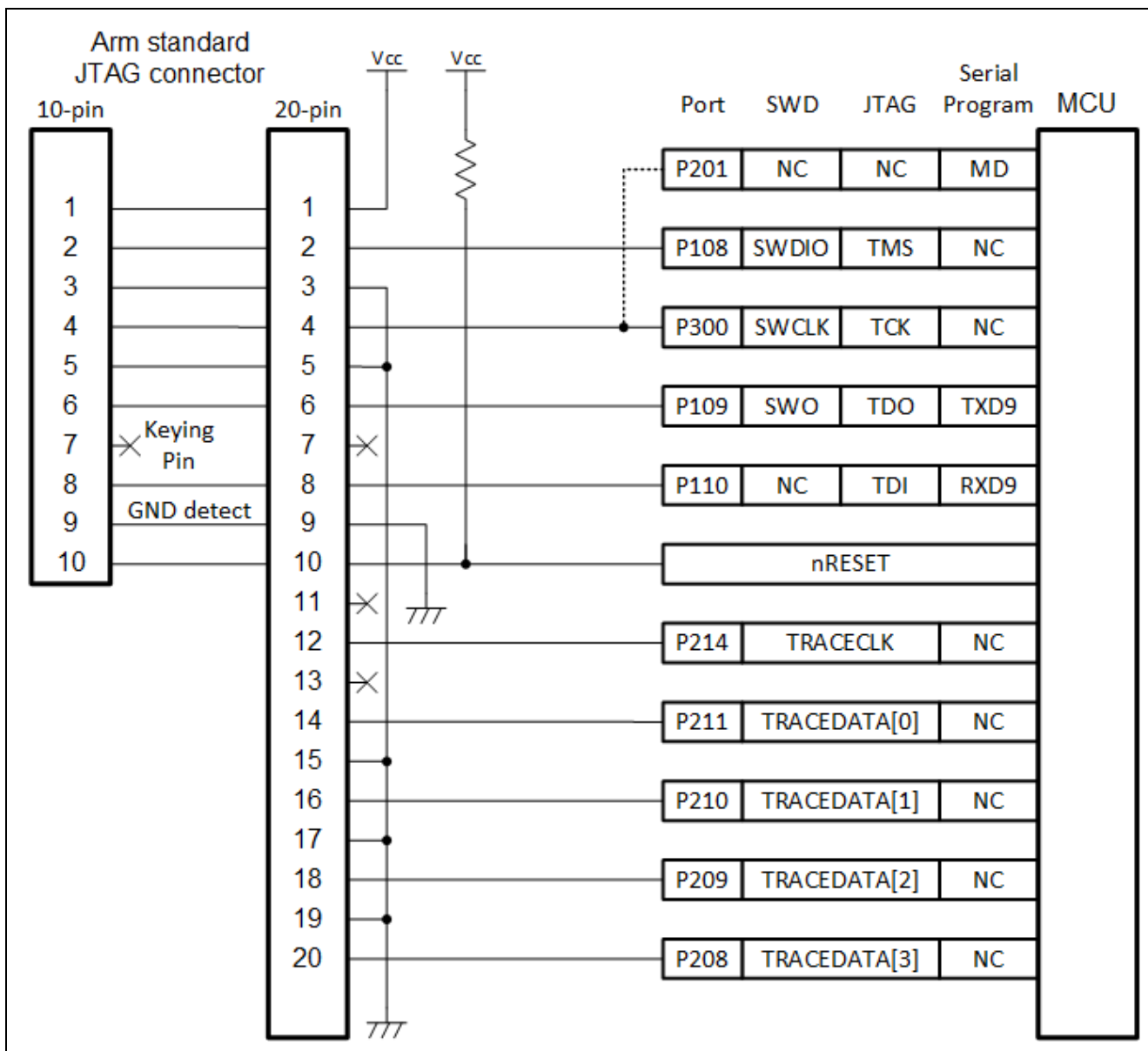


Figure 5. Multiple Emulator Interface Connections

- Notes:
1. Reset circuitry on the target must be open-collector. Pull up the nRESET signal. Do not put a capacitor on this signal as it may affect the operation of the power-on reset circuit.
 2. **To use both debugging and serial programming on devices with TrustZone support, connect P201/MD to P300/SWCLK/TCK using a wired OR circuit.**
 3. Arm Cortex®-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins.

P201/MD can be connected to P300/SWCLK to allow the debugger to control the MCU Operating Mode. See section 3 for more details.

2.6 Software Setups for Emulator Connections

2.6.1 SWD and JTAG Interfaces

SWD and JTAG pins are in default state after reset. Table 4 shows the associated pins and their default settings after reset.

Table 4. SWD/JTAG Pins

Pin	P108	P109	P110	P300
Function	TMS/SWDIO	TDO/SWO	TDI	TCK/SWCLK

2.6.2 Trace Port

A 4-bit Trace Port Interface Unit (TPIU) and Serial Wire Output (SWO) provide trace output in many RA4 devices.

Trace ports and clock need to be enabled before they can be used by the debugger script. When using the Trace Port functionality, avoid using the trace pins for other functions.

Table 5 lists the Trace Port pins and their associated functions.

Table 5. Trace Ports

Pin	P208	P209	P210	P211	P214
Function	TDATA3	TDATA2	TDATA1	TDATA0	TCLK

Arm® Cortex®-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins. For these devices, trace data is available through the SWO pin.

Some Arm® Cortex®-M33 devices, such as RA4E2, do not support TRACECLK, TRACEDATA[n] or SWO pins. Trace data is available through ETB registers on these devices.

For an example of using the Trace Port on Arm Cortex-M33 core devices with SEGGER J-Trace Pro, refer to the following link:

<https://wiki.segger.com/RA6M4>

For an example of using the Trace Port on Arm Cortex-M4 core devices with SEGGER J-Trace Pro, refer to the following link:

https://wiki.segger.com/J-Link_Renesas_RA6M3

Trace ports can also be enabled at runtime by using the Pin Configurator in Renesas FSP, but some trace data may be lost in this case.

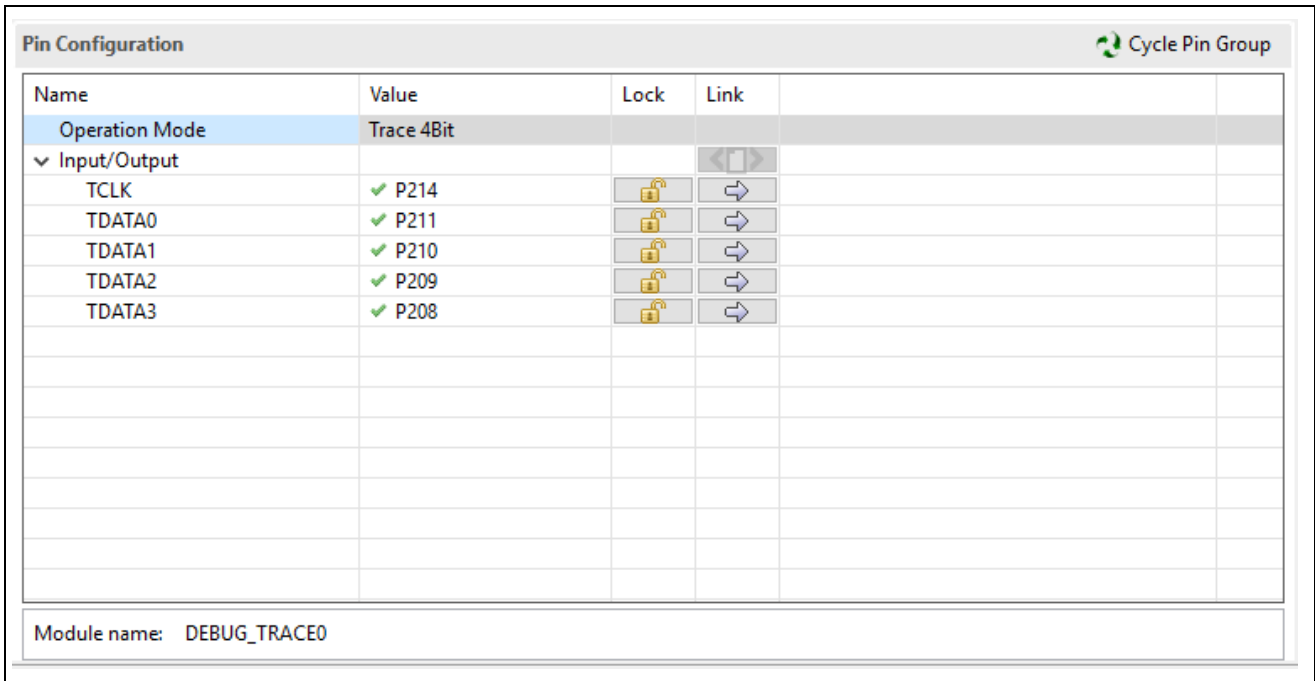


Figure 6. Enabling Trace Ports at Runtime Using FSP Configurator

3. MCU Operating Modes

Most RA4 MCU series devices can enter one of two modes after reset: Single-chip mode or SCI/USB boot mode. The boot mode is selected by the MD pin.

Table 6. Operating Modes Available at Reset

Operating Mode	MD	On-Chip Flash Memory	External Bus
Single-chip mode	1	Enable	Disable
SCI/USB boot mode	0	Enable	Disable

Figure 7 shows operating mode transitions as determined by the Mode-Setting (MD) pin.

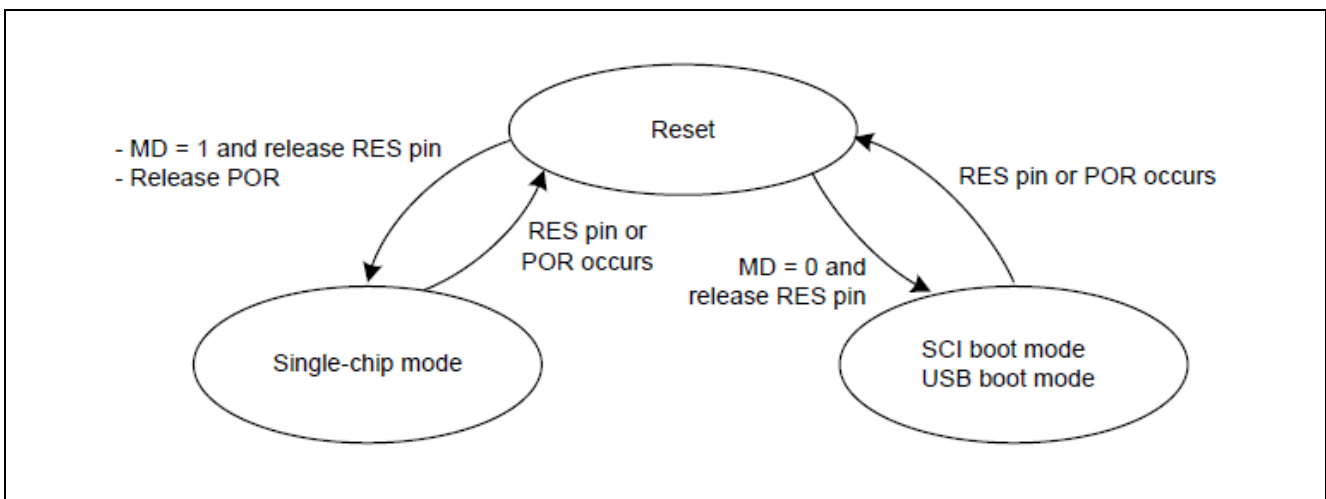


Figure 7. Mode Setting Pin level and Operating Mode

A typical MCU boot mode circuit includes a jumper and a couple of resistors to allow selections to connect the MD pin to VCC or Ground. RA4 MCU devices include an internal pull up resistor on P201/MD which is enabled by default. The internal pull up resistor may replace the external pull up resistor in Figure 8.

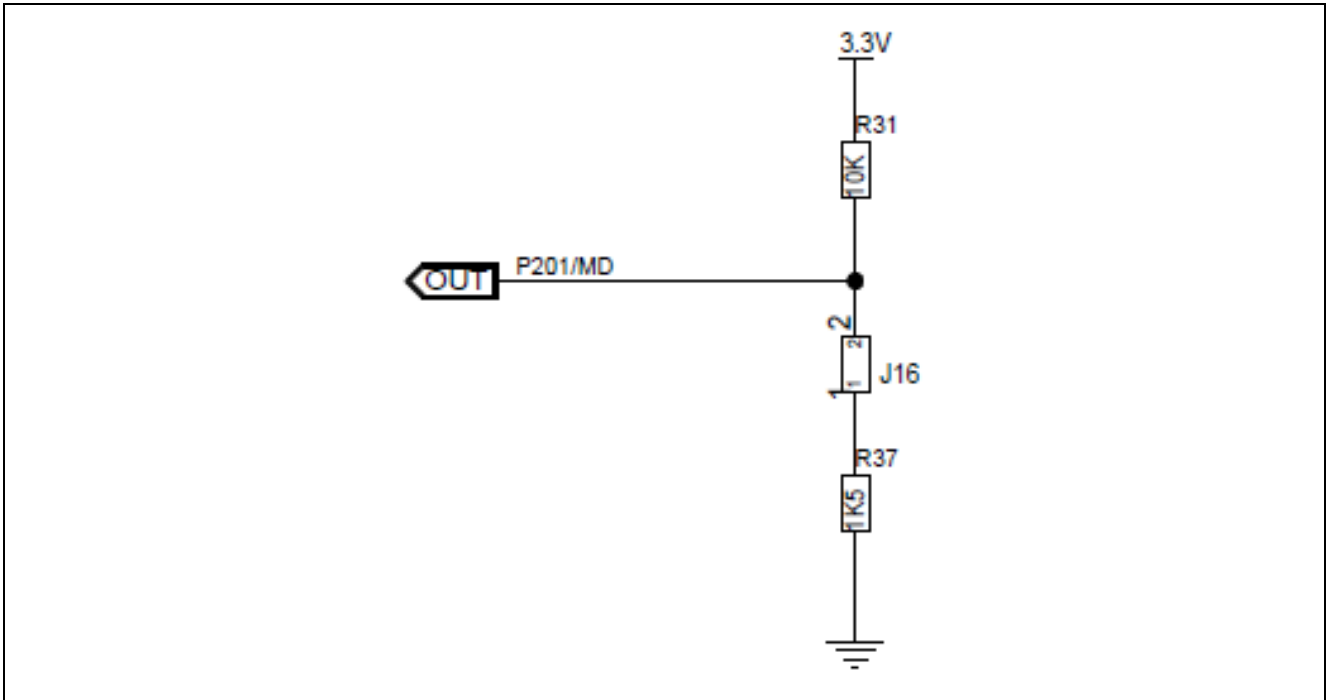


Figure 8. Typical Circuit for MCU Boot Mode Selection

3.1 RA4E2 MCU Operating Modes

In addition to single-chip mode, SCI boot mode, and USB boot mode, RA4E2 MCU devices also include SWD boot mode.

In this mode, the on-chip flash memory programming routine (SWD boot program) stored in the boot area within the MCU, is used. The on-chip flash, including code flash memory and data flash memory, can be modified from outside the MCU by using the SWD interface. To enter this mode, it is necessary to input the request from the SWD interface during RES pin reset.

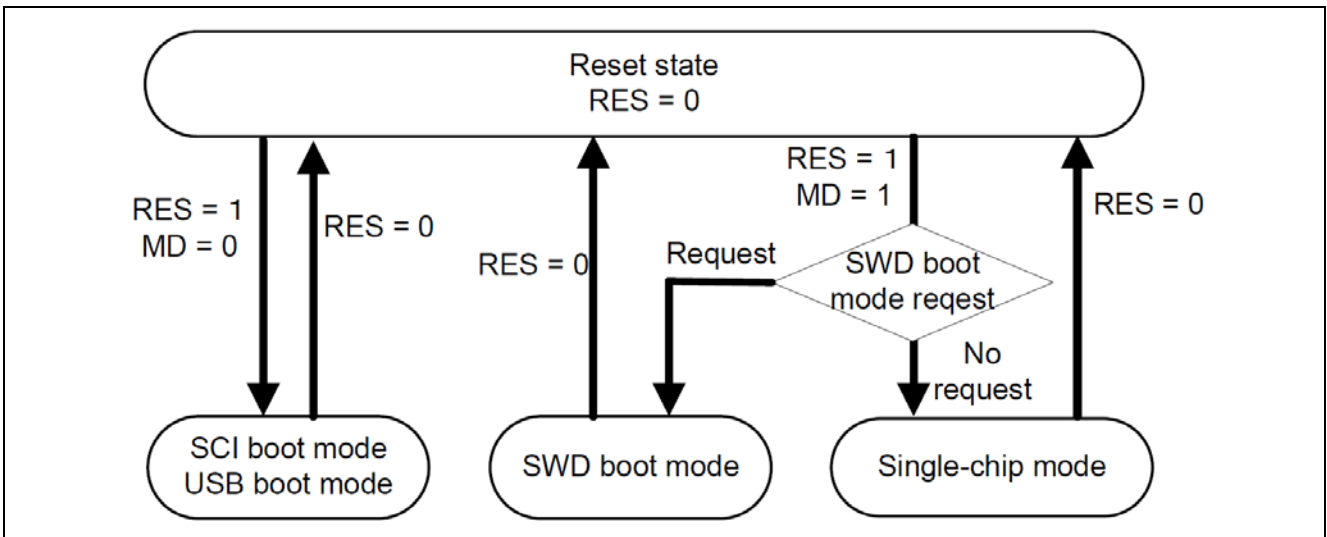


Figure 9. RA4E2 Mode-setting pin level and operating mode

4. Option Setting Memory

The option-setting memory determines the state of the MCU after a reset. It is allocated to the configuration setting area and the program flash area of the flash memory. Option setting memory may be different in size and layout for Arm® Cortex®-M33 based devices.

The registers are detailed in the *Option Setting Memory* chapter in the Hardware User's Manual.

The flash option registers occupy space in the code flash memory map. Although the registers are located in a portion of the flash memory that was reserved on the RA MCUs, **it is possible that some customers may store data in these locations inadvertently.** The user must check to ensure that no unwanted data is written to these locations or else unexpected behavior of the chip may result. For instance, settings in the flash option registers can enable the Independent Watchdog Timer (IWDT) immediately after reset. If data stored in program ROM inadvertently overlaps the Option Setting Memory register, it is possible to turn on the IWDT without realizing it. This will cause the debugger to have communications problems with the board.

The figure below shows the option setting memory, which consists of the option function select registers on RA4M3, which is an Arm Cortex-M33 device. The Option Setting Memory may be different for each device. Please consult MCU Hardware User's Manual for the specific device details.

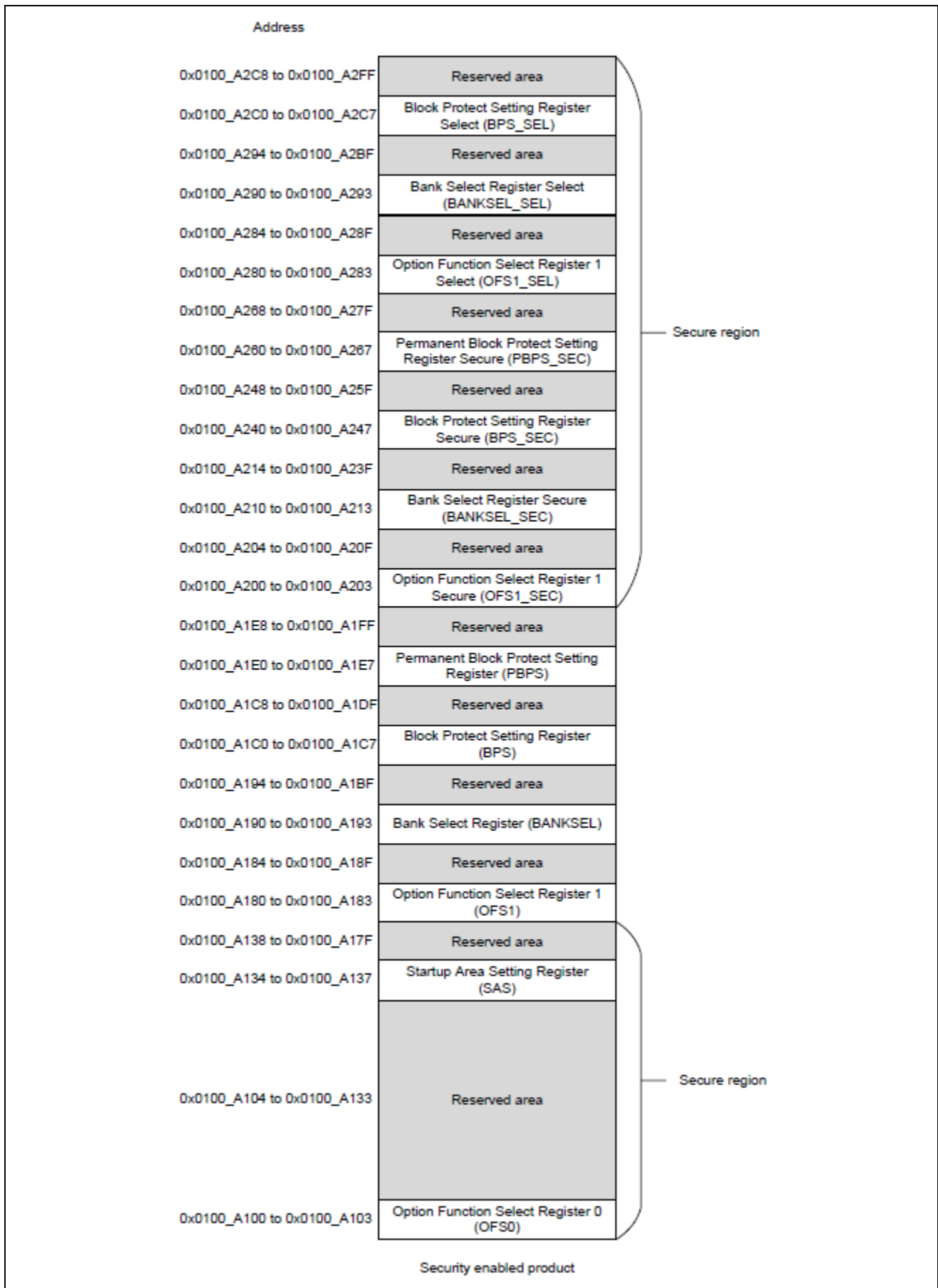


Figure 10. Option Function Select Registers for RA4M3

4.1 Option Setting Memory Registers

Following is a summary of the Option Setting Memory registers. Make sure that they are configured properly before startup.

- OFS0 register
 - Independent Watchdog Timer (IWDT) auto start
 - IWDT timeout, frequency, windowing, interrupt type, and low power mode behavior
 - Watchdog Timer (WDT) auto start
 - WDT timeout, frequency, windowing, and interrupt type
- OFS1 register
 - LVDO enable after reset
 - HOCO startup after reset

Renesas FSP Configurator supports setting of option memory in BSP settings, as shown in the following figure for RA4M3 MCU. The settings made through the FSP configurator are reflected in the binary file compiled to operate on the MCU.

EK-RA4M3		
Settings	Property	Value
	▼ R7FA4M3AF3CFB	
	part_number	R7FA4M3AF3CFB
	rom_size_bytes	1048576
	ram_size_bytes	131072
	data_flash_size_bytes	8192
	package_style	LQFP
	package_pins	144
	> RA4M3	
	▼ RA4M3 Family	
	> Security	
	▼ OFS0 register settings	
	▼ Independent WDT	
	Start Mode	IWDT is Disabled
	Timeout Period	2048 cycles
	Dedicated Clock Frequency Divisor	128
	Window End Position	0% (no window end position)
	Window Start Position	100% (no window start position)
	Reset Interrupt Request Select	Reset is enabled
	Stop Control	Stop counting when in Sleep, Snooze mode, or Software Standby
	▼ WDT	
	Start Mode Select	Stop WDT after a reset (register-start mode)
	Timeout Period	16384 cycles
	Clock Frequency Division Ratio	128
	Window End Position	0% (no window end position)
	Window Start Position	100% (no window start position)
	Reset Interrupt Request	Reset
	Stop Control	Stop counting when entering Sleep mode
	▼ OFS1 register settings	
	Voltage Detection 0 Circuit Start	Voltage monitor 0 reset is disabled after reset
	Voltage Detection 0 Level	2.80 V
	HOCO Oscillation Enable	HOCO oscillation is disabled after reset

Figure 11. Option Memory Settings in FSP Configuration for RA4M3 MCU

5. Clock Circuits

The RA4 MCUs have six primary oscillators. Five of these may be used as the source for the main system clock. The remaining oscillator is dedicated to the Independent Watchdog Timer. In a typical system, the main clock is driven with an external crystal or clock. This input is directed to the PLL where it is multiplied up to the PLL clock, then post-divided down into the main system clock (ICLK), flash clock, peripheral module clocks, external bus clock, trace clock, and USB clock. The ICLK is further used for the CPU clock, DMAC clock, internal flash clock and SDRAM clock. Refer to the *Clock Generation Circuit* chapter in the Hardware User’s Manual for the block diagram of the clock generation circuit.

Each clock has specific tolerances and timing values. Refer to the *AC Characteristics* section in the *Electrical Characteristics* chapter Hardware User’s Manual for the Frequency and Clock Timing specifications. Refer to the *Clock Generation Circuit* chapter Hardware User’s Manual for the relationship between the various clock frequencies.

Table 7. RA4 Oscillators

Oscillator	Input Source	Frequency	Primary Uses
Main clock	External crystal/resonator or External clock	8 MHz to 24 MHz ³ Up to 24 MHz ³	PLL input, PLL2 input ¹ , main system clock, CLKOUT, CAN clock, CAC clock, LCD clock ²
Sub-clock (SOSC)	External crystal/resonator	32.768 kHz	Real-time clock, main system clock in low power modes, CLKOUT, AGT clock, CAC clock, Real-time clock, LCD clock ²
High-speed on-chip (HOCO)	On-chip oscillator	16/18/20 MHz ⁴	PLL input ¹ , main system clock, CLKOUT, CAC clock, LCD clock ² , USB clock ²
Middle-speed on-chip (MOCO)	On-chip oscillator	8 MHz	Main system clock at startup, CLKOUT, CAC clock
Low-speed on-chip (LOCO)	On-chip oscillator	32.768 kHz	Main system clock in low power modes & during main oscillator stop detection, Systick timer ¹ , AGT clock, CLKOUT, CAC clock, Real-time clock
Independent Watchdog (IWDT)	On-chip oscillator	15 kHz	Independent watchdog timer clock, CAC clock

- Note
1. On Arm® Cortex®-M33 devices
 2. On Arm Cortex-M4 devices
 3. On Arm Cortex-M4 devices, the main clock input frequency range using an external crystal resonator or external clock source is 1 MHz to 20 MHz. The maximum input frequency for an external clock or external crystal resonator may be limited to 8 MHz, 4 MHz, or 1 MHz, depending on the supply voltage to the MCU.
 4. On Arm Cortex-M4 devices, the HOCO frequency options are 24/32/48/64 MHz.

5.1 Reset Conditions

After reset, RA4 MCUs begin running with the middle-speed on-chip oscillator (MOCO) as the main clock source. At reset, the main oscillator and the PLL are off by default. The HOCO and IWDT may be on or off depending on the settings in the option setting memory (see section 3.1).

5.2 Clock Frequency Requirements

Minimum and maximum clock oscillation frequencies are shown in the tables below. Details can be found in the *Overview* section of the *Clock Generation Circuit* chapter in the MCU Hardware User's Manual, including external and internal clock source specifications. Additional details can be found in the *AC Characteristics* section of the *Electrical Characteristics* chapter in the MCU Hardware User's Manual.

Table 8. Frequency Range for Arm Cortex-M4 MCU Internal Clocks

	ICLK	PCLKA	PCLKB	PCLKC	PCLKD
Maximum Frequency [MHz]	48	48	32	64	64
Minimum Frequency [MHz]	—	—	—	—	—

	FCLK ¹	UCLK	CANCLK	SLCDC	
Maximum Frequency [MHz]	32	48	20	64	
Minimum Frequency [MHz]	1	48	1	—	

- Note
1. The FCLK must run at a frequency of at least 4 MHz when writing or erasing ROM or data flash.

Table 9. Frequency Range for Arm® Cortex®-M33 MCU Internal Clocks

	ICLK ¹	PCLKA ¹	PCLKB	PCLKC	PCLKD
Maximum Frequency [MHz]	100	100	50	50	100
Minimum Frequency [MHz]	—	—	—	—	—

	FCLK ¹	USBCLK	CANCLK		
Maximum Frequency [MHz]	50	48	24		
Minimum Frequency [MHz]	4	48	8		

Note 1. The FCLK must run at a frequency of at least 4 MHz when writing or erasing ROM or data flash.

5.2.1 Requirements for USB Communications

The USB 2.0 Full-Speed Module (USBFS) requires a 48 MHz USB clock signal (UCLK or USBCLK).

When USB is used on Arm Cortex-M33 devices and the HOCO is selected as the clock source for the PLL, the Frequency Locked Loop (FLL) function must be enabled. Arm Cortex-M4 devices do not have the FLL function.

When the USB peripheral is used, the main clock oscillator frequency is limited to specific choices. This is due to the specific division ratios available in the clock generation circuit and the 48 MHz clock required by the USB modules. The limitations are dependent on the multiplication and division settings in the associated registers.

For Arm Cortex-M4 devices, the divider used depends on the setting of the control bits in the PLLCCR2 register (PLL Clock Control Register 2).

For Arm Cortex-M33 devices, the divider used depends on the setting of the USBCKDIV bits in the USBCKDIVCR register. The USBCLK is also dependent on the PLL settings in the PLLCCR and PLL2CCR registers.

For details of the relevant division and multiplication ratios, see the Clock Generation Circuit chapter of the specific MCU Hardware User's Manual.

5.2.2 Requirements for Programming and Erasing ROM or Data Flash

The FCLK must be at least 4 MHz to perform programming and erasing on internal ROM and data flash.

5.3 Lowering Clock Generation Circuit (CGC) Power Consumption

To aid in saving power, set the dividers for any unused clocks to the highest possible value whenever possible. Also, when not using a clock then make sure that it has been stopped by adjusting settings in the appropriate register(s). The registers for controlling each clock source are shown in the table below.

Table 10. Clock Source Configuration Registers

Oscillator	Register	Description
Main clock	MOSCCR	Starts/stops main clock oscillator
Sub-clock	SOSCCR	Starts/stops sub-clock oscillator
High-speed on-chip (HOCO)	HOCOCCR	Starts/stops HOCO
Middle-speed on-chip (MOCO)	MOCOCCR	Starts/stops MOCO
Low-speed on-chip (LOCO)	LOCOCCR	Starts/stops LOCO

5.4 Writing the System Clock Control Registers

Care should be taken when writing to the individual bit fields in the System Clock Division Control Register (SCKDIVCR) and System Clock Source Control Register (SCKSCR).

When the clock source of the peripheral module clock is switched, the duration of the peripheral module clock cycle becomes longer during the clock source transition period. See Figure 12. As a result, a delay in instruction processing must be added to allow the clocks to stabilize whenever the source is switched.

To ensure correct processing after the clock frequency changes, first write to the relevant Clock Control register to change the frequency, then read the value from the register, and finally perform the subsequent processing.

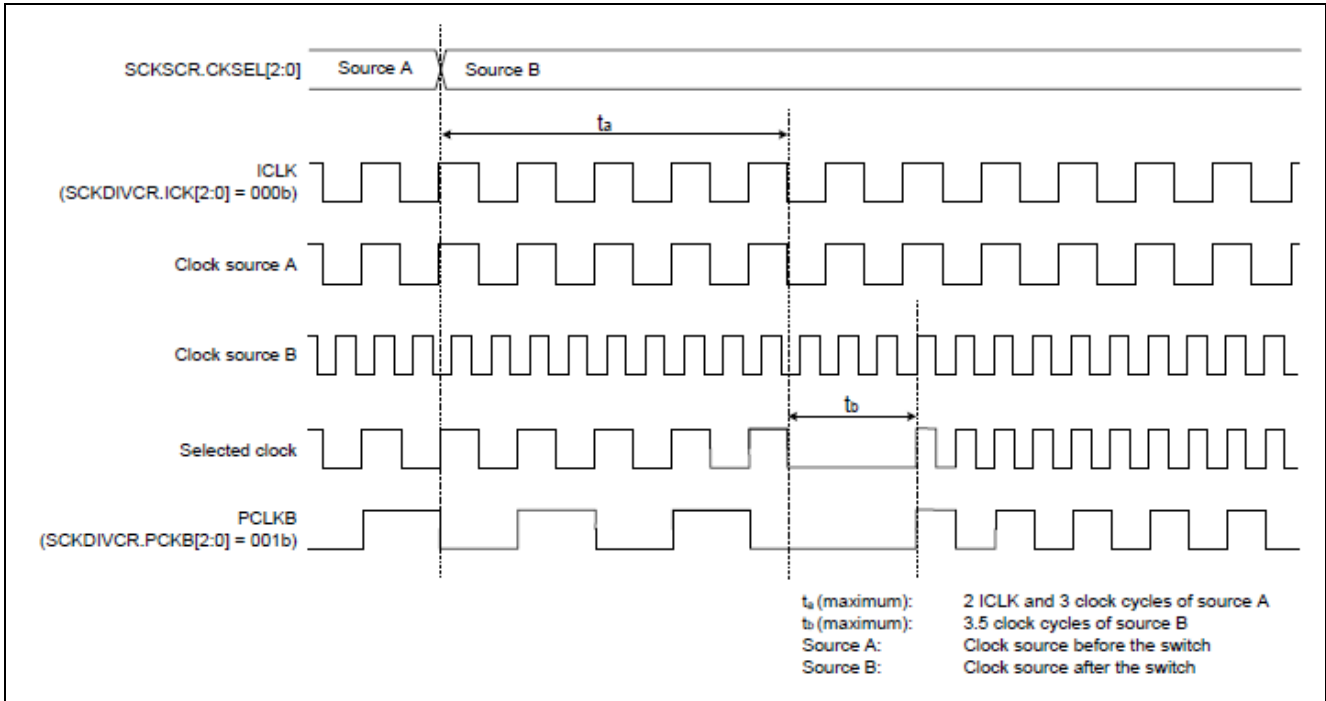


Figure 12. Timing of Clock Source Switching

5.5 Clock Setup Example

Renesas FSP provides a simple, visual clock configuration tool for RA4M3 MCU shown as follows.

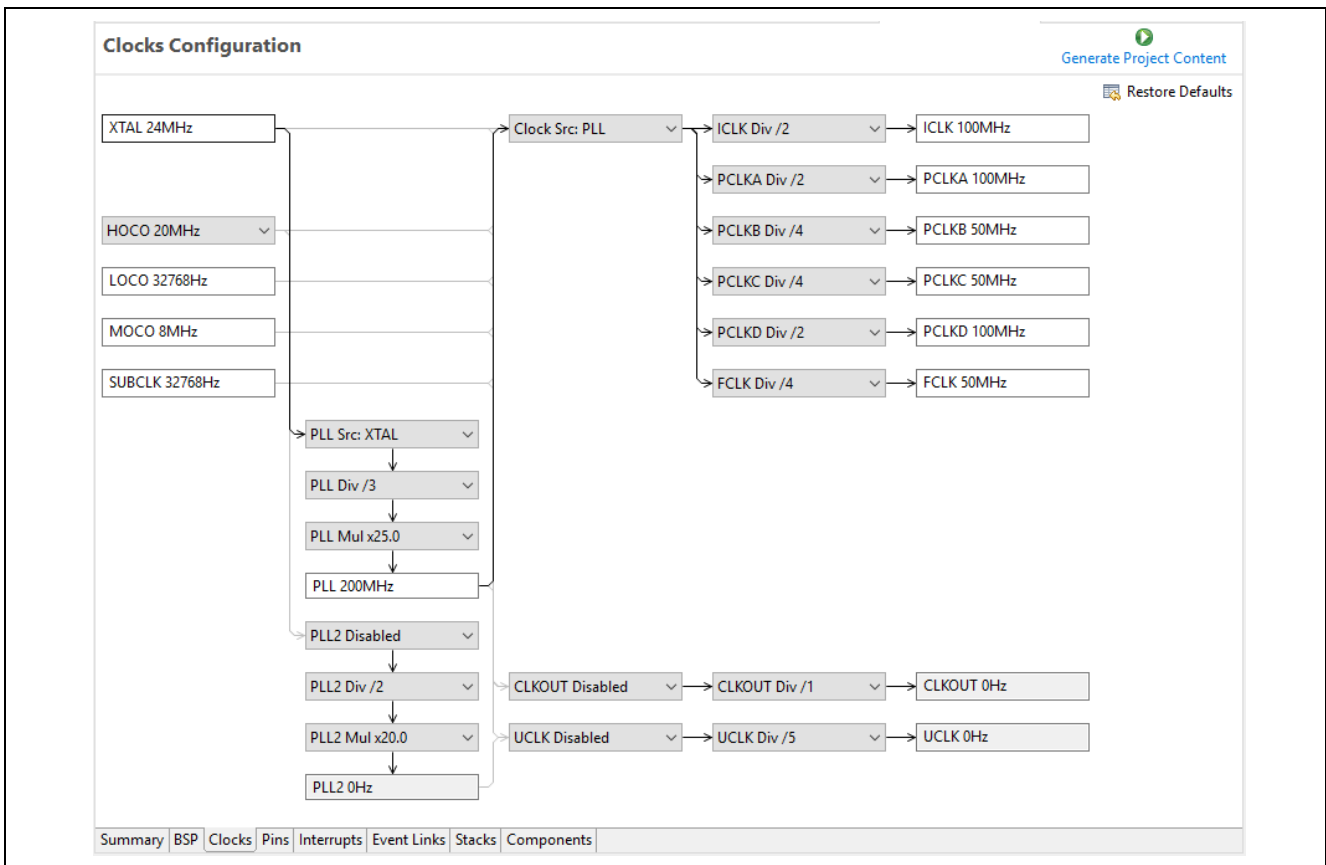


Figure 13. Clock Settings Using Renesas FSP Configurator

5.6 HOCO Accuracy

The internal high-speed on-chip oscillator (HOCO) runs at 16 MHz, 18 MHz, or 20 MHz for Arm® Cortex®-M33 core devices, and 24 MHz, 32 MHz, 48 MHz, or 64 MHz for Arm Cortex-M4 devices, with a typical accuracy of +/-2% or better. HOCO accuracy specifications are characterized for various ambient operating temperature (Ta) ranges.

For Arm Cortex-M33 devices, the accuracy of the HOCO may be improved by enabling the Frequency Locked Loop (FLL) function, which results in a clock accuracy of +/-0.25% or better. Refer to the *Electrical Specifications* in the hardware manual for details.

The HOCO may be used as an input to the PLL circuit. When the HOCO is used this way, no external oscillator is required. This may be an advantage when space constraints, cost, or other limitations require a reduced component count in a PCB design. However, there are performance tradeoffs and limitations due to the clock accuracy which should be evaluated for your application.

5.7 Flash Interface Clock

The Flash interface Clock (FCLK) is used as the operating clock when programming and erasing internal flash (ROM and DF) and for reading from the data flash. Therefore, the frequency setting of the FCLK will have a direct impact on the amount of time it takes to read from the data flash. If the user's program is reading from the data flash, or performing programming or erasures on internal flash, then using the maximum FCLK frequency is recommended.

The FCLK must run at a frequency of at least 4 MHz when writing or erasing code flash (ROM) or data flash. Please note that the FCLK frequency does not have any impact upon reading from ROM or reading and writing to RAM.

5.8 Board Design

Refer to the *Usage Notes* section of the Clock Generation Circuit (CGC) chapter in the Hardware User's Manual for more information on using the CGC and for board design recommendations.

When a crystal resonator is used, place the resonator and its load capacitors as close to the MCU clock pins (XTAL/EXTAL, XCIN/XCOUT) as possible. Avoid routing any other signals between the crystal resonator and the MCU. Minimize the number of connecting vias used on each trace.

5.9 External Crystal Resonator Selection

An external crystal resonator may be used as the main clock source. The external crystal resonator is connected across the EXTAL and XTAL pins of the MCU. The frequency of the external crystal resonator must be in the frequency range of the main clock oscillator.

Selection of a crystal resonator will be largely dependent on each unique board design. Due to the large selection of crystal resonators available that may be suitable for use with RA4 MCU devices, carefully evaluate the electrical characteristics of the selected crystal resonator to determine the specific implementation requirements.

The following diagram shows a typical example of a crystal resonator connection.

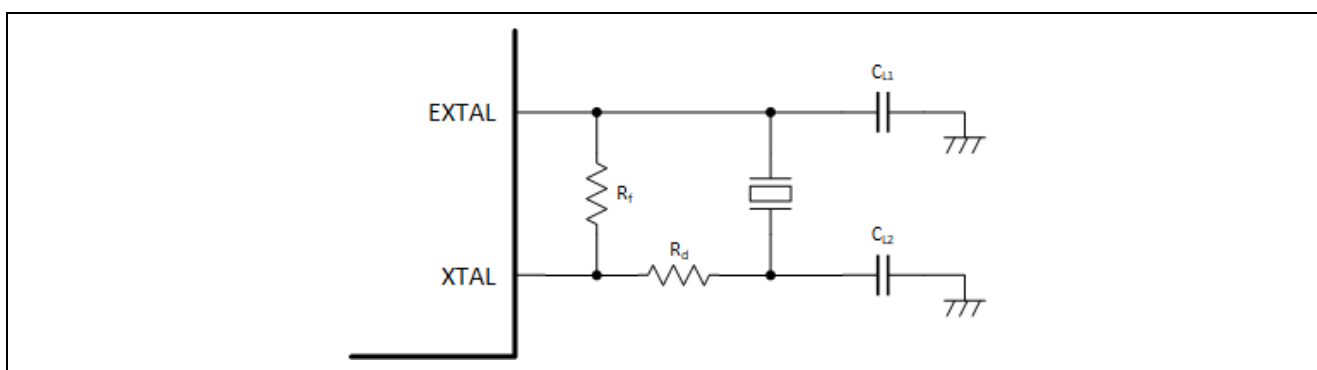


Figure 14. Example of Crystal Resonator Connection

Careful evaluation must be used when selecting the crystal resonator and the associated capacitors. The external feedback resistor (R_f) and damping resistor (R_d) should be added if recommended by the crystal resonator manufacturer.

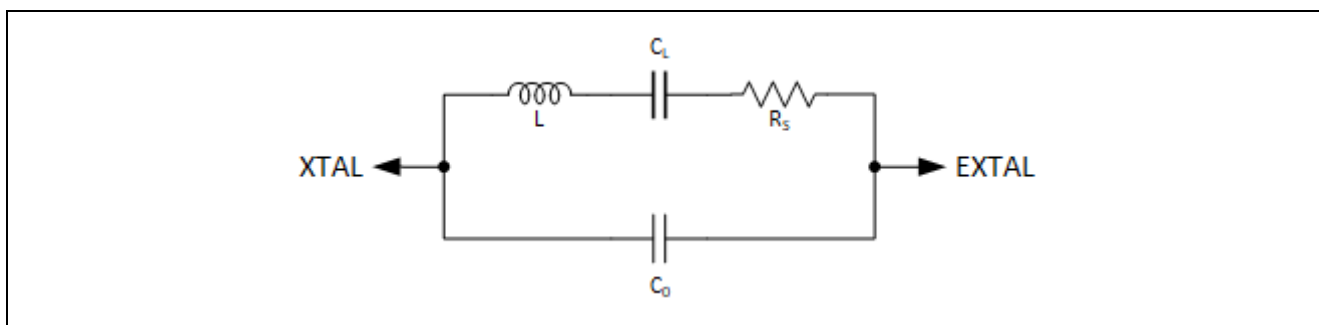


Figure 15. Equivalent Circuit of the Crystal Resonator

Selection of the capacitor values for CL1 and CL2 will affect the accuracy of the internal clock. To understand the impact of the values for CL1 and CL2, the circuit should be simulated using the equivalent circuit of the crystal resonator in the figure above. For more accurate results, also take in to account the stray capacitance associated with the routing between the crystal resonator components.

5.10 External Clock Input

A digital clock input may be used as the main clock source. Figure 16 shows an example of connecting an external clock input. To operate the oscillator with an external clock signal, set the MOMCR.MOSEL bit to 1. The XTAL pin becomes high impedance.

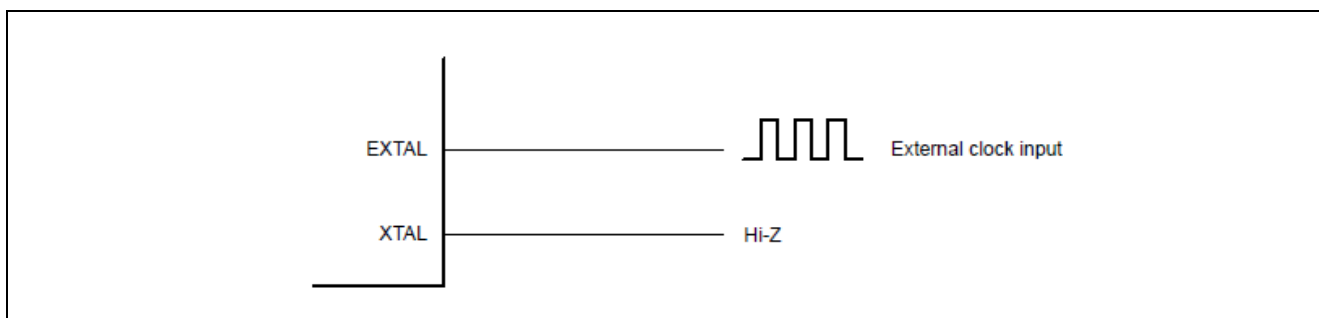


Figure 16. Equivalent Circuit for External Clock

Note: The frequency of the external clock input can only be changed when the main clock oscillator is stopped. Do not change the frequency of the external clock input when the setting of the Main Clock Oscillator Stop bit (MOSCCR.MOSTP) is 0.

6. Reset Requirements and the Reset Circuit

There are fourteen types of resets for Arm® Cortex®-M4 devices.

Table 11. Arm Cortex-M4 Device Resets

Reset Name	Source
Pin reset	RES# is driven low
Power-on reset	VCC rises (voltage detection: VPOR)
VBATT-selected voltage power-on reset	VCC falls (voltage detection: VDETBATT)
Independent watchdog timer reset	The independent watchdog timer underflows, or a refresh does not occur
Watchdog timer reset	The watchdog timer underflows, or a refresh does not occur
Voltage monitor 0 reset	VCC falls (voltage detection Vdet0)
Voltage monitor 1 reset	VCC falls (voltage detection Vdet1)
Voltage monitor 2 reset	VCC falls (voltage detection Vdet2)
SRAM parity error reset	SRAM parity error detection
SRAM ECC error reset	SRAM ECC error detection
Bus master MPU error reset	Bus master MPU error detection
Bus slave MPU error reset	Bus slave MPU error detection
Stack pointer error reset	Stack pointer error detection
Software reset	Register setting

There are thirteen or fourteen types of resets for Arm® Cortex®-M33 devices, depending on the specific device.

Table 12. Arm® Cortex-M33 Device Resets

Reset Name	Source
Pin reset	RES# is driven low
Power-on reset	VCC rises (voltage detection: VPOR)
Independent watchdog timer reset	The independent watchdog timer underflows, or a refresh does not occur
Watchdog timer reset	The watchdog timer underflows, or a refresh does not occur
Voltage monitor 0 reset	VCC falls (voltage detection Vdet0)
Voltage monitor 1 reset	VCC falls (voltage detection Vdet1)
Voltage monitor 2 reset	VCC falls (voltage detection Vdet2)
SRAM parity error reset	SRAM parity error detection
SRAM ECC error reset	SRAM ECC error detection
Bus master MPU error reset	Bus Master MPU error detection
TrustZone error reset	TrustZone error detection
Cache Parity error reset ^{*1}	Cache Parity error detection
Deep software standby reset	Deep Software Standby mode is canceled by an interrupt
Software reset	Register setting

Note 1. RA4M3 and RA4E2 devices only.

6.1 Pin Reset

When the RES# pin is driven low, all processing is aborted and the MCU enters a reset state. To reset the MCU while it is running, RES# should be held low for the specified reset pulse width. Refer to the *Reset Timing* section of the *Electrical Characteristics* chapter of the Hardware User's Manual for more detailed timing requirements. Also refer to section 2 of this document, *Emulator Support* for details on reset circuitry in relation to debug support.

There is no need to use an external capacitor on the RES# line because the POR circuit holds it low internally for a good reset and a minimum reset pulse is required to initiate this process.

6.2 Power-On Reset

There are two conditions that will generate a power-on reset (POR):

1. If the RES# pin is in a high-level state when power is supplied.
2. If the RES# pin is in a high-level state when VCC is below V_{POR}.

After VCC has exceeded the power-on reset voltage (V_{POR}) and the power-on reset time (t_{POR}) has elapsed, the chip is released from the power-on reset state. The power-on reset time is a period that allows for stabilization of the external power supply and the MCU. Refer to the *POR and LVD Characteristics* section of the *Electrical Characteristics* chapter of the Hardware User's Manual for voltage level and timing details.

Because the POR circuit relies on having RES# high concurrently with VCC, do not place a capacitor on the reset pin. This will slow the rise time of RES# in relation to VCC, preventing the POR circuit from properly recognizing the power-on condition.

If the RES# pin is high when the power supply (VCC) falls to or below V_{POR}, a power-on reset is generated. The chip is released from the power-on state after VCC has risen above V_{POR} and the t_{POR} has elapsed.

After a power-on reset, the PORF bit in RSTSR0 is set to 1. Following a pin reset PORF is cleared to 0.

6.3 VBATT-Selected Voltage Power-On Reset

When the voltage at the VCC pin drops, power can be supplied to the RTC, LOCO and sub-clock oscillator from the VBATT pin. When a power supply drop from the VCC pin is detected, connection to power is switched from the VCC pin to the VBATT pin.

For Arm Cortex-M4 devices, when this occurs a reset can be generated to flag the switch from VCC to VBATT. Details of this reset and the related VBATT configuration can be found in the *Battery Backup Function* chapter of the MCU Hardware User's Manual. This reset is not present on Arm Cortex-M33 devices.

6.4 Independent Watchdog Timer Reset

This is an internal reset generated by the Independent Watchdog Timer (IWDT).

When the IWDT underflows, an independent watchdog timer reset is optionally generated (NMI can be generated instead) and the IWDTRF bit in RSTSR1 is set to a 1. After a short delay the IWDT reset is canceled. Refer to MCU User's Manual for the specific timing.

6.5 Watchdog Timer Reset

This is an internal reset generated by the Watchdog Timer (WDT).

When the WDT overflows, a watchdog timer reset is optionally generated (NMI can be generated instead), and the WDTRF bit in RSTSR1 is set to a 1. After a short delay the WDT reset is canceled. Refer to MCU User's Manual for the specific timing.

6.6 Voltage-Monitoring Resets

The RA4 MCU family includes circuitry that allows the MCU to protect against unsafe operation during brownouts. On-board comparators check the supply voltage against three reference voltages, V_{det0} , V_{det1} , and V_{det2} . As the supply dips below each reference voltage, an interrupt or a reset can be generated. The detection voltages V_{det0} , V_{det1} , and V_{det2} are each selectable from 3 different levels.

When VCC subsequently rises above V_{det0} , V_{det1} , or V_{det2} , release from the voltage-monitoring reset proceeds after a stabilization time has elapsed.

Low Voltage Detection is disabled after a power-on reset. Voltage monitoring can be enabled by using the Option Function register OFS1. For more details, see the chapter *Low Voltage Detection (LVD)* in the Hardware User's Manual.

After an LVD Reset, the LVDnRF ($n = 0, 1, 2$) bit in RSTSR0 is set to 1.

6.7 Deep Software Standby Reset

Deep Software Standby Reset is an internal reset generated when deep software standby mode is canceled by an interrupt.

When deep software standby mode is canceled, a deep software standby reset is generated, and clock oscillation starts. On receiving the interrupt, after the Deep Standby Cancellation Wait Time (t_{DSBYWT} 34-35 clock cycles) has elapsed, reset is canceled, and normal processing starts. For details of the deep software standby mode refer to the *Low Power Modes* chapter in the Hardware User's Manual.

After a Deep Software Standby Reset, the DPSRSTF bit in RSTSR0 is set to 1.

6.8 Software Reset

The software reset is an internal reset generated by a software setting of the SYSRESETREQ bit in the AIRCR register in the Arm core. When the SYSRESETREQ bit is set to 1, a software reset is generated. When the internal reset time (t_{RESW2}) elapses after the software reset is generated, the internal reset is canceled and the CPU starts the reset exception handling. Refer to MCU User's Manual for the specific timing.

For details on the SYSRESETREQ bit, see the Arm® Cortex®-M33 and Cortex®-M4 Technical Reference Manuals.

6.9 Other Resets

Most peripheral functions within the MCU can generate a reset under specific fault conditions. No hardware configuration is required to enable these resets. Refer to the relevant chapters in the Hardware User's Manual for details of the conditions that will generate a reset for each peripheral function.

6.10 Determination of Cold/Warm Start

The RA4 MCUs allow the user to determine the cause of the reset processing. The CWSF flag in RSTSR2 indicates whether a power-on reset caused the reset processing (cold start) or a reset signal input during operation caused the reset processing (warm start).

The flag is set to 0 when a power-on reset occurs. Otherwise, the flag is not set to 0. The flag is set to 1 when 1 is written to it through software. It is not set to 0 even on writing 0 to it.

6.11 Determining the Reset Source

The RA4 MCUs allow the user to determine the reset signal generation source. Read RSTSR0 and RSTSR1 to determine which reset was the source of the reset. Refer to the Hardware User's Manual section *Determination of Reset Generation Source* for the flow diagram.

The following sample code shows how to determine if a reset is caused by Software Reset, Deep Software Standby or power-on reset using CMSIS based register structure in Renesas FSP.

```

/* Deep Software Standby Reset */
if(1 == R_SYSTEM->RSTSR0_b.DPSRSTF)
{
    /* Do something */
}

/* Power-on Reset */
if(1 == R_SYSTEM->RSTSR0_b.PORF)
{
    /* Do something */
}

/* Software Reset */
if(1 == R_SYSTEM->RSTSR1_b.SWRF)
{
    /* Do something */
}

```

7. TrustZone® Support

7.1 Implementation of Arm® TrustZone Technology

Some RA4 MCUs, such as RA4M2 and RA4M3, include Arm TrustZone (TZ) security features. For full details of TZ implementation, please refer to Arm documentation (<https://developer.arm.com/ip-products/security-ip/trustzone>) or the appropriate Hardware User's Manual.

Arm TZ technology can create separations in the memory map within the MCU and therefore separate the application into Secure and Non-Secure partitions. Secure applications can access both Secure and Non-Secure memory and resources. Non-Secure code can access Non-Secure memory and resources as well as Secure resources through a set of so-called veneers located in the Non-Secure Callable (NSC) region. This ensures a single access point for Secure code when called from the Non-Secure partition.

The FSP configures the MCU to start the secure application upon reset. The security state of the CPU can be either Secure or Non-Secure. The MCU code flash, data flash, and SRAM are divided into Secure (S) and Non-Secure (NS) regions. Code flash and SRAM include a further region known as Non-Secure Callable (NSC). These memory security attributes are set into the non-volatile memory via SCI or USB boot mode commands when the device lifecycle is Secure Software Debug (SSD) state. The memory security attributes are loaded into the Implementation Defined Attribution Unit (IDAU) peripheral and the memory controller before application execution and cannot be updated by application code.

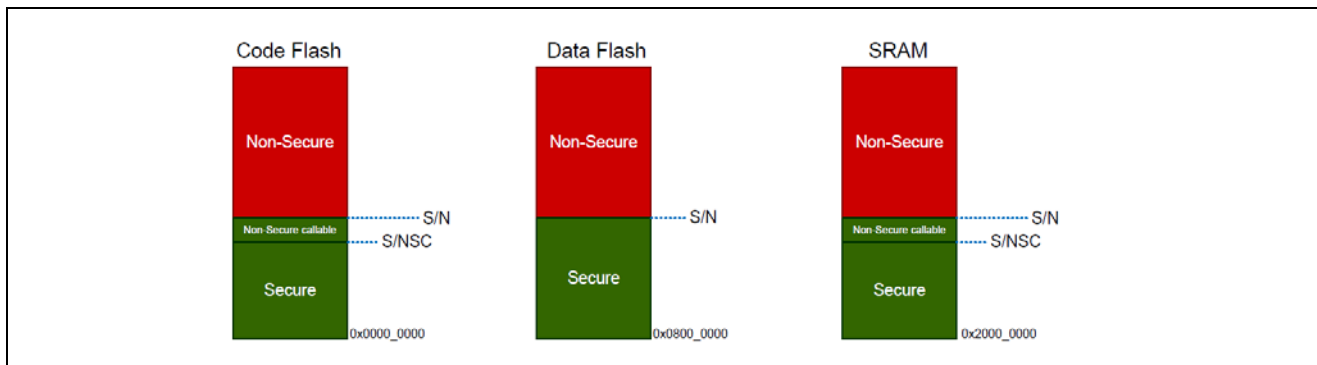


Figure 17. Secure and Non-Secure Regions

Note: All external memory accesses are considered to be Non-Secure.

Code Flash and SRAM can be divided into Secure, Non-Secure, and Non-Secure Callable. All secure memory accesses from the Non-Secure region MUST go through the Non-Secure Callable gateway and target a specific Secure Gateway (SG) assembler instruction. This forces access to Secure APIs at a fixed location and prevents calls to sub-functions and so on. Failing to target an SG instruction will generate a TZ exception. TZ enabled compilers will manage generation of the NSC veneer automatically using CMSE extensions. These Secure, Non-Secure, and Non-Secure Callable memory regions are easily configured and managed using FSP.

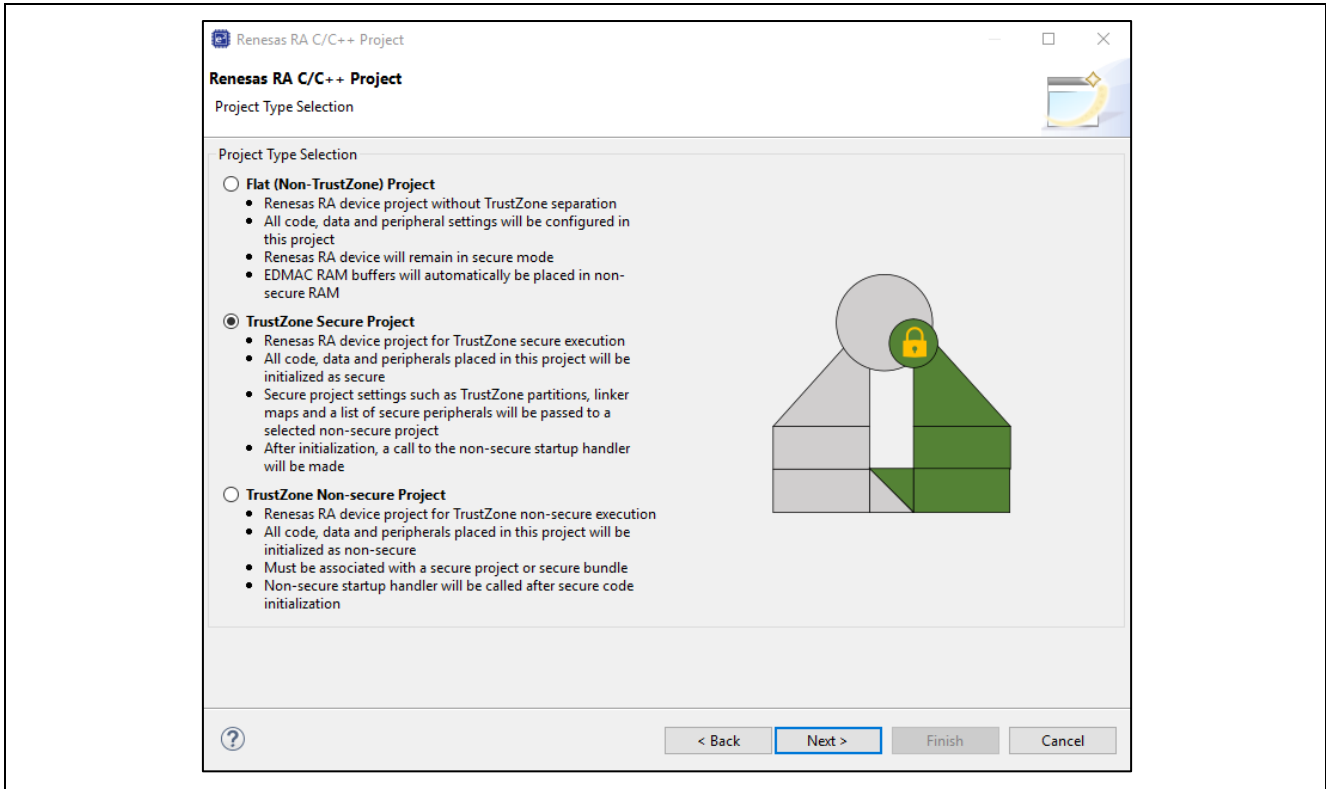


Figure 18. Using the RA Project Generator to Set Up New TZ Enabled Projects

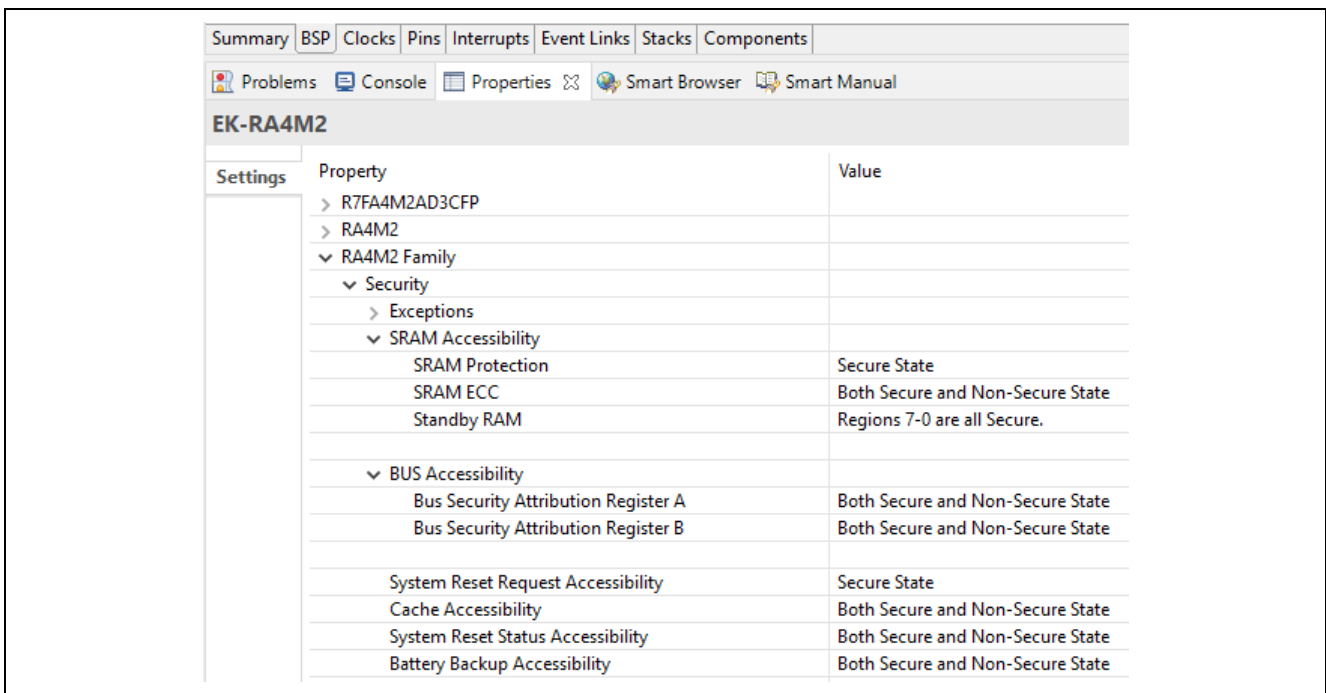


Figure 19. Secure and Non-Secure Settings in FSP Configurator

7.2 Emulator Support for TrustZone®

Renesas provides an emulator which supports both debugging using SWD or JTAG communication and serial programming using SCI communication. This emulator makes it easy to switch between debugging and serial programming. The following table shows the pinout of a 10-pin or 20-pin socket when using this emulator. The pinout of SWD and JTAG is Arm standard, and MD, TXD, and RXD pins are added for the serial programming using SCI communication.

The serial programming interface must be used to program the Arm® TrustZone IDAU boundary register settings, except for RA4E2 devices. It is recommended to connect P300/SWCLK/TCK and P201/MD pins using wired OR circuit on the board to use both debugging and serial programming.

For RA4E2 MCU devices, the IDAU boundary registers are set at runtime via the application. See the Security Design with Arm® TrustZone® - IP Protection document R11AN0467EU for more information.

Table 13. Pin Assignments for Emulator

Pin No.	SWD	JTAG	Serial Programming Using SCI
1	VCC	VCC	VCC
2	P108/SWDIO	P108/SWDIO	NC
4	P300/SWCLK Wired OR with P201/MD	P300/TCK Wired OR with P201/MD	P201/MD
6	P109/SWO/TXD9	P109/TDO/TXD9	P109/TDO/TXD9
8	P110/SWO/RXD9	P110/TDI/RXD9	P110/TDI/RXD9
9	GNDdetect	GNDdetect	GNDdetect
10	nRESET	nRESET	nRESET
12	P214/TCLK	P214/TCLK	NC
14	P211/TDATA[0]	P211/TDATA[0]	NC
16	P210/TDATA[1]	P210/TDATA[1]	NC
18	P209/TDATA[2]	P209/TDATA[2]	NC
20	P208/TDATA[3]	P208/TDATA[3]	NC
3, 5, 15, 17, 19	GND	GND	GND
7	NC	NC	NC
11,13	NC	NC	NC

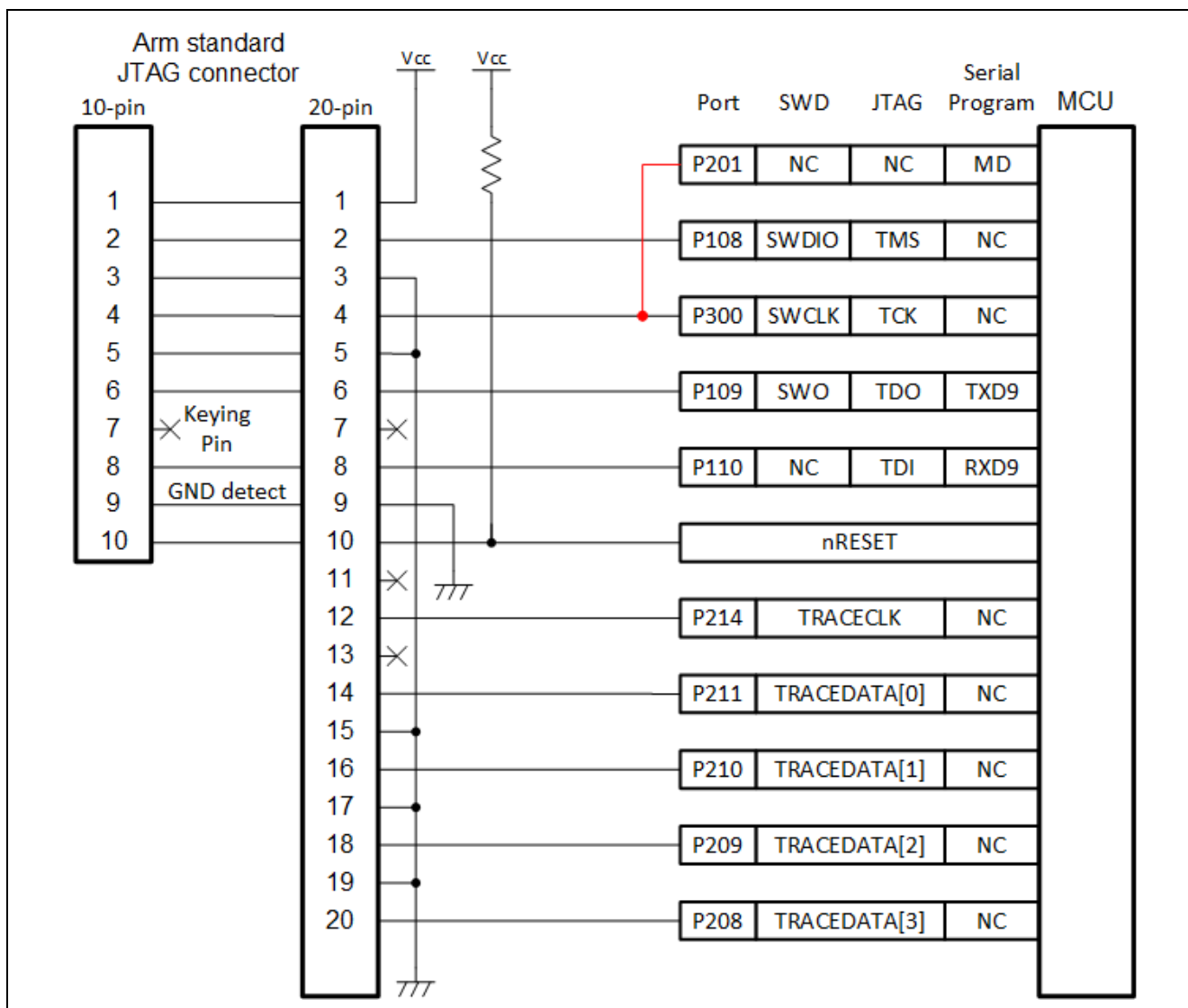


Figure 20. Emulator Connections for MCUs that Support Arm® Trustzone®

7.2.1 Device Lifecycle Management

Most RA4 MCUs with Arm® Cortex®-M33 cores are equipped with Device Lifecycle Management (DLM), which is the management of the process by which a product goes from inception to development to production and then eventually end-of-life. The RA Family MCU debug capability and serial programming capability are defined by the device lifecycle states.

Refer to the *Device Lifecycle Management Key Installation* application note for more details.

7.2.2 ID Authentication

RA4E2 MCU devices use ID authentication to prohibit programming and on-chip debugging. The device validates or invalidates the ID code and determines the ID code based on an ID code stored in the flash memory. When ID code protection is enabled, the ID code sent from the host is compared with the ID code in the flash memory to determine whether they match. Programming and on-chip debugging are enabled only when the two match. The ID code in flash memory consists of four 32-bit words.

The ID code is set using the OSIS (OCD/Serial Programmer ID Setting) register.

8. Memory

The RA4 MCUs support a 4-GB linear address space ranging from 0000 0000h to FFFF FFFFh that can contain program, data, and external memory bus. Program and data memory share the address space; separate buses are used to access each, increasing performance and allowing same-cycle access of program and data. Contained within the memory map are regions for on-chip RAM, peripheral I/O registers, program code flash, and data flash.

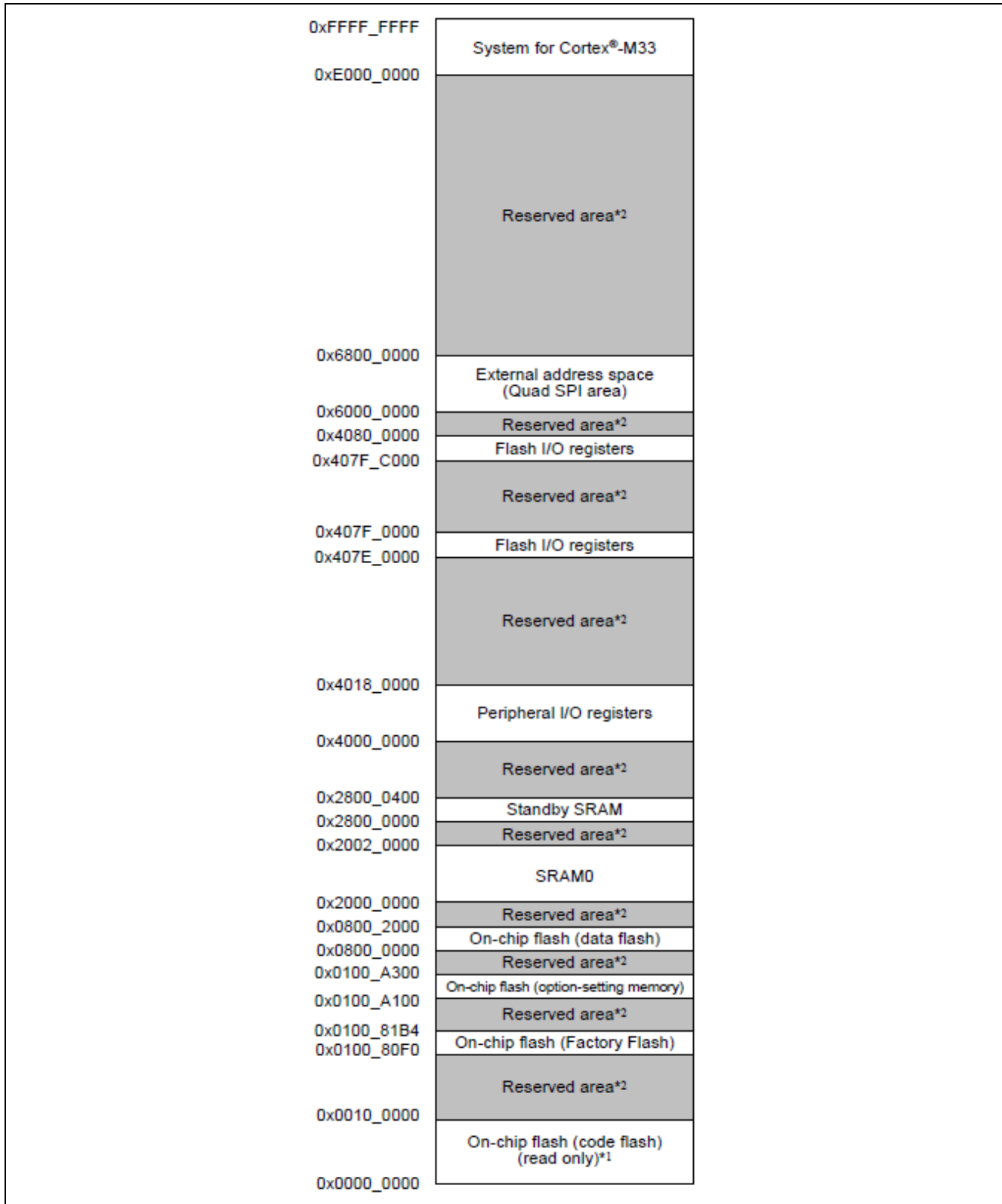


Figure 21. RA4M3 Memory Map

8.1 SRAM

The RA4 MCUs provide on-chip high-speed SRAM modules with either parity-bit checking or ECC (Error Correction Code). The first 32 KB of SRAM0 is subject to ECC. Parity check is performed on other areas. The following table lists the SRAM specifications. The number of SRAM modules and capacity vary by device. Consult the Hardware User’s Manual for specifics.

Parameter	Without ECC	With ECC
SRAM capacity	SRAM0: 64 KB	SRAM0: 64 KB
SRAM address	SRAM0: 0x2001_0000 to 0x2001_FFFF	SRAM0: 0x2000_0000 to 0x2000_FFFF
Access	Can access with no wait. One wait access is set at initial state. For details, see section 42.3.9. Access Cycle	
Data retention function	Not available in deep standby mode	
Module-stop function	Module-stop state can be set to reduce power consumption	
Parity	Even parity with 8-bit data and 1-bit parity	No parity
Error checking	even-parity (Data:8bit, parity:1bit)	SEC-DED (Single-Error Correction and Double-Error Detection Code)
Security	TrustZone Filter is integrated for memory access and SFR access. Access to the memory space is controlled by setting the memory Security Attribution (SA). And, access to I/O space (SFR) space is controlled by setting the register SA. See section 42.3.6. TrustZone Filter function .	

Figure 22. RA4M3 SRAM Specification

8.2 Standby SRAM

The RA4 MCUs provide an on-chip SRAM to retain data in Deep Software Standby mode. The following table lists the Standby SRAM specifications.

The power supply to the Standby SRAM in Deep Software Standby mode is enabled by the DPSBYCR.DEEPCUT[1:0] bits. If the DPSBYCR.DEEPCUT[1:0] bits are set to 00b, data in the Standby SRAM is retained in Deep Software Standby mode. See section 11, Low Power Modes, for details on the DPSBYCR.DEEPCUT[1:0] bits.

Item	Description
SRAM capacity	1 KB
SRAM address	0x2800_0000 to 0x2800_03FF
Access	Standby SRAM clock is the same clock as the PCLKB. See section 43.3.5. Access Cycle for details.
Data retention function	Data can be retained in deep standby mode. See section 43.3.1. Data Retention for details.
parity	Even parity (data: 8 bits, parity: 1 bit)
Module-stop function	Module-stop state can be set to reduce power consumption. See section 43.3.2. Setting for the Module-stop Function for details.
Security	Permits the read and write operations to Standby RAM following TrustZone Filter function. See section 43.3.4. TrustZone Filter function for details.

Figure 23. RA4M3 Standby SRAM Specification

The LPM (Low Power Mode) driver in Renesas FSP provides an option to cut or keep power to Standby SRAM as shown in the following figure. The LPM driver’s APIs still need to be invoked to write the selected settings to the MCU registers.

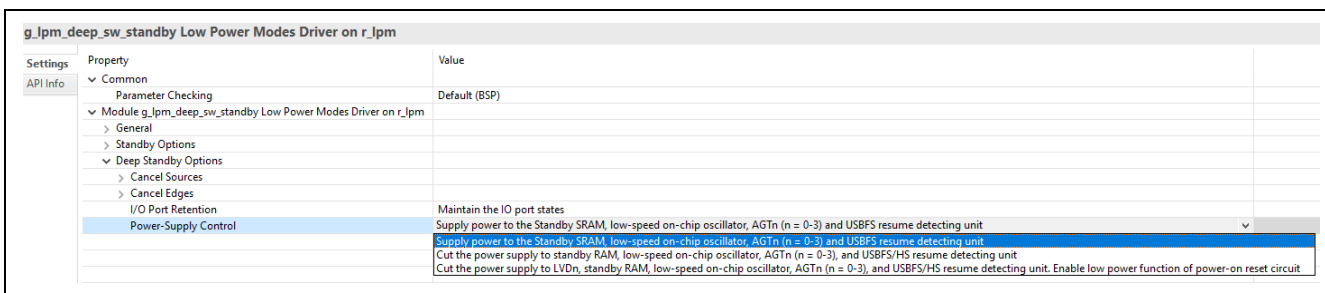


Figure 24. Enable/Disable Power Supply to Standby SRAM Using Renesas FSP Configurator

8.3 Peripheral I/O Registers

Blocks of peripheral I/O registers appear at various locations in the memory map depending on the device and the current operating mode. The majority of peripheral I/O registers occupy a region from address 4000 0000h to 400F FFFFh. However, this may vary in location and size by device. See the Hardware User's Manual for specifics. Details can be found in the *I/O Registers* appendix, and also in the register descriptions for each peripheral function. This region contains registers that are available at all times in all modes of operation. Flash I/O registers to control access flash memory occupy two regions, 407E 0000h to 407E FFFFh and 407F C000h to 407F FFFFh.

The Renesas FSP provides C header files in CMSIS data structure that map all of the peripheral I/O registers for a specific device to easily accessible I/O data structures.

8.4 On-Chip Flash Memory

The RA4 MCUs feature two flash memory sections, code flash and data flash, which vary in size and programmable cycle capacity by device. The Flash Control Unit (FCU) controls programming and erasure of the flash memory. The Flash Application Command Interface (FACI) controls the FCU in accordance with the specified FACI commands.

The code flash is designed to store user application code and constant data. The data flash is designed to store information that may be updated from time to time such as configuration parameters, user settings, or logged data. The units of programming and erasure in the data flash area are much smaller than that of the code flash (4/8/16 bytes for data flash versus 128 bytes for code flash).

Both the data flash and code flash areas can be programmed or erased by application code. This enables field firmware updates without having to connect an external programming tool.

Renesas FSP provides HAL layer drivers for both code flash memory and data flash memory.

The following figure shows example specifications of code flash memory and data flash memory.

Table 44.1 Specifications of flash memory (1 of 2)

Item	Code flash memory	Data flash memory
Memory capacity	User area: 1 Mbytes max	Data area: 8 Kbytes
Read cycle	See section 44.16.3. Access Cycle	See section 44.16.3. Access Cycle
Value after erasure	0xFF	Undefined
Programming/erasing method	<ul style="list-style-type: none"> Programming and erasing the code flash memory and data flash memory, and programming the option-setting memory are handled by the FACI commands specified in the FACI command issuing area (0x407E_0000) (self-programming). Programming/erasure through transfer by a serial-programmer via a serial interface (serial programming) 	
Protection	Protects against erroneous rewriting of the flash memory	
Block swap function	The block swap structure makes a safe update for a part of non-secure application possible in case where programming is suspended.	Not available
Background operations (BGOs)	<ul style="list-style-type: none"> The data flash memory can be read while the code flash memory is being programmed or erased. The code flash memory can be read while the data flash memory is being programmed or erased. 	
Units of programming and erasure	<ul style="list-style-type: none"> Units of programming for the user area: 128 bytes Units of erasure for the user area: Block units 	<ul style="list-style-type: none"> Unit of programming for the data area: 4/8/16 bytes Unit of erasure for the data area: 64/128/ 256 bytes
Other functions	Interrupts can be accepted during self-programming. In the initial settings of this MCU, an expansion area of the option-setting memory can be set.	
On-board programming (four types)	Programming/erasure in boot mode (for the SCI interface) <ul style="list-style-type: none"> The asynchronous serial interface (SCI9) is used. The transfer rate is adjusted automatically. Programming/erasure in boot mode (for the USB interface) <ul style="list-style-type: none"> USBFS is used. Dedicated hardware is not required, so direct connection to a PC is possible. Programming/erasure in On-chip debug mode <ul style="list-style-type: none"> JTAG or SWD interface is used Programming and erasure by self-programming <ul style="list-style-type: none"> This allows code flash memory programming/erasure without resetting the system. 	
Unique ID	A 16-byte ID code provided for each MCU	

Figure 25. Specifications of Code Flash Memory and Data Flash Memory on RA4M3 MCU

Note: Erase state of code flash is FFh but erase state of data flash is undefined.

8.4.1 Background Operation

RA4 MCUs support background operations for code flash and data flash. This means that when a program or erase is started, the user can keep executing and accessing memory from memory areas other than the one being operated on. For example, the CPU can execute application code from code flash while the data flash memory is being erased or programmed. Also, the CPU can execute application code from SRAM while the code flash memory is being erased or programmed.

8.4.2 ID Code Protection

Some RA4 MCUs, RA4E2 devices and those with Arm Cortex-M4 cores, have a 128-bit memory in the option setting memory area that is used as an ID code. If this ID code is left blank (0xFF's) then no protection is enabled and access to the MCU is allowed through boot mode or using the on-chip debugger. If the ID code is set then the user can control access to these modes. The user can choose to always disallow connections or can choose to allow connections when a matching ID code is input. Refer to the OCD/Serial Programmer ID Setting Register (OSIS) and ID Code Protection and sections of *RA4 MCU Hardware User's Manual* for more information.

The Renesas FSP configurator provides options to set up ID code protection for RA4 MCUs with the Arm Cortex-M4 core.

Property	Value
> R7FA4M1AB3CFP	
> RA4M1	
▼ RA4M1 Family	
> OFS0 register settings	
> OFS1 register settings	
> MPU	
Use Low Voltage Mode	Disabled
Main Oscillator Wait Time	262144 cycles
ID Code Mode	Unlocked (Ignore ID)
ID Code (32 Hex Characters)	FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
> RA Common	

Figure 26. ID Code Setup for RA4M1 (Arm Cortex-M4 Core) Using Renesas FSP Configurator

Note: ID code protection settings must be handled carefully to prevent mistakes that may result in blocking access to the MCU.

8.4.3 Flash Block Protection

RA4 MCUs with Arm Cortex-M33 core have a Flash Block Protection feature that protects secure or non-secure flash region from being erased or reprogrammed by secure or non-secure software. It is worth noting that the protection is for both Secure and Non-secure software accesses.

Refer to section *Configuring the Flash Block Protection* in *Securing Data at Rest Using the Arm® TrustZone®* application note for more details.

8.4.4 Memory Protection Unit

RA4 MCUs have a Memory Protection Unit (MPU). They have the ability to protect various MCU memory regions from illegal access. The choices include allowing both reading and writing, prohibiting writing, and prohibiting writing and reading. Select one of these options by setting the corresponding constant value at the specific memory address. See *Memory Protection Unit* in the MCU Hardware User's Manual for more details.

Property	Value
> R7FA4M1AB3CFP	
> RA4M1	
▼ RA4M1 Family	
> OFS0 register settings	
> OFS1 register settings	
▼ MPU	
Enable or disable PC Region 0	Disabled
PC0 Start	0x00FFFFFF
PC0 End	0x00FFFFFF
Enable or disable PC Region 1	Disabled
PC1 Start	0x00FFFFFF
PC1 End	0x00FFFFFF
Enable or disable Memory Region 0	Disabled
Memory Region 0 Start	0x00FFFFFF
Memory Region 0 End	0x00FFFFFF
Enable or disable Memory Region 1	Disabled
Memory Region 1 Start	0x200FFFC
Memory Region 1 End	0x200FFFF
Enable or disable Memory Region 2	Disabled
Memory Region 2 Start	0x407FFFC
Memory Region 2 End	0x407FFFF
Enable or disable Memory Region 3	Disabled
Memory Region 3 Start	0x400DFFFC
Memory Region 3 End	0x400DFFFF
Use Low Voltage Mode	Disabled
Main Oscillator Wait Time	262144 cycles
ID Code Mode	Unlocked (Ignore ID)
ID Code (32 Hex Characters)	FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
> RA Common	

Figure 27. MPU Setup for RA4M1 (Arm Cortex-M4 core) Using Renesas FSP Configurator

Note: MPU settings must be handled carefully to prevent mistakes that may result in blocking accesses to an MCU region.

8.5 Restriction on Endian

Memory space containing instruction codes must be little-endian to execute code on the Arm® Cortex®-M core.

9. Register Write Protection

The register write protection function protects important registers from being overwritten because of software errors. The registers to be protected are set with the Protect Register (PRCR). Table 14 lists the association between the PRCR bits and the registers to be protected.

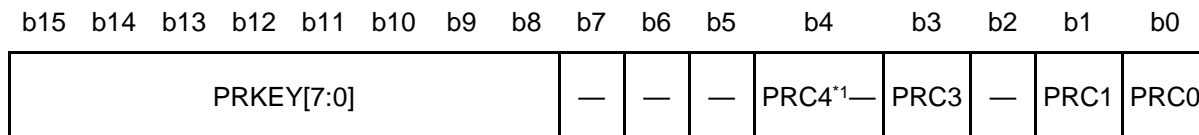


Figure 28. PRCR Register

Note 1. Not present on Arm Cortex-M4 devices.

Table 14. PRCR Protection Bits

PRCR bit	Description
PRC0	<ul style="list-style-type: none"> Registers related to the Clock Generation Circuit: SCKDIVCR, SCKSCR, PLLCCR, PLLCR, BCKCR, MOSCCR, HOCOCCR, MOCOCCR, CKOCR, TRCKCR, OSTDCR, OSTDSR, EBCKOCR, SDCKOCR, MOCOUTCR, HOCOUTCR, MOSCWTCR, MOMCR, SOSCCR, SOMCR, LOCOCCR, LOCOUTCR, HOCOWTCR, FLLCR1, FLLCR2
PRC1	<ul style="list-style-type: none"> Registers related to the low power modes: SBYCR, SNZCR, SNZEDCR, SNZREQCR, OPCCR, SOPCCR, DPSBYCR, DPSIER0-3, DPSIFR0-3, DPSIEGR0-2, SYOCDCR, STCONR Registers related to the battery backup function: VBTBKR_n (n = 0 to 511), VBTICTLR
PRC3	<ul style="list-style-type: none"> Registers related to the LVD: LVD1CR1, LVD1SR, LVD2CR1, LVD2SR, LVCMPCCR, LVDLVLR, LVD1CR0, LVD2CR0
PRC4 ^{*1}	<ul style="list-style-type: none"> Registers related to the security function: CGFSAR, RSTSAR, LPMSAR, LVDSAR, BBFSAR, DPFSAR, CSAR, SRAMSAR, STBRAMSAR, DTCSAR, DMACSAR, ICUSAR_x, BUSSAR_x, MMPUSAR_x, TZFSAR, CPUDSAR, FSAR, PSAR_x, MSSAR, PmSAR, ELCSAR_x
PRKEY[7:0]	These bits control write access to the PRCR register. To modify the PRCR register, write A5h to the eight higher-order bits and the wanted value to the eight lower-order bits as a 16-bit unit.

Note 1. Not present on Arm® Cortex®-M4 devices.

The Renesas FSP provides two APIs (R_BSP_RegisterProtectEnable and R_BSP_RegisterProtectDisable) to enable and disable Register Write Protection respectively.

10. I/O Port Configuration

The *I/O Ports* section of the Hardware User's Manual describes exact pin configurations based on peripheral selection and other register settings. Some general information is listed as follows.

It is important to note that after a reset, each pin will be in the default state for that pin. Most pins are not configured until the application code starts to execute. There may be a small period where some pins may be in an undesirable state. This will be true regardless of what configuration method is used. The user should consider the impact this may have for each application, including the effect this may have on other system features.

The IO Port Configuration may be set using either direct write to registers or using FSP Pin Configuration.

10.1 Multifunction Pin Selection Design Strategies

Most pins on the RA4 Series of MCUs can be configured from a selection of multiple peripheral functions. Tools, such as the pin configurator in FSP, are available from Renesas to assist with assigning pins for each peripheral function. When several peripheral functions are needed, use the following design strategies to help with pin selection.

- Assign peripheral functions with only one pin option first. For example, there is only one pin option for each Trace Data signal in the debug function. When this function is needed, assign these pins first.
- Assign peripheral functions with limited pin options next. For example, devices that support the QSPI peripheral typically only have two pin options for each QSPI signal.
- Assign peripheral functions with multiple pin options last. One example would be the Serial Communications Interface (SCI) which typically has many available pin options.
- Some peripheral function pin options are interchangeable, while others must be assigned in logical groups. For example, the IIC peripheral has some pins with the suffix “_A” while others have the suffix “_B” in the signal name. Pins should be selected to have the same suffix for the peripheral function. Other peripheral functions do not have this type of suffix, and pins may be assigned interchangeably, such as the USB_VBUSEN signal for the USBFS peripheral function. Also see section 15.3 in this document.

10.2 Setting Up and Using a Pin as GPIO

There are two methods for setting up and using a pin as GPIO, either using the Port Control Register (PCNTR1), or the PmnPFS registers.

Method 1: Port Control Register (PCNTR1)

- Select a pin as an output by writing a “1” to the Port Direction bit (PDRn) in Port Control Register 1 (PCNTR1).
- The Port Direction bits (PDRn) are read/write. Setting the value to a “1” selects the pin as an output. Default state for I/O Ports is “0” (input). The port direction registers can be read on the RA4 MCUs.
- The Port Output Data bits (PODRn) in the corresponding Port Control Register (PCNTR1) are read/write. When the PODR is read the state of the output data latch (not the pin level) is read.
- The Port Input bits (PIDRn) in Port Control Register 2 (PCNTR2) are read only. Read the PIDRn bit in the PCNTR2 register to read the pin state.

Method 2: Port mn Pin Function Select (PmnPFS) registers

- The Port Mode Register (PMR) is read/write and is used to specify whether individual pins function as GPIO or as peripheral pins. Just after reset, all PMR registers are set to 0, which sets all pins to work as GPIO. If a PMR register is set to 1 then that corresponding pin will be used for peripheral functions. The peripheral function is defined by that pin’s MPC setting.
- When setting a pin as an output, it is recommended that the desired output value of the port be written to the data latch first, then the direction register is set to an output. Though not important in all systems, this prevents an unintended output glitch on the port being set up.

In general, using PCNTR1 to configure a port will provide faster access but will have fewer configuration features available. Using the PmnPFS registers will have more configuration features available but will have slower access.

The Renesas FSP provides a Pin Configurator to configure GPIO pins after reset as shown below. After the GPIO is configured, it can be controlled using HAL layer APIs in FSP.

Pin Configuration		
Name	Value	Link
Symbolic Name	PMOD1_SS3	
Comment		
Mode	Output mode (Initial Low)	
Pull up	None	
IRQ	None	
Drive Capacity	Low	
Output type	CMOS	
▼ Input/Output		
P302	✓ GPIO	→

Module name: P302

Port Capabilities: BUS_ASYNC0: A07
 GPT_OP50: GTOUUP
 GPT4: GTIOCA
 ICU0: IRQ05
 SCI2: SDA
 SCI2: TXD
 SPI0: SSL3

Figure 29. Configuring P302 as Output and Low using FSP Configurator

10.2.1 Internal Pull-Ups

- Most pins on ports 0 through 9 have the option of enabling a pull-up resistor. The pull-up is controlled by the Pull-Up Control (PCR) bit in each Port mn Pin Function Select (PmnPFS) Register. The PCR bit in each PmnPFS register controls the corresponding pin on the port.
- The pin must first be set as an input with the associated bit in the PmnPFS register. Set the PCR bit to “1” to enable the pull-up and to “0” to disable it.
- After reset, all PCR registers are cleared to “0”, so all pull-up resistors are disabled.
- The pull-up is automatically turned off whenever a pin is designated as an external bus pin, a GPIO output, or a peripheral function output pin.

10.2.2 Open-Drain Output

- Pins configured as outputs normally operate as CMOS outputs.
- Most pins on ports 0 through 9 have the option of being configured as an NMOS open-drain output.
- The N-channel open-drain control (NCODR) bit in each Port mn Pin Function Select (PmnPFS) Register controls which pins operate in open-drain mode. Setting the applicable bit in each register to a “1” makes the output open-drain. Setting the applicable bit in each register to a “0” sets the port to CMOS output.

10.2.3 Drive Capacity

Most pins on ports 1 through 9 have the option of enabling an output drive capacity. For Arm Cortex-M4 devices, the drive capacity can be set to low- or middle-drive capacity. For Arm Cortex-M33 devices, the drive capacity can be set to low-, middle- or high-drive capacity.

- The drive capacity switching is controlled by the Drive Capacity Control Register (DSCR) bits in each Port mn Pin Function Select (PmnPFS) register.
- After reset all DSCR registers are cleared to 0 therefore all pins are set to low drive output. Setting a value other than “00” will change the drive capacity of the output for the selected pin.
- The maximum total output of all pins summed together is 60 mA for Arm® Cortex®-M4 devices or 80 mA for Arm Cortex-M33 devices.
- The typical differences the drive levels are shown below. Actual output current levels vary by device and pin type. See the specific MCU User Manual for details.

Table 15. Pin Drive Capacity

Typical output pins	DSCR[1:0]	Drive Capacity	Max (mA)
Permissible output current per pin	0 0	Low Drive	4.0
Permissible output current per pin	0 1	Middle Drive	8.0
Invalid setting; do not use	1 0	-	
Permissible output current per pin	1 1	High Drive	32

High drive output pins	DSCR[1:0]	Drive Capacity	Max (mA)
Permissible output current per pin	0 0	Low Drive	4.0
Permissible output current per pin	0 1	Middle Drive	8.0
Invalid setting; do not use	1 0	-	
Permissible output current per pin	1 1	High Drive	40

Output drive capacity can have a significant impact on overall performance of a board design. The following points should be considered when selecting the drive capacity for each output.

- It is recommended to start with all pins set to low-drive capacity (default) and evaluate the performance.
- Depending on the board layout, pins set to middle- or high-drive capacity may result in higher EMI radiation.
- Long traces may require higher drive capacity for signals to propagate correctly to the receiver.

10.3 Setting Up and Using Port Peripheral Functions

The Port mn Pin Function Select Registers (PmnPFS) are used to configure the characteristics of each port. The PSEL bits select the peripheral function selected for each port.

- Since most pins have multiple functions, the RA4 MCUs have Pin Function Control Registers (PmnPFS) that allow you to change the function assigned to a pin.
- Each pin has its own PmnPFS register.
- Each PmnPFS register allows a pin to be used for peripheral function (PSEL bits), as an IRQ input pin (ISEL bit), or as an analog input pin (ASEL bit). If the ASEL bit is set to “1” (use pin as analog input pin) then the pin’s PMR bit should be set for GPIO use and the pin’s PDR bit should be set for input.
- Refer to the “Peripheral Select Settings for each Product” section in the “I/O Ports” chapter of the Hardware User’s Manual.
- In order to ensure that no unexpected edges are input or output on peripheral pins, make sure to clear the Port Mode Control (PMR) bit for the targeted pin before modifying the pin’s PmnPFS register.
- All PmnPFS registers are write protected after reset. In order to write to these registers, the Write-Protect Register (PWPR) must first be used to enable writing.
- Care should be taken when setting PmnPFS registers such that a single function is not assigned to multiple pins. The user should not do this but the MCU will allow it. If this occurs the function on the pins will be undefined.
- If you are using the external bus, the Ethernet controller, or USB, there are additional registers in the MPC that must be configured before using these peripherals.
- The figure below shows an example of enabling QSPI pins using FSP Pin configuration.

Pin Configuration

Name	Value	Lock	Link
Pin Group Selection	_B only		
Operation Mode	Quad		
▼ Input/Output			◀ ▶
QSPCLK	✓ P305	🔒	➡
QSSL	✓ P306	🔒	➡
QIO0	✓ P307	🔒	➡
QIO1	✓ P308	🔒	➡
QIO2	✓ P309	🔒	➡
QIO3	✓ P310	🔒	➡

Module name: QSPI0

Usage: For QSPI, same Pin Group Recommended

Figure 30. Enabling QSPI pins Using Pin Configurator in Renesas FSP

10.4 Setting Up and Using IRQ Pins

- Certain port pins can be used as hardware interrupt lines (IRQ). See the *Peripheral Select Settings for each Product* section in the *I/O Ports* chapter of the Hardware User’s Manual for information on which pins are available for your MCU.
- Some IRQ pins have a “-DS” suffix (for example, IRQ1-DS). The “-DS” designates that this pin can be used to wake the MCU out of deep software standby mode.
- It is not possible to use IRQn and IRQn-DS at the same time. Same number interrupts with the -DS and without the -DS suffix connect to the same interrupt internally, even though they use different external pin connections.
- To set a port pin to be used as an IRQ pin, the Interrupt Input Function Select bit (ISEL) in the pin’s PFS register must be set to “1”.
- Pins can be used for both IRQ and peripheral functions simultaneously. To enable this the user should set both the ISEL and PSEL bits in the pin’s PFS register.
- IRQ functions of the same number must only be enabled on one pin.
- IRQ pins can trigger interrupts on detection of:
 - Low level
 - Falling edge
 - Rising edge
 - Rising and falling edges
 Which trigger is selected is chosen using the IRQ Control Registers (IRQCRi).
- Digital filtering is available for IRQ pins. The filters are based on repetitive sampling of the signal at one of four selectable clock rates (PCLK, PCLK/8, PCLK/32, PCLK/64). They filter out short pulses: any high or low pulse less than 3 samples at the filter rate. The filters are useful for filtering out ringing and noise in these lines but are much too quick for filtering out long events like mechanical switch bounce. Enabling filtering adds a short bit of latency (the filter time) to the hardware IRQ lines.
- Digital filtering can be enabled for each IRQ pin independently. This is done by setting the IRQ Pin Digital Filter Enable (FLTEN) bit in the IRQCRi register for each IRQ.
- The clock rate for digital filtering is configurable for each IRQ pin independently. This is done by setting the IRQ Pin Digital Filter Setting (FCLKSEL[1:0]) bits in the IRQCRi register for each IRQ.
- Figure 31 and Figure 32 show examples of enabling and configuring IRQ pins using Renesas FSP.

Pin Configuration				
Name	Value	Lock	Link	
Operation Mode	Enabled			
▼ Input/Output			◀ ▶	
NMI	None		→	
IRQ00	None		→	
IRQ01	None		→	
IRQ02	None		→	
IRQ03	✓ P202		→	
IRQ04	None		→	
IRQ05	None		→	
IRQ06	✓ P000		→	
IRQ07	None		→	
IRQ08	None		→	
IRQ09	None		→	
IRQ10	None		→	
IRQ11	None		→	

Module name: ICU0

Usage: To use IRQ function with output or peripheral modes, change directly in port dialog

Figure 31. Enable P202, P000 as IRQ03, IRQ06 Inputs Respectively Using Pin Configurator in Renesas FSP

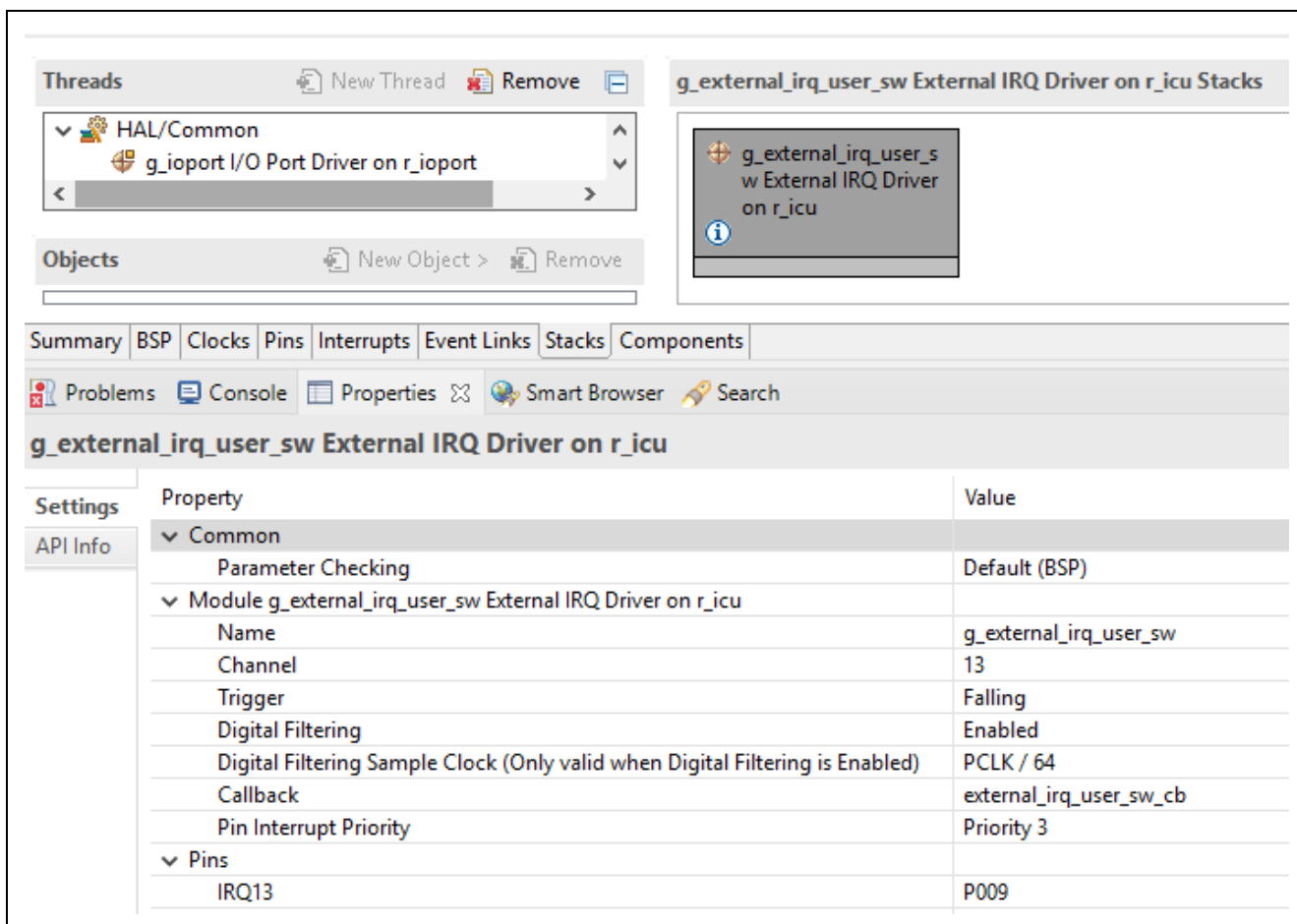


Figure 32. Configure IRQ13 using the Renesas FSP Configurator

10.5 Unused Pins

Note: Some pins require specific termination: See the *Handling of Unused Pins* section of the Hardware User’s Manual for specific recommendations.

Unused pins that are left floating can consume extra power and leave the system more susceptible to noise problems. Terminate unused pins with one of the methods detailed here:

1. The first option is to set the pin to an input (the default state after reset) and connect the pin to VCC or VSS using a resistor. There is no difference to the MCU between one connection or another. However, there may be an advantage from a system noise perspective. VSS is probably the most typical choice. Avoid connecting a pin directly to VCC or VSS since an accidental write to the port’s direction register that sets the pin to an output could create a shorted output.
2. A second method is to set the pin to an output. The pin level may be set high or low. However, setting the pin as an output and making the output low connects the pin internally to the ground plane. This may help with overall system noise concerns.
A disadvantage of setting unused pins to outputs is that the configuration of the port must be done via software control. While the MCU is held in reset and until the direction register is set for output, the pin will be a floating input and may draw extra current. If the extra current can be tolerated during this time, this method eliminates the external resistors required in the first method.
3. A variation on leaving the pins as inputs and terminating them with external resistors uses the internal pull-ups available on many ports of the MCU. This has the same limitation as setting the pins to outputs (requires the program to set up the port) but it does limit the effect of accidental pin shorts to ground, adjacent pins or VCC since the device will not be driving the pin.

10.6 Nonexistent Pins

Each RA4 MCU group is available in multiple package sizes, with different total pin counts. For any package smaller than the largest package for that MCU group (typically 100 pins or 144 pins), set the corresponding bits of nonexistent ports in the PDR register to “1” (output) and in the PODR register to “0”. The user can see which ports are available on each MCU package by reviewing the *Specifications of I/O Ports* table in the *I/O Ports* section of the Hardware User’s Manual. For example, pins 0 and 1 on port 1 are only available on 176 pin packages. Note that no additional handling of nonexistent pins is required.

10.7 Electrical Characteristics

Normal GPIO ports typically require CMOS level inputs (High $\geq 0.8 * VCC$, Low $\leq 0.2 * VCC$). Some GPIO ports have Schmitt Trigger inputs, which have slightly different input requirements. See the Hardware User’s Manual section *Electrical Characteristics* for more information.

11. Module Stop Function

To maximize power efficiency, the RA4 series of MCUs allow on-chip peripherals to be stopped individually by writing to the Module Stop Control Registers (MSTPCR_i, i=A, B, C, D, E). Once a module stops, access to the module registers is not possible.

After a reset, most of the modules are placed in module-stop state, except for DMAC, DTC, and SRAM. See Hardware User’s Manual for details.

Before accessing any of the registers for a peripheral, it must be enabled by taking it out of stop mode by writing a ‘0’ to the corresponding bit in the MSTPCR_i register.

Peripherals may be stopped by writing a ‘1’ to the proper bit in the MSTPCR_i register.

HAL drivers in Renesas FSP handle module start/stop function automatically.

12. Interrupt Control Unit

The Interrupt Controller Unit (ICU) controls which event signals are linked to the NVIC, DTC, and DMAC modules. The ICU also controls non-maskable interrupts. Figure 33 shows an example of the ICU specifications, and Figure 34 shows an example of the ability to raise the IRQ_i event from the I/O pins. Refer to the Hardware User’s Manual for details for each RA4 MCU Group.

Parameter		Description
Maskable interrupts	Peripheral function interrupts	<ul style="list-style-type: none"> Interrupts from peripheral modules Number of sources: 223 (select factor within event list numbers 32 to 511)
	External pin interrupts	<ul style="list-style-type: none"> Interrupt detection on low level⁴, falling edge, rising edge, rising and falling edges. One of these detection methods can be set for each source Digital filter function supported 16 sources, with interrupts from IRQi (i = 0 to 15) pins.
	Interrupt requests to CPU (NVIC)	<ul style="list-style-type: none"> 96 interrupt requests are output to NVIC.
	DMAC control	<ul style="list-style-type: none"> The DMAC can be activated using interrupt sources¹ The target interrupt source can be selected individually for every DMAC channels.
	DTC control	<ul style="list-style-type: none"> The DTC can be activated using interrupt sources¹ The method for selecting an interrupt source is the same as that of the interrupt request to NVIC.
Non-maskable interrupts ²	NMI pin interrupt	<ul style="list-style-type: none"> Interrupt from the NMI pin Interrupt detection on falling edge or rising edge Digital filter function supported
	WDT underflow/refresh error ³	Interrupt on an underflow of the down-counter or occurrence of a refresh error
	IWDT underflow/refresh error ³	Interrupt on an underflow of the down-counter or occurrence of a refresh error
	Low voltage detection 1 ³	Voltage monitor 1 interrupt of the voltage monitor 1 circuit (LVD_LVD1)
	Low voltage detection 2 ³	Voltage monitor 2 interrupt of the voltage monitor 2 circuit (LVD_LVD2)
	RPEST ⁵	Interrupt on SRAM parity error
	RECCST ⁵	Interrupt on SRAM ECC error
	Bus master MPU error ⁵	Interrupt on MPU bus master error
	TZFST ⁵	TrustZone Filter error.
	CPEST ⁵	Cache RAM Parity error.
	Oscillation stop detection interrupt ³	Interrupt on detecting that the main oscillation has stopped
Low power modes	<ul style="list-style-type: none"> Sleep mode: return is initiated by non-maskable interrupts or any other interrupt source Software Standby mode: return is initiated by non-maskable interrupts. Interrupt can be selected in the WUPEN register. Snooze mode: return is initiated by non-maskable interrupts. Interrupt can be selected in the SELSR0 and WUPEN registers. <p>See section 13.2.17. SELSR0 : SYS Event Link Setting Register and section 13.2.18. WUPEN0 : Wake Up Interrupt Enable Register 0, section 13.2.19. WUPEN1 : Wake Up interrupt enable register 1.</p>	
TrustZone Filter	Available	

Figure 33. RA4M3 ICU Specifications

Pin name	I/O	Description
NMI	Input	Non-maskable interrupt request pin
IRQi (i = 0 to 15)	Input	External interrupt request pins

Figure 34. RA4M3 ICU I/O Pins

The following figure is an example of using Renesas FSP configurator to enable and configure an interrupt using Renesas FSP. The ICU and interrupts are configured as part of the HAL driver configuration through FSP.

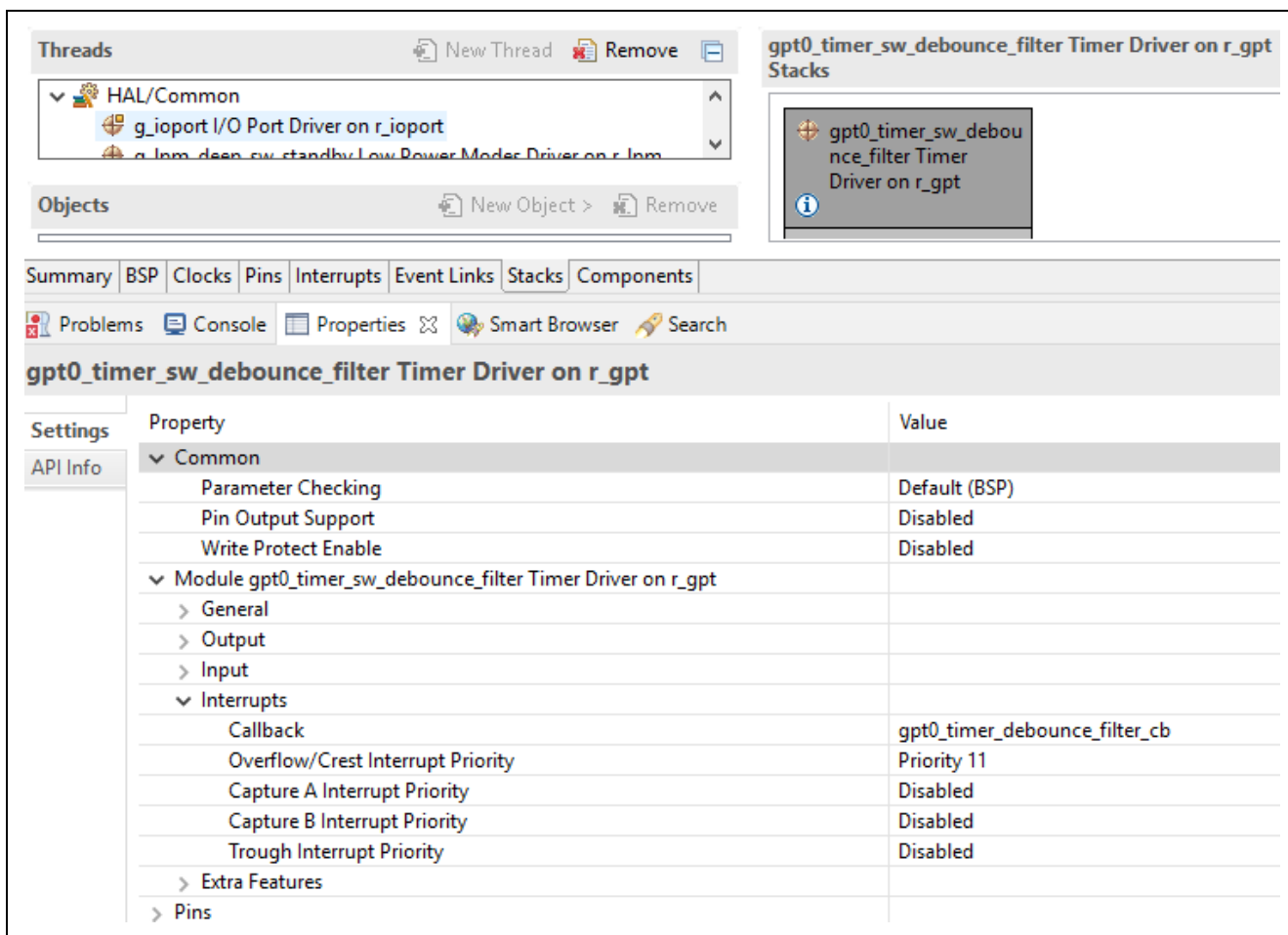


Figure 35. Enable GTP0 Overflow Interrupt and Set User Callback Functions Invoked by Interrupt Service Routine

13. Low Power Consumption

The RA4 devices have several functions for reducing power consumption. These include setting clock dividers, stopping modules, selecting power control mode in Normal mode, and transitions to low power modes. Refer to the chapter *Low Power Modes* in the Hardware User’s Manual for more details.

RA4 MCUs support four different types of LPM depending on the MCU Group. These are:

- Sleep mode
- Software Standby mode
- Snooze mode
- Deep Software Standby mode.

The following table is an overview of the functions available for reducing power consumption.

Table 16. Specifications of the Lower Power Mode Functions

Item	Specification
Reducing power consumption by modifying clock signals	The frequency division ratio can be selected independently for the system clock (ICLK), peripheral module clock (PCLKA, PCLKB, PCLKC, PCLKD), and flash interface clock (FCLK).* ¹
Module stop	Functions can be stopped independently for each peripheral module.
Low-power modes	<ul style="list-style-type: none"> • Sleep mode • Software Standby mode • Snooze mode • Deep Software Standby mode
Power control modes	Three operating power control modes: <ul style="list-style-type: none"> • High-speed mode • Low-speed mode • Subosc-speed mode
TrustZone® Filter* ²	Security attributes can be set for each register

Notes: 1. For details, see the chapter *Clock Generation Circuit* in the Hardware User's Manual.

2. For devices that support Arm® TrustZone® security features.

The following table lists the conditions to transition to low power modes, the states of the CPU and the peripheral modules, and the method for cancelling each mode.

Table 17. Low Power Consumption Modes

State of operation* ¹	Sleep Mode	All-Module Clock Stop Mode	Software Standby Mode	Deep Software Standby Mode
Transition condition	WFI instruction while SBYCR.SSBY=0	WFI instruction while SBYCR.SSBY=1 and DPSBYCR.DPSBY=0	Snooze request trigger in Software Standby mode. SNZCR.SNZE=1	WFI instruction while SBYCR.SSBY=1 and DPSBYCR.DPSBY=1
Canceling method	All interrupts. Any reset available in the mode.	Interrupts defined for this mode. Any reset available in the mode.	Interrupts defined for this mode. Any reset available in the mode.	Interrupts defined for this mode. Any reset available in the mode.
State after cancellation by an interrupt	Program execution state (interrupt processing)	Program execution state (interrupt processing)	Program execution state (interrupt processing)	Reset state
State after cancellation by a reset	Reset state	Reset state	Reset state	Reset state

Notes: 1. Refer to the table *Operating Conditions of Each Low Power Mode* in the Hardware User's Manual for additional details.

RA4 devices include register settings that allow the MCU to operate with lower power consumption in Normal mode and Sleep mode. These modes are referred to as the operating power control modes and are controlled by the OPCCR register.

The following is a summary of the operating power consumption control modes and the maximum permissible clocking and voltage levels under each mode.

Table 18. Available Oscillators in Each Operating Power Consumption Control Mode

Mode	Oscillator						
	PLL, PLL2	High-speed on-chip oscillator	Middle-speed on-chip oscillator	Low-speed on-chip oscillator	Main clock oscillator	Sub-clock oscillator	IWDT-dedicated on-chip oscillator
High-speed	Available	Available	Available	Available	Available	Available	Available
Low-speed	N/A	Available	Available	Available	Available	Available	Available
Subosc-speed	N/A	N/A	N/A	Available	N/A	Available	Available

Note: While it may be possible to set the value in the OPCCR register to any of the low power operating modes, clocking and voltage levels must also be set to meet the requirements of the desired mode. Otherwise, the settings in the OPCCR register will not have any effect in lowering power consumption.

In order to achieve the lowest power consumption, use the maximum possible frequency division ratios in the clock generation circuits.

Low power modes are canceled by various interrupt sources such as RES pin reset, power-on reset, voltage monitor reset, and peripheral interrupts. Refer to the *Low Power Modes* section in the Hardware User's Manual for a list of interrupt sources for different LPMs.

Only Snooze mode is triggered by a Snooze request to enter Snooze mode from Software Standby mode. The transitions to other LPMs are done by executing a WFI instruction with appropriate settings in the Standby Control register (SBYCR).

Renesas FSP provides a low power mode (LPM) driver and driver configurator to set up low power mode, wake source/cancel source, and so forth.

Property	Value
▼ Common	
Parameter Checking	Default (BSP)
▼ Module g_lpm_deep_sw_standby Low Power Mod	
▼ General	
Name	g_lpm_deep_sw_standby
Low Power Mode	Deep Software Standby mode
Output port state in standby and deep stan	No change
▼ Standby Options	
> Wake Sources	
> Snooze End Sources	
Snooze Request Source	RXD0 falling edge
DTC state in Snooze Mode	Disabled
Snooze Cancel Source	None
▼ Deep Standby Options	
> Cancel Sources	
> Cancel Edges	
I/O Port Retention	Maintain the IO port states
Power-Supply Control	Supply power to the Standby SRAM, low-speed on-chip oscillator, AGTn and USBFS resume detect...

Figure 36. Set up Low Power Mode Using Renesas FSP Configurator

After a specific LPM mode is set up by FSP Configurator, the LPM driver's API can be used to initialize LPM driver and place MCU in configured LPM mode, as shown in the following example:

```

/* Open LPM driver and initialize LPM mode */
err = R_LPM_Open(&g_lpm_deep_sw_standby_ctrl, &g_lpm_deep_sw_standby_cfg);
/* Handle error */
if (FSP_SUCCESS != err)
{
    return (err);
}
/* Transition to configured LPM mode: Deep Software Standby Mode */
err = R_LPM_LowPowerModeEnter(&g_lpm_deep_sw_standby_ctrl);
/* Handle error */
if (FSP_SUCCESS != err)
{
    return (err);
}
    
```

Refer to the *Getting Started with Low Power Applications* Application Notes for RA devices for examples of how to use FSP configurator and driver APIs for LPM.

14. Buses

The buses in Arm® Cortex®-M33 MCU consist of a 32-bit AHB (Advanced High-performance Bus) bus matrix. Figure 37 lists the bus masters and bus slaves and Figure 38 shows the bus configuration.

Note: Memory space is accessed in little-endian format when executing Arm Cortex instruction code.

Classification	Bus Master/Slave name	Bus I/F Max Freq	Sync Clock	Specifications
Bus Masters	Code bus (Cortex-M33)	100 MHz	ICLK	Connected to the CPU Instruction Cache for instructions and operands
	System bus (Cortex-M33)	100 MHz	ICLK	Connected to the CPU Data Cache for system
	DMAC / DTC	100 MHz	ICLK	Connected to the DMAC/DTC
Bus Slaves	FHBIU	100 MHz	ICLK	Connected to Code Flash memory and Configuration area
	FLBIU	50 MHz	FCLK	Connected to Data Flash memory, FACI
	SOBIU	100 MHz	ICLK	Connected to SRAM0 (Standby RAM)
	PSBIU	100 MHz	ICLK	Connected to peripheral system modules (DTC, DMAC, ICU, Flash, MPU, SRAM, Debug/Trace module, System controller and BUS controller)
	PLBIU	50 MHz	PCLKB	Connected to peripheral modules (CAC, ELC, I/O ports, POEG, RTC, WDT, IWDT, AGT, IIC, CAN, USBFS, SDHI, SSIE, TSN, and CTSU)
	PHBIU	100 MHz	PCLKA	Connected to peripheral modules (GPT, SCI, SPI, CRC, DOC, ADC12, DAC12 and SCE9)
	EQBIU (QSPI area)	100 MHz	PCLKA	Connected to the QSPI (External Memory Interface)

Note: FHBIU: Flash High speed Bus Interface Unit.
 FLBIU: Flash Low speed Bus Interface Unit.
 SOBIU: SRAM0 Bus Interface Unit.
 PSBIU: Peripheral System Bus Interface Unit.
 PLBIU: Peripheral Low speed Bus Interface Unit.
 PHBIU: Peripheral High speed Bus Interface Unit.
 EQBIU: External memory interface Qspi Bus Interface Unit.

Figure 37. RA4M3 Bus Specifications

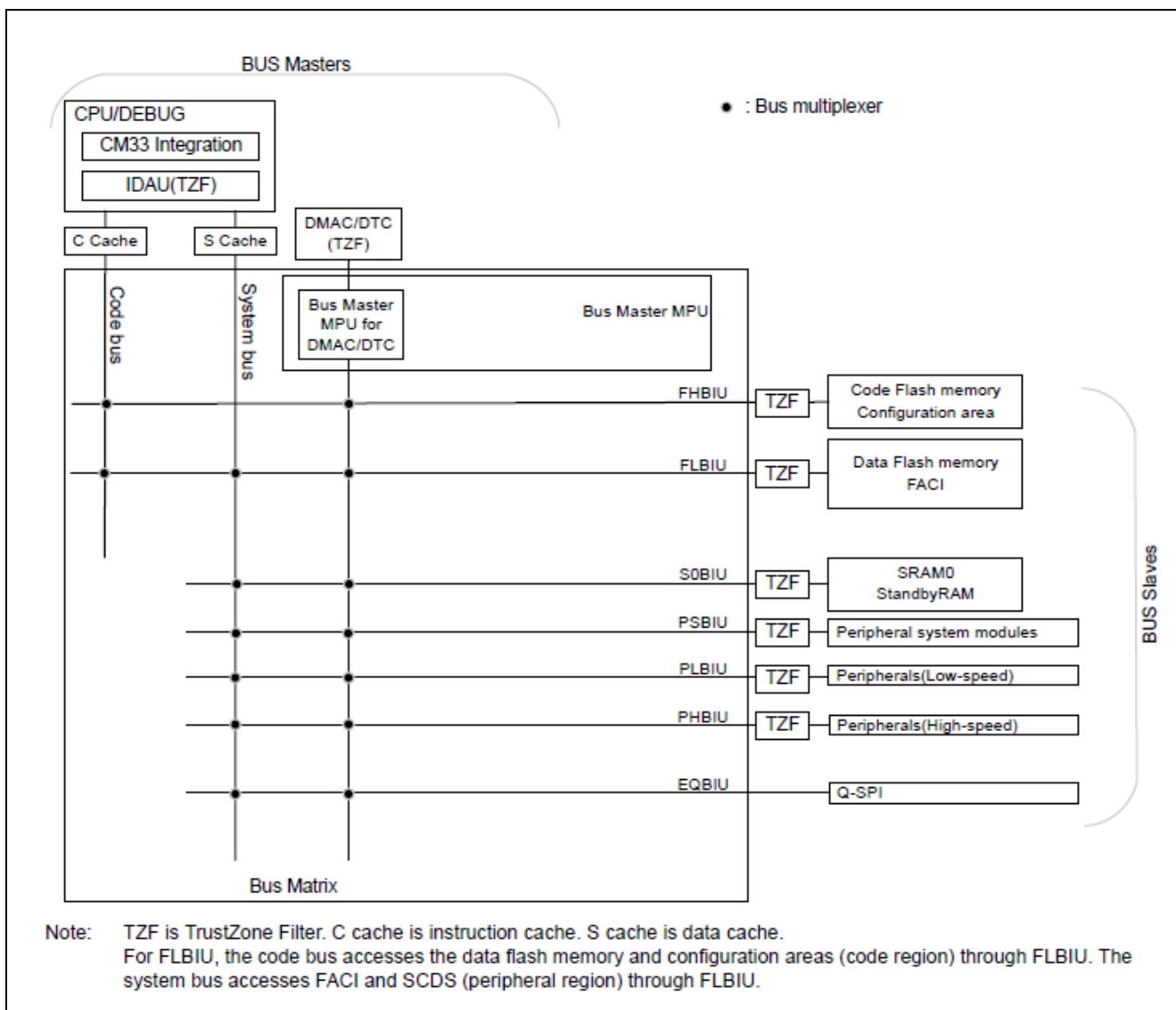


Figure 38. RA4M3 Bus Connection

14.1 Bus Error Monitoring

The bus error monitoring system monitors each individual area. When an error is detected, an error is returned to the requesting master IP using the AHB-Lite error response protocol.

14.1.1 Bus Error Types

The following types of errors can occur on each bus:

- Illegal address access.
- Bus master MPU error.
- TrustZone® Filter error (MCUs that support Trustzone only).
- Bus error transmitted from each slave IP.

14.1.2 Operations When a Bus Error Occurs

When a bus error occurs, operation is not guaranteed, and the error is returned to the requesting master IP. The bus errors that occur for each master are stored in the BUSnERRADD and BUSnERRSTAT registers. These registers must only be cleared by a reset. For more information, see section *Bus Error Address Register (BUSnERRADD)* and *Bus Error Status Register (BUSnERRSTAT)* in the Hardware User's Manual.

Note: The DMAC and DTC do not receive bus errors, so their operation is not affected by bus errors.

15. General Layout Practices

15.1 Digital Domain vs. Analog Domain

Renesas RA4 Microcontroller devices have three primary types of pin functions: Power, Digital, and Analog.

Generally, power pins are dedicated for voltage and reference input and do not have multiple functions. Power pins are typically dedicated to specific portions, or domains, within the MCU. For example, the main supply voltage for the MCU will provide power to the digital core, many of the digital peripheral functions and many of the digital I/O pins. The digital domain can be defined as the digital circuitry, digital I/O pins, and the related power pins. Power pins which are designated for analog functions (such as AVCC0 and the associated AVSS0) supply specific analog circuitry within the MCU, which is separate from the digital domain circuitry. The analog domain can be defined as the analog circuitry, analog I/O pins, and the related power pins.

Digital signals are typically repetitive, switched patterns that are associated with periodic clocks. The transitions on digital signals tend to be relatively sharp edges, with stable levels of high or low between the transitions. Each signal must be stable at an acceptable voltage level, referred to as a logic state, within a specified timeframe. The state of the signal is typically sampled at predetermined clock intervals, using the edge transition of a clock to evaluate the associated data signals. Small variations in the voltage level of digital signals are typically acceptable, as long as the level remains within a specified range. However, large external influences on digital signals can have an acute influence on a digital signal, which can result in an incorrect logic state at the moment when the data is sampled.

Analog signals are usually quite different. Analog signals may be periodic, but the evaluation of an analog signal is typically a measurement of voltage over a range instead of logic state. The voltage level of an analog signal is sampled based on a specific trigger event, and the resulting measurement is processed using the analog circuitry in the MCU. The accuracy of an analog measurement is directly related to the accuracy of the sampled voltage level. Any unwanted external influence which may change the voltage level of an analog input signal, even slightly, can influence the accuracy of the measurement.

Due to the highly multiplexed nature of the I/O pins on Renesas RA4 MCU devices, many I/O pins can be used for either Analog or Digital functions. This can result in situations where digital and analog functions may overlap and result in data errors.

To minimize potential problems between digital and analog signal domains, consider the following guidelines.

- When assigning I/O pin functions, select pin functions such that analog pins and digital pins are physically separated as much as possible.
- Each analog signal should be separated from all other signals as much as possible.
- PCB routing should isolate each analog signal as much as possible. Avoid routing any other signals, either analog or digital, in the same area.
- Ensure that analog supply voltages and analog reference voltages include appropriate AC filters. This may be in the form of recommended capacitors located near the MCU voltage pin, or appropriate inductive filters. The goal is to provide voltage supply and reference voltage with little or no voltage ripple.
- When using dedicated power layers in a PCB design, avoid routing digital signals in the areas of analog voltages, and avoid routing analog signals in the areas of digital voltages.

For highly sensitive applications, it is highly recommended to evaluate the specific design using simulation tools to understand the effect that circuit design has on the performance. For example, this may include applications such as precision sensor designs, or very high-speed digital bus interfaces. Refer to the *Electrical Characteristics* chapter in the Hardware User's Manual for the specific requirements for each peripheral function.

15.2 High Speed Signal Design Considerations

As clock speeds for digital signals increase, the influence of external stimuli on those signals can become more significant. Some peripheral functions can be classified as High Speed digital signals. Additional design considerations should be made for high-speed digital signals.

Crosstalk is a condition where transitions on one signal have an inductive influence on another nearby signal. When this crosstalk effect is strong enough, the first signal may cause errors on the second signal. To reduce the effects of crosstalk, use the following general PCB routing guidelines.

- Provide sufficient space between routed signals on the same routing layer. Generally, keep a minimum of one trace width space between signals of the same digital group, and a minimum of 3-5 trace widths space between signals of different digital groups.
- Provide extra space between clock signals and data signals on the same routing layer. Generally, keep a minimum of 3-5 trace widths space between clocks and any other digital signals.
- Avoid parallel routing of digital signals on any adjacent routing layers. If signals must be routed on adjacent signals layers, try to use only orthogonal crossings wherever possible.

If possible, separate PCB signal layers using power or ground layers between signal layers. The solid copper of the power or ground layer can act as a "shield" for the digital signals.

Each standardized interface will have specific requirements. To ensure that the PCB is designed to avoid signal crosstalk problems, it is strongly suggested to refer to the relevant standards for each interface in the design.

15.3 Signal Group Selections

Some pin names have an added `_A`, `_B`, or `_C` suffix to indicate signal groups. When assigning certain peripheral functions, such as IIC, SPI, SSIE, ETHERC, and SDHI, select the functional pins having the same suffix. In some cases, the AC timing characteristics shown in the *Electrical Characteristics* chapter of the Hardware User's Manual are measured for each signal group. If the signal groups are mixed, the peripheral is not guaranteed to function and the stated AC timing characteristics may not apply.

If the pin names for a peripheral function do not have a signal group suffix, it is safe to select the most convenient pin assignment for each function signal.

Refer to the sections *Peripheral Select Settings for each Product* and *Notes on the PmnPFS Register Setting* in the I/O Ports chapter of the Hardware User's Manual.

16. References

The following documents were used in creating this Quick Design Guide. Visit the [Renesas website](#) for the latest version of each of these documents.

Reference	Document Number	Description
1	R01UH0887	Renesas RA4M1 Group, User's Manual: Hardware
2	R01UH0892	Renesas RA4M2 Group, User's Manual: Hardware
3	R01UH0893	Renesas RA4M3 Group, User's Manual: Hardware
4	R20AN0577	RA Arm® TrustZone® Tooling Primer
5	R11AN0467	Security Design with Arm® TrustZone® - IP Protection
6	R11AN0468	Securing Data at Rest Using the Arm® TrustZone®
7	R11AN0475	Establishing and Protecting Device Identity using SCE9 and Arm® TrustZone®
8	R11AN0469	Device Lifecycle Management Key Installation

Website and Support

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

RA Product Information	www.renesas.com/ra
RA Product Support Forum	www.renesas.com/ra/forum
RA Flexible Software Package	www.renesas.com/FSP
Renesas Support	www.renesas.com/support

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jul.21.21	—	Initial release
1.01	Dec.10.21	21, 22	Clarifies conditions for watchdog timer and independent watchdog time reset.
		23	Registers RSTSR0 and RSTSR1 show the reset source.
		31	Units of programming and erasure are 4/8/16 bytes for data flash, not 2 bytes.
1.02	Mar.29.23	5-10, 12	Removed references to external pull up resistors on emulator signals
1.03	May.20.24	—	Added information related to RA4E1 and RA4E2.

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.

3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.).
9. 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.
10. 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.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
 2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
 3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
 5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
 6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
 - "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
 - "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
- Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
 8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
 9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
 10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
 12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
 13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/.