Renesas RA Family

Quick Start Guide: Modbus TCP

Introduction

This document is a quick start guide for evaluating Modbus® communication with the RA microcomputer evaluation board.
Modbus protocol is a communication protocol developed by Modicon Inc. (Schneider Electric SA.) for programmable logic controllers (PLCs), and its specifications are open to the public.
For details, refer to the protocol specifications (PI-MBUS-300 Rev.J).

Target Device

RA6M3, RA6M4, RA6M5
RA8D1, RA8M1, RA8T1
RA8T2, RA8D2, RA8P1, RA8M2

Supported Evaluation Boards

EK-RA6M3, EK-RA6M4, EK-RA6M5
EK-RA8D1, EK-RA8M1, MCK-RA8T1
MCK-RA8T2, EK-RA8D2, EK-RA8P1, EK-RA8M2, EK-RA8T2

Contents

1. Overview

This document describes the Modbus protocol stack that operates on the RA evaluation board. It provides an overview of its functions and a Modbus sample application for developing and implementing applications using the protocol stack.

This sample program package supports the Ethernet-based Modbus TCP protocol.

This Quick Start Guide provides:

- Sample program package configuration
- Operating environment requirements
- Evaluation board connection setup
- Procedure for creating, modifying, and building the Modbus sample project using the Flexible Software Package (FSP) and e^2 studio Integrated Development Environment (IDE).
- Instructions for connecting with a client and operating a simple demo.

1.1 Abbreviations/Definitions

Table 1.1 Abbreviations/Definitions

Index	Abbreviations /Definitions	Description
1	IP	Internet Protocol
2	TCP	Transmission Control Protocol
3	USB	Universal Serial Bus
4	PC	Personal Computer
5	SW	Switch
6	EWARM	Embedded Workbench® for Arm
7	LED	Light Emitting Diode
8	Wireshark	Free packet capture tool to check packets flowing on LAN

1.2 Reference

Technical information about Modbus is available through the Modbus organization site, and information about the RA evaluation board is available through Renesas.

Table 1.2 Technical Inputs (1/2)

Index	Technical Inputs
1	Modbus Application Protocol Specification Vxxx
2	Evaluation Kit for RA6M3 Microcontroller Group EK-RA6M3 Quick Start Guide / r20qs0011euxxxx
3	Evaluation Kit for RA6M3 Microcontroller Group EK-RA6M3 v1 User's Manual / r20ut4623euxxxx
4	Evaluation Kit for RA6M4 Microcontroller Group EK-RA6M4 Quick Start Guide / r20qs0016egxxxx
5	Evaluation Kit for RA6M4 Microcontroller Group EK-RA6M4 v1 User's Manual / r20ut4836egxxxx
6	Evaluation Kit for RA6M5 Microcontroller Group EK-RA6M5 Quick Start Guide / r20qs0021egxxxx
7	Evaluation Kit for RA6M5 Microcontroller Group EK-RA6M5 v1 User's Manual / r20ut4829egxxxx
8	Evaluation Kit for RA8D1 Microcontroller Group EK-RA8D1 Quick Start Guide / r20qs0065egxxxx
9	Evaluation Kit for RA8D1 Microcontroller Group EK-RA8D1 v1 User's Manual / r20ut5205egxxxx
10	Evaluation Kit for RA8M1 Microcontroller Group EK-RA8M1 Quick Start Guide / r20qs0035egxxxx
11	Evaluation Kit for RA8M1 Microcontroller Group EK-RA8M1 v1 User's Manual / r20ut5149egxxxx
12	MCK-RA8T1 Quick Start Guide / r12qs0067ejxxxx
13	MCK-RA8T1 User's Manual / r12uz0133ejxxxx
14	MCK-RA8T2 Quick Start Guide / r12qs0088ejxxxx
15	MCK-RA8T2 User's Manual / r12uz0172ejxxxx
16	Evaluation Kit for RA8D2 Microcontroller Group EK-RA8D2 Quick Start Guide / r20qs0077egxxxx
17	Evaluation Kit for RA8D2 Microcontroller Group EK-RA8D2 v1 User's Manual / r20ut5523egxxxx
18	Evaluation Kit for RA8P1 Microcontroller Group EK-RA8P1 Quick Start Guide / r20qs0051egxxxx
19	Evaluation Kit for RA8P1 Microcontroller Group EK-RA8P1 v1 User's Manual / r20ut5309egxxxx
20	Evaluation Kit for RA8M2 Microcontroller Group EK-RA8M2 Quick Start Guide / r20qs0069egxxxx
21	Evaluation Kit for RA8M2 Microcontroller Group EK-RA8M2 v1 User's Manual / r20ut5451egxxxx

Table 1.3 Technical Inputs (2/2)

Index	Technical Inputs
22	Evaluation Kit for RA8T2 Microcontroller Group EK-RA8T2 v1 Quick Start Guide / r20qs0097egxxxx
23	Evaluation Kit for RA8T2 Microcontroller Group EK-RA8T2 v1 User's Manual / r20ut5714egxxxx

2. Features

The Modbus protocol stack for the RA evaluation board allows for quick and easy development of Modbus TCP applications.

Modbus function codes supported by the initialization API are also specified. The following nine function codes can be implemented in this stack:

- 1(0x01) – Read coils
- 2(0x02) – Read discrete input
- 3(0x03) – Read holding registers
- 4(0x04) – Read input registers
- 5(0x05) – Write single coil
- 6(0x06) – Write single register
- 15(0x0F) – Write multiple coils
- 16(0x10) – Write multiple registers
- 23(0x17) – Read/Write multiple registers

For more information about Modbus, refer to the following site:
http://www.modbus.org

Note: The version number may differ depending on the update. Refer to the latest manual.

3. Sample Program Package Configuration

This sample program package consists of three components:

- Modbus sample project using Modbus protocol stack.
- Modbus sample application using Modbus protocol stack.
- Modbus sample demo application

3.1 Modbus Sample Project

- Modbus_TCP / project / EK-RA6M5
  - This folder contains a folder called “RA_Modbus” which includes a Modbus sample project for EK-RA6M5 boards that uses the Modbus protocol stack.
  - The sample project is created for GCC compilers. If you want to use another compiler, refer to section "**6.2 Creation of new Modbus Project**" and create another project.
  - The sample project is created for EK-RA6M5. If you want to run it on EK-RA6M3, EK-RA6M4, EK-RA8D1, EK-RA8M1, MCK-RA8T1, refer to step (4) of "**6.1 Import Modbus Sample Project**" and modify the project with respect to different boards.
- Modbus_TCP / project / MCK-RA8T2
- Modbus_TCP / project / EK-RA8D2
- Modbus_TCP / project / EK-RA8P1
- Modbus_TCP / project / EK-RA8M2
- Modbus_TCP / project / EK-RA8T2
  - These folders contain a folder called “RA_Modbus” which includes a Modbus sample project for MCK-RA8T2 / EK-RA8D2 / EK-RA8P1 / EK-RA8M2 / EK-RA8T2 boards that uses the Modbus protocol stack.
  - The sample projects are created for GCC compilers. If you want to use another compiler, refer to section "**6.2 Creation of new Modbus Project**" and create another project.

3.2 Modbus Sample Application

- Modbus_TCP / src / modbus_func.c, modbus_user.c, new_thread0_entry.c
  - User can register their own implementations of Modbus function codes in the Modbus protocol stack.
  - The code in this directory provides examples of the Modbus protocol stack initialization process and the Modbus function codes processing using the Modbus protocol stack API.

3.3 Modbus Demo Application

- Modbus_tool / ModbusDemoApplication.exe
  - This executable file is a Modbus demo application used for Modbus communication. It can be used to demonstrate the operation of the Modbus sample application.

4. Operating Environment Requirements

The sample program package described in this manual runs in the following environment.

Table 4.1 Operating environment

Item	Description
Board	RA evaluation board
Integrated development environment	IAR Systems - IAR Embedded Workbench® for Arm Version 9.70.2 or later Renesas Electronics - e² Studio 2025-12 or later - Renesas RA Smart Configurator 2025-12 or later
Toolchain	IAR Embedded Workbench for Arm - IAR C/C++ Compiler for Arm 9.70.2 or later e² Studio - GCC Arm Embedded (13.2.1.arm-13-7) or later - LLVM for Arm (21.1.1) or later - Arm Compiler 6.24 or later
MCU software package	FSP (Flexible Software Package) v6.4.0 or later
Emulator	J-LINK® OB
Communications protocol	Modbus TCP
Client tool	ModbusDemoApplication.exe: Modbus Demo Application

5. Evaluation Board Connection Setup

Connect the PC to a supported evaluation board. Power is supplied by connecting a USB micro-B cable to the board. For Modbus TCP communication, use an RJ45 connector and connect to the PC with a LAN cable.

The connection setting diagrams for the EK RA8M1 evaluation board, the MCK-RA8T1 board, the MCK-RA8T2, the EK-RA8T2 board and Switch SW4 setting table are shown below.

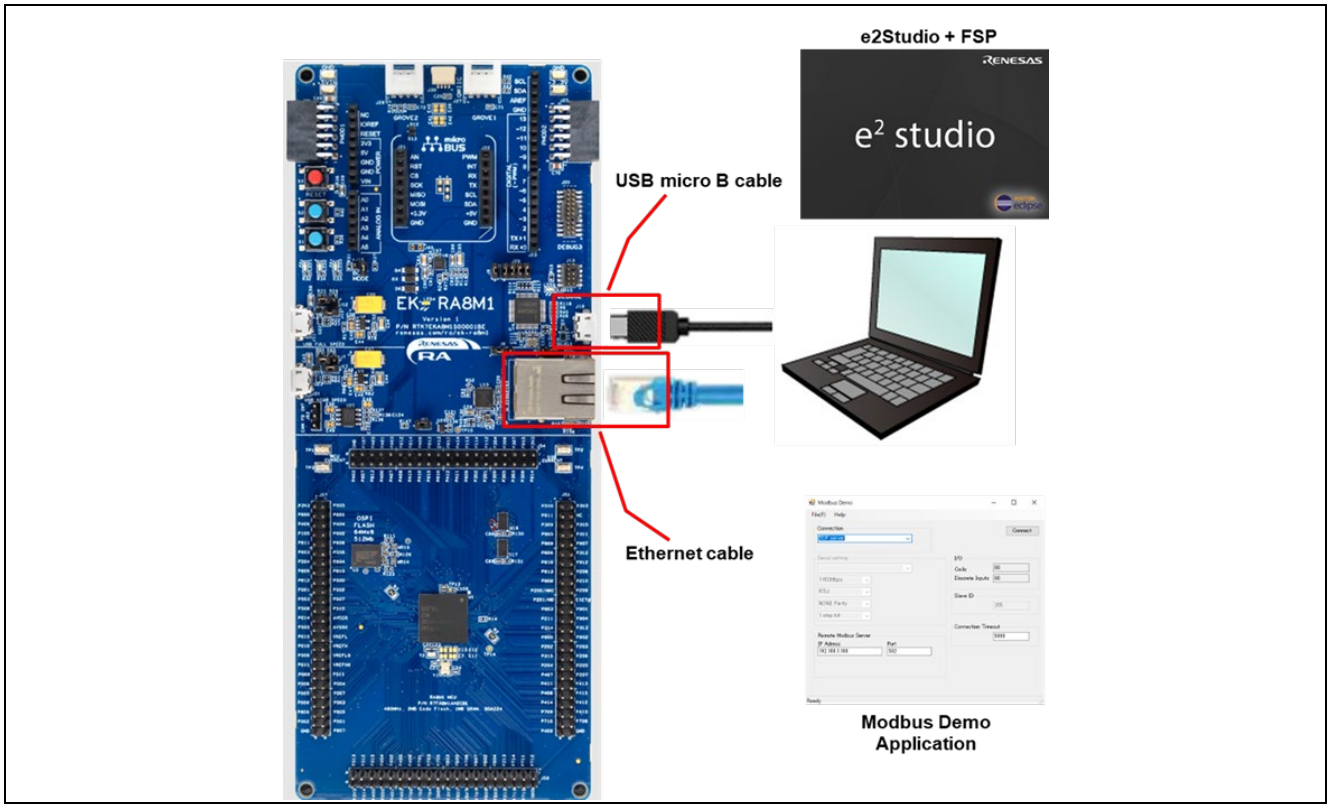


Figure 5.1: EK evaluation board connection setup for RA (Example: EK-RA8M1)

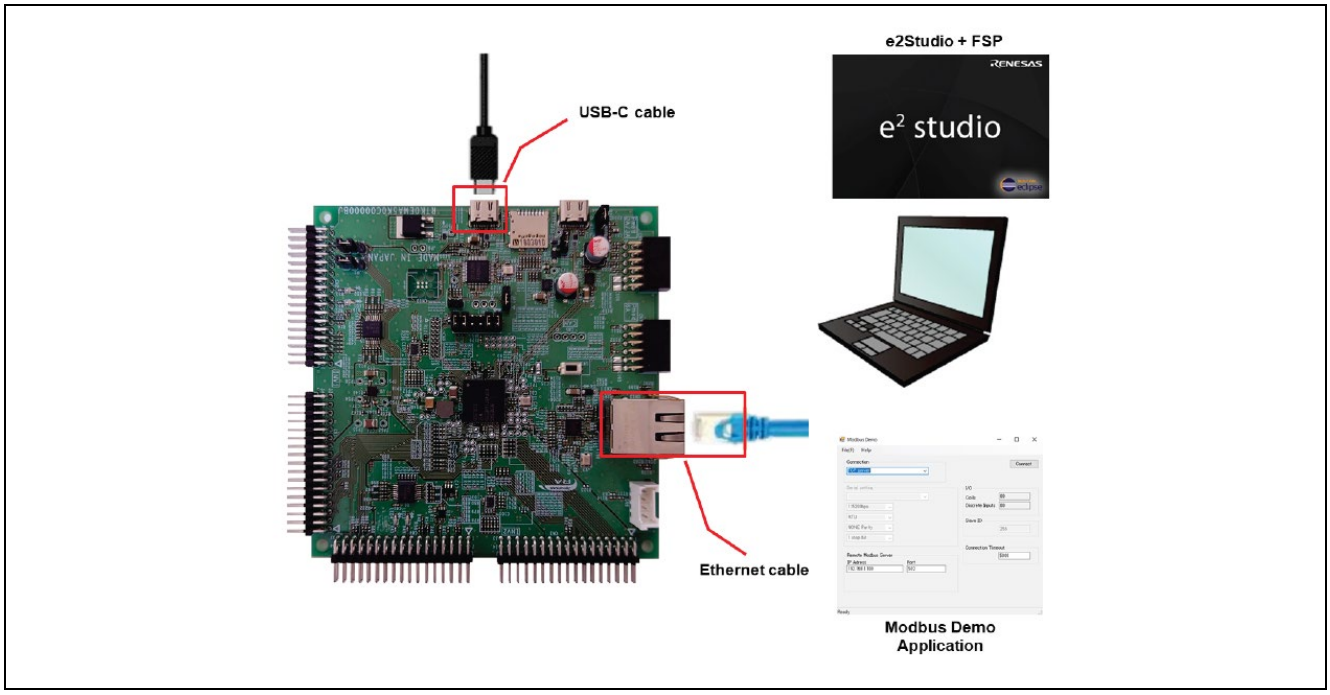


Figure 5.2: MCK-RA8T1 board connection setup

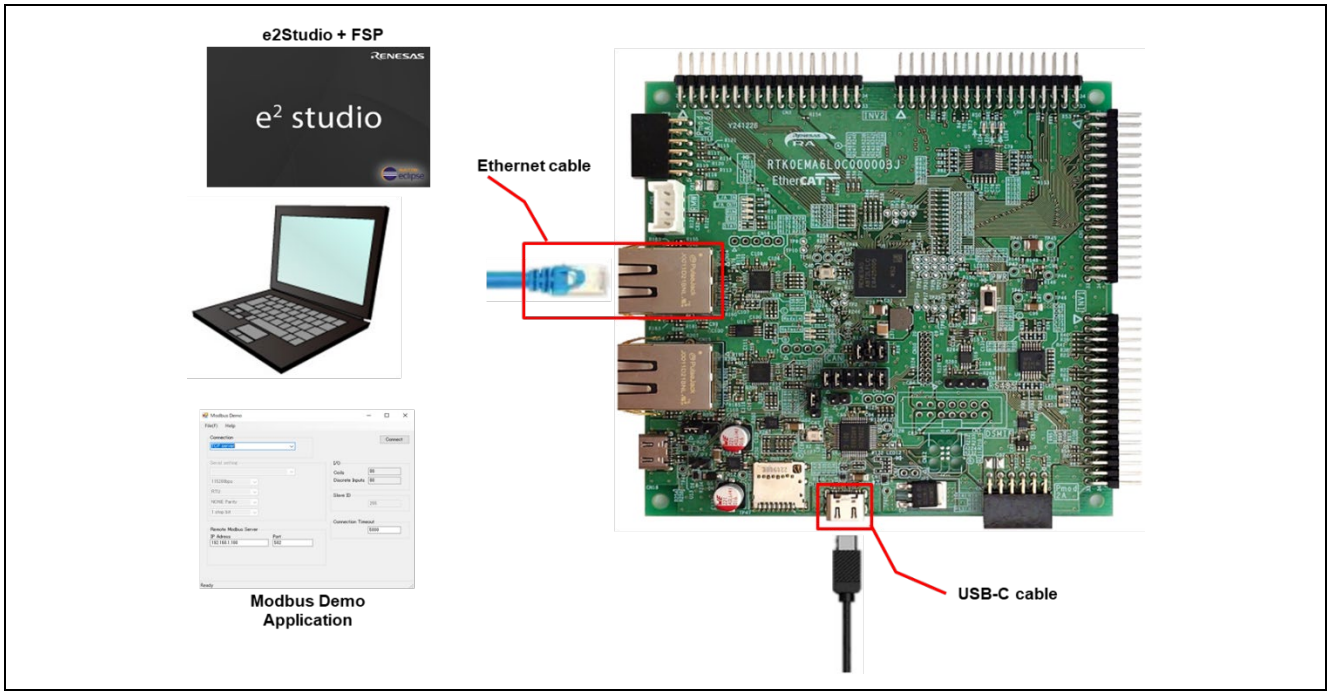


Figure 5.3: MCK-RA8T2 board connection setup

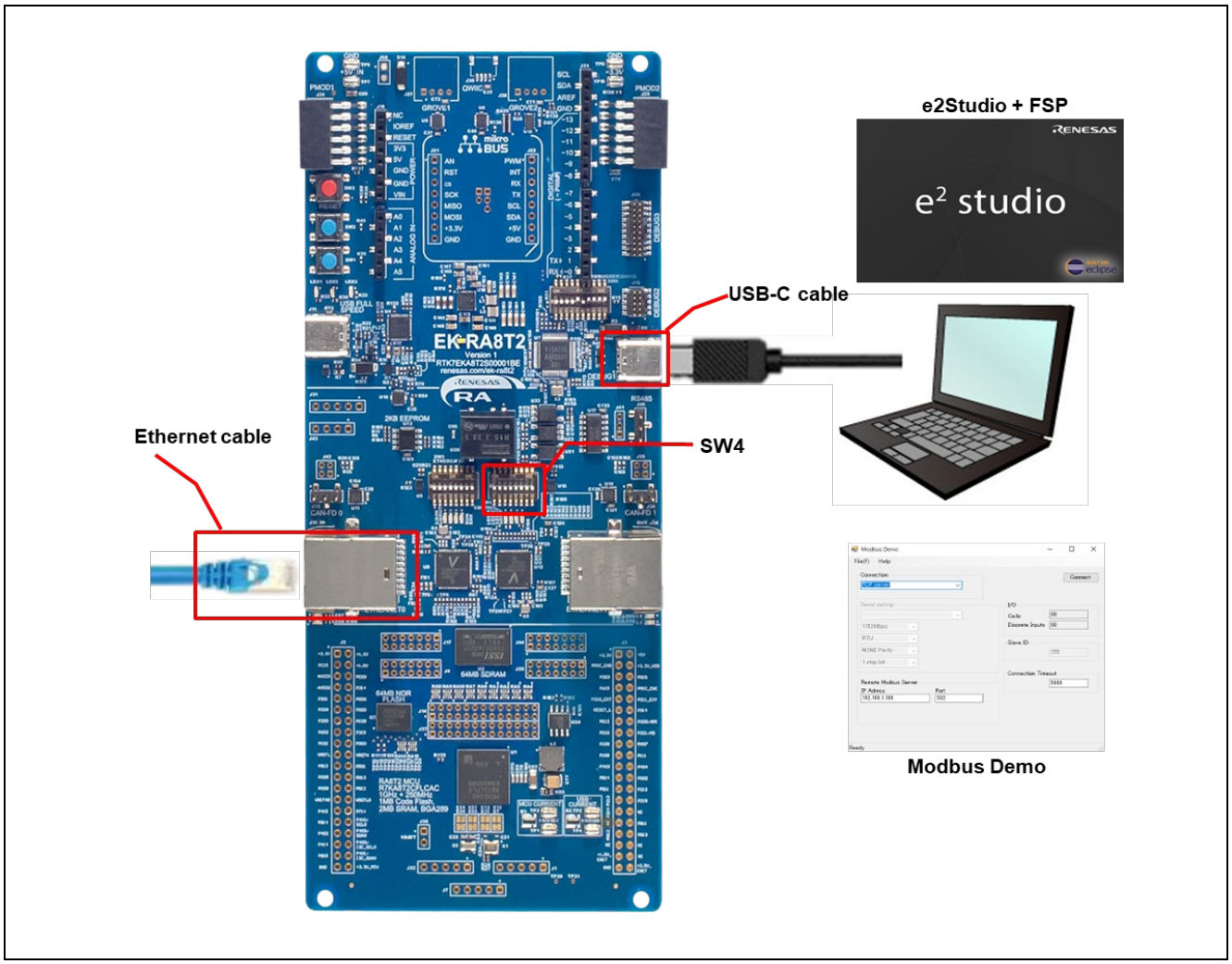


Figure 5.4: EK-RA8T2 board connection setup

Table 5.1 Switch SW4 setting

SW4	Setting	Description
SW4-6	OFF	**Ethernet PHY COMA_MODE pin set low**

6. Setting Up the Modbus Sample Project

This section describes the procedure for importing/creating a Modbus sample project. Before this, read section "**4. Operating Environment Requirements**" first and complete the installation of the tools.

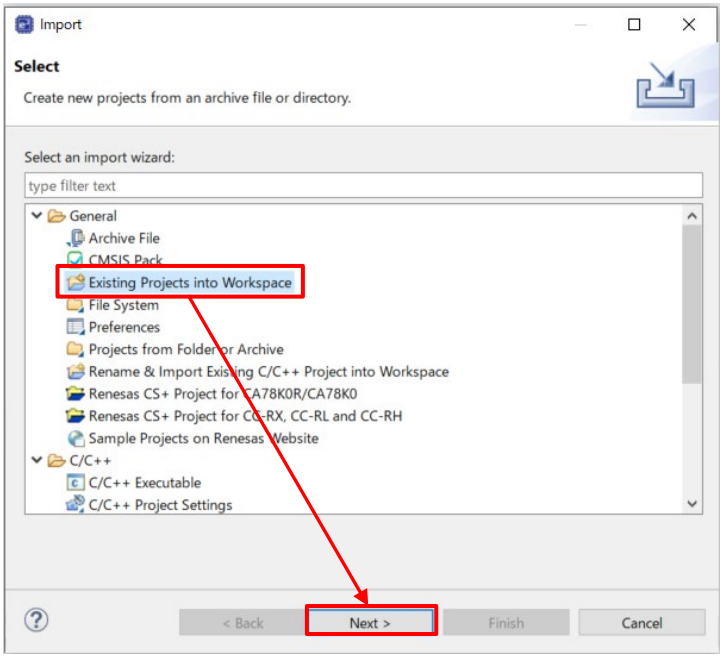
6.1 Import Modbus Sample Project

This section describes the procedure for importing the Modbus sample project and changing the evaluation board.

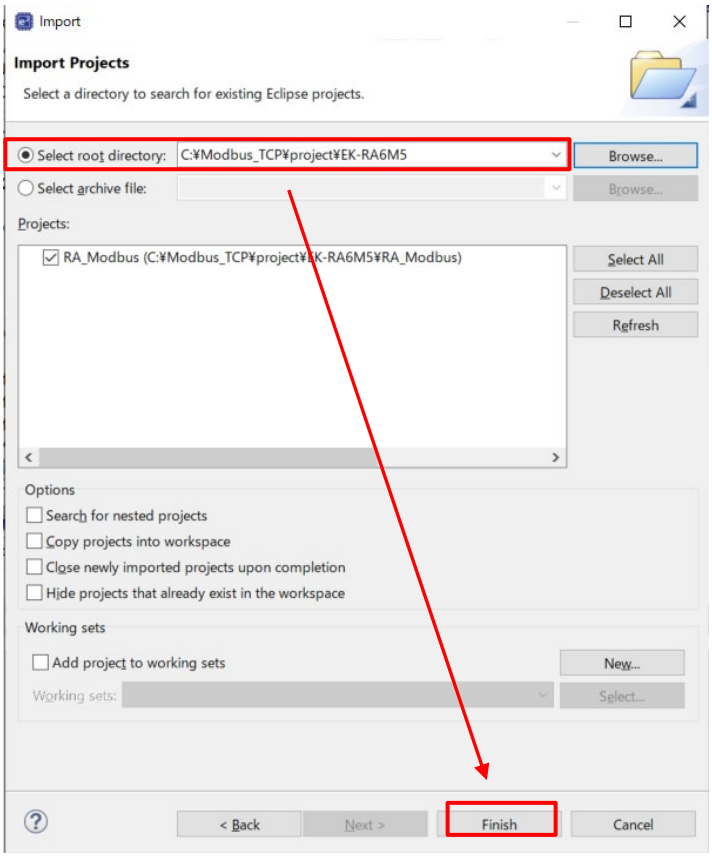
6.1.1 EK-RA6Mx / EK-RA8x1 / MCK-RA8T1 Importing Procedures

This section describes the procedures for importing EK-RA6Mx (EK-RA6M3, EK-RA6M4, EK-RA6M5) / EK-RA8x1 (EK-RA8D1, EK-RA8M1) / MCK-RA8T1.

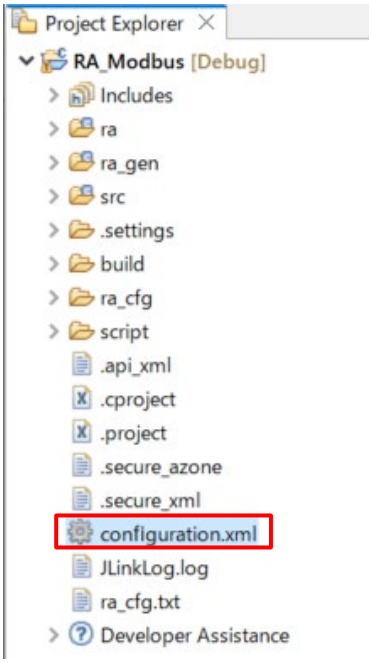
1. Import the sample project. Start e^2 studio, select [File] → [Import], and when the Import window appears, select [General] → [Existing Projects into Workspace].



Check "Select root directory" and select the Modbus sample project folder (“Modbus_TCP/project/[evaluation board]”).

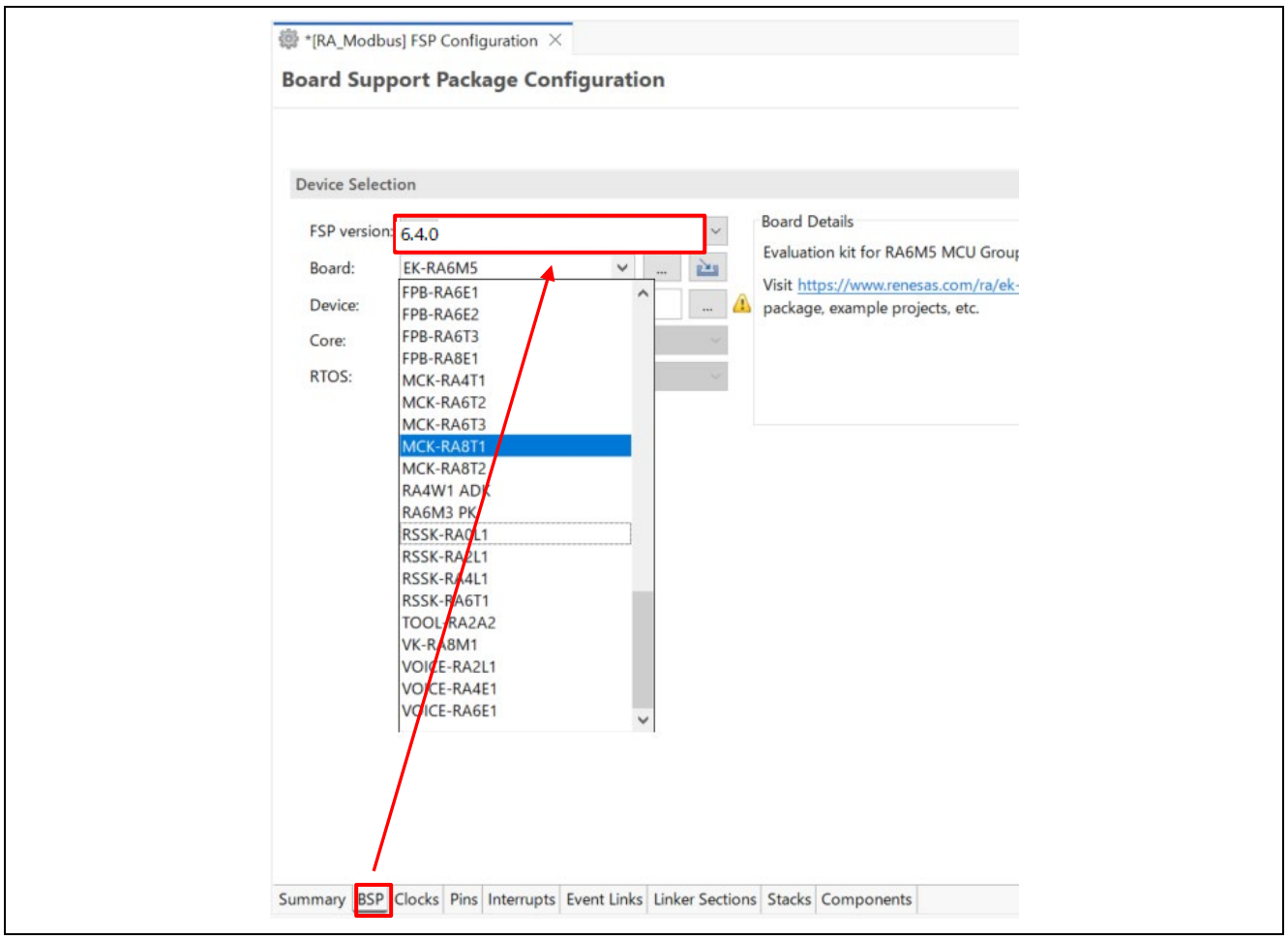


2. Open “configuration.xml” of the “RA_Modbus” project.

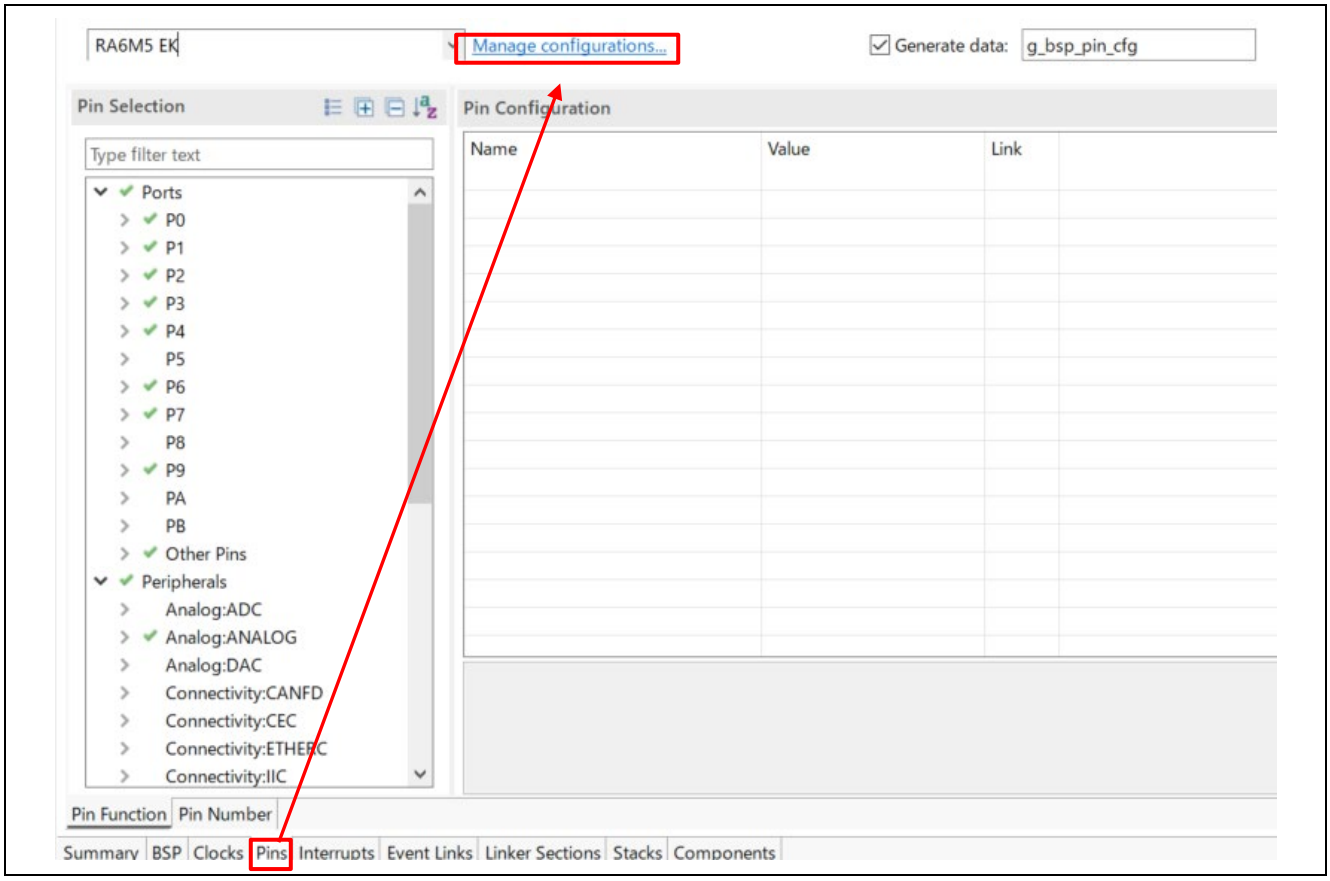


3. The "RA_Modbus" project under the "Modbus_TCP/project/EK-RA6M5" folder is created for EK-RA6M5. To run it on another supported evaluation board, modify the project by following the steps (1) to (4) below.

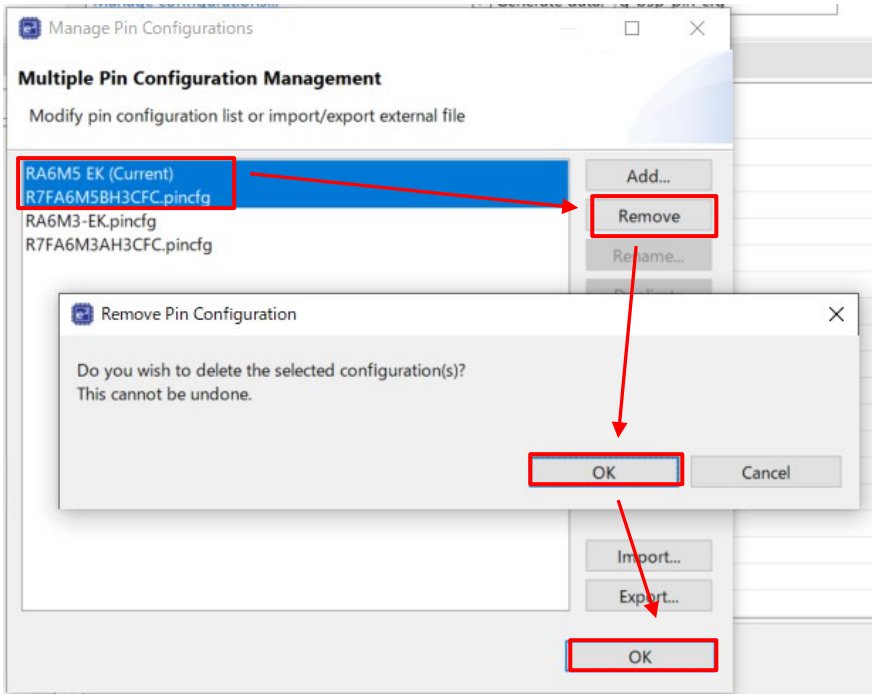
   (1) Click the "BSP" tab, then select "EK-RA6M3", "EK-RA6M4", "EK-RA8D1", "EK-RA8M1", or "MCK-RA8T1" from "Board".



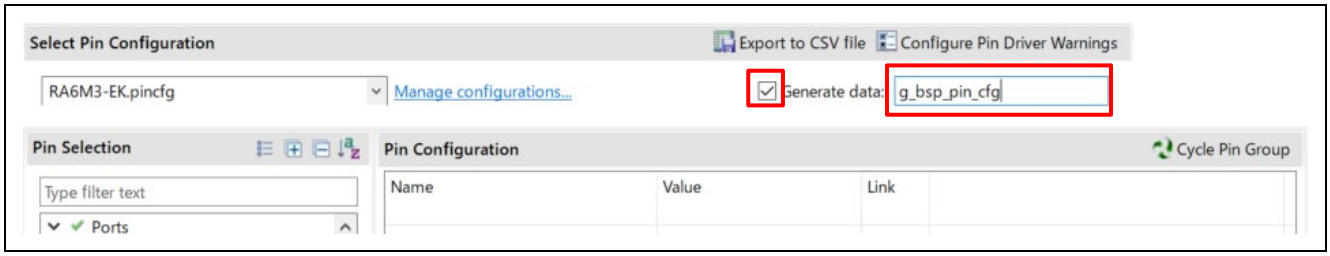
(2) Click "Manage configurations" on the "Pins" tab



(3) Select "RA6M5 EK (Current)" and "R7FA6M5BH3CFC.pincfg" and click "Remove". Click "OK" in the "Remove Pin Configuration" pop-up, then click "OK" in "Manage Pin Configurations".

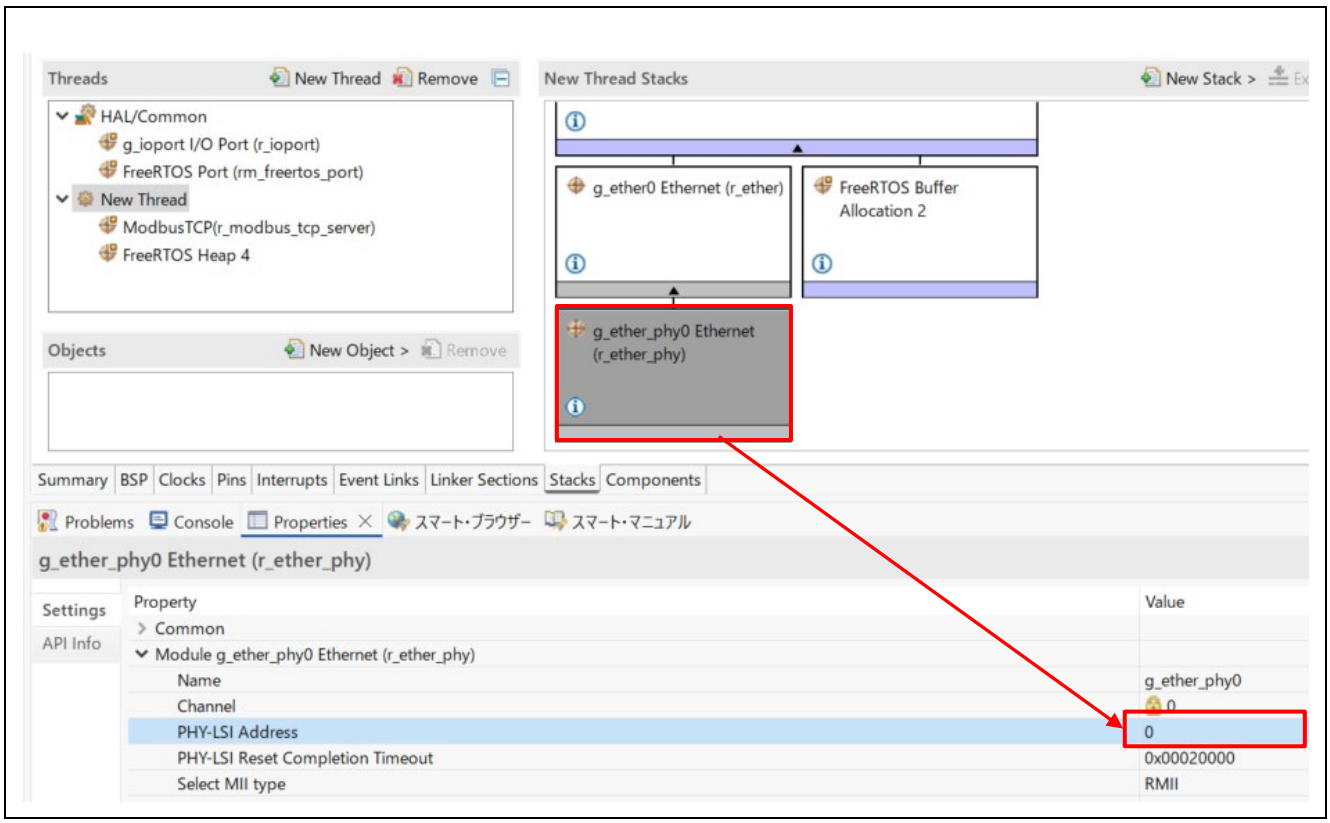


(4) Check the “Generate data” checkbox and enter “g_bsp_pin_cfg” in the text box.



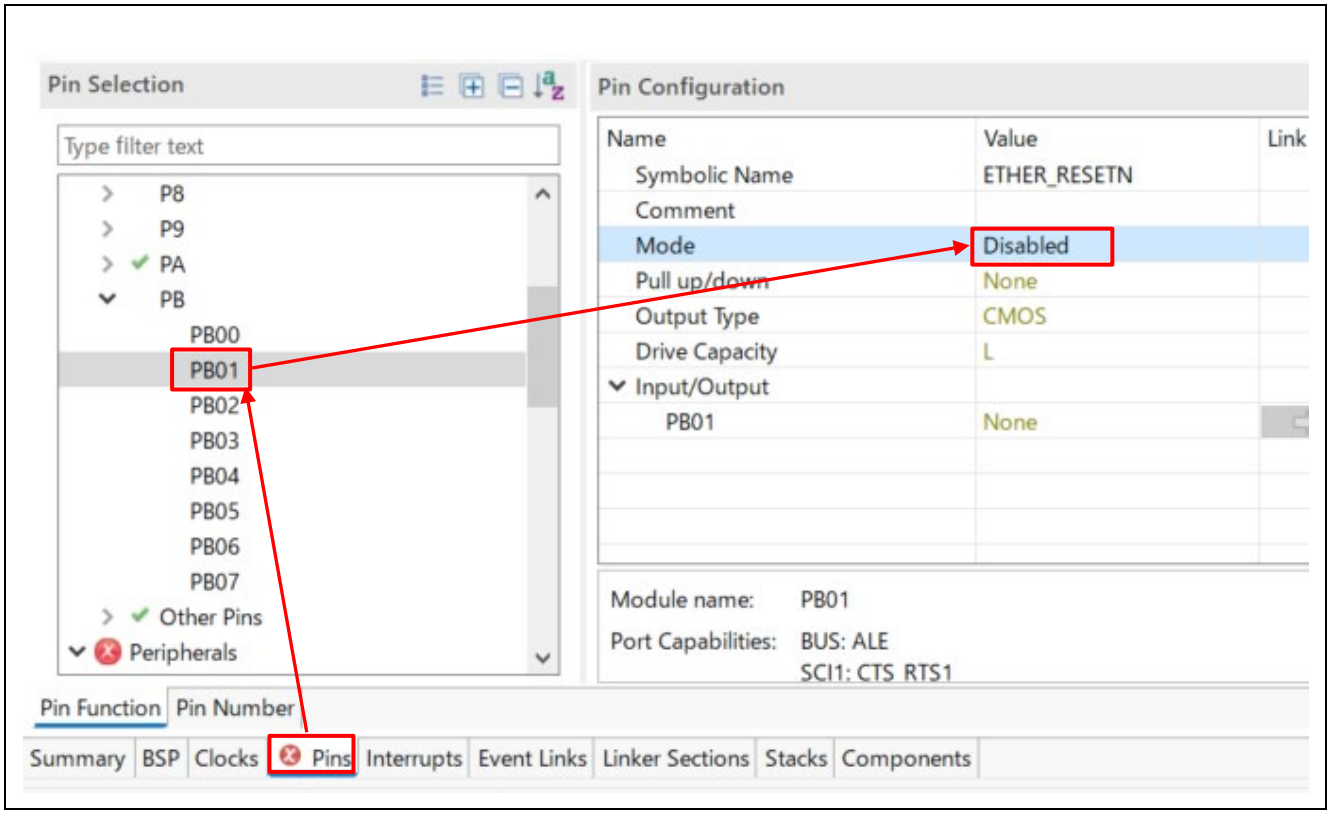
4. For "EK-RA8D1", "EK-RA8M1" and "MCK-RA8T1", change "PHY-LSI Address" in "Stacks" → "g_ether _phy0 Ethernet (r_ether_phy)" → "Module g_ether_phy0 Ethernet (r_ether_phy)" to the following value.

   PHY-LSI Address: **5**



5. For "EK-RA8D1" and "MCK-RA8T1", Click the "Pins" tab, then select Reset pin [Reset Pin for each evaluation board] (see below), Go to “Pin Configuration” and change the "Mode" to "Disabled".

EK-RA8D1: **P706,** MCK-RA8T1: **PB01**

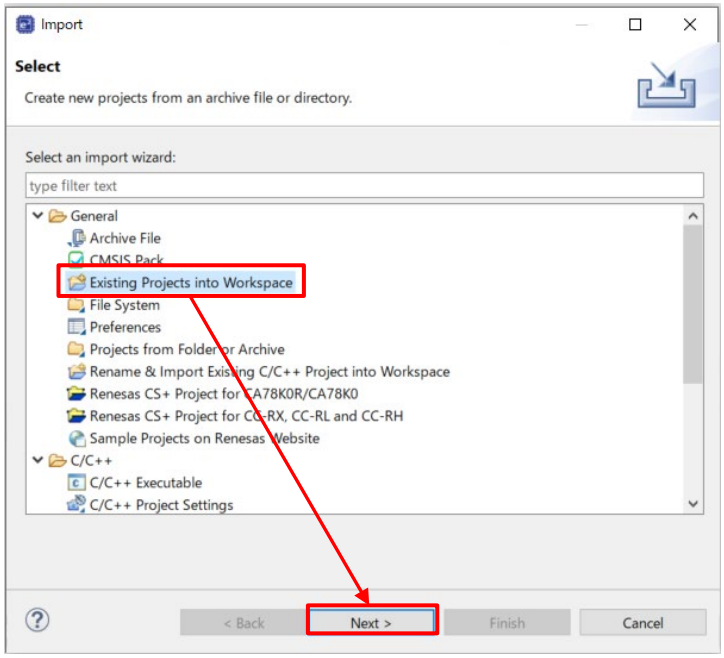


6. Execute the Modbus Sample Project.
Refer to "**7. Execution of Modbus Sample Project**" and follow the steps.

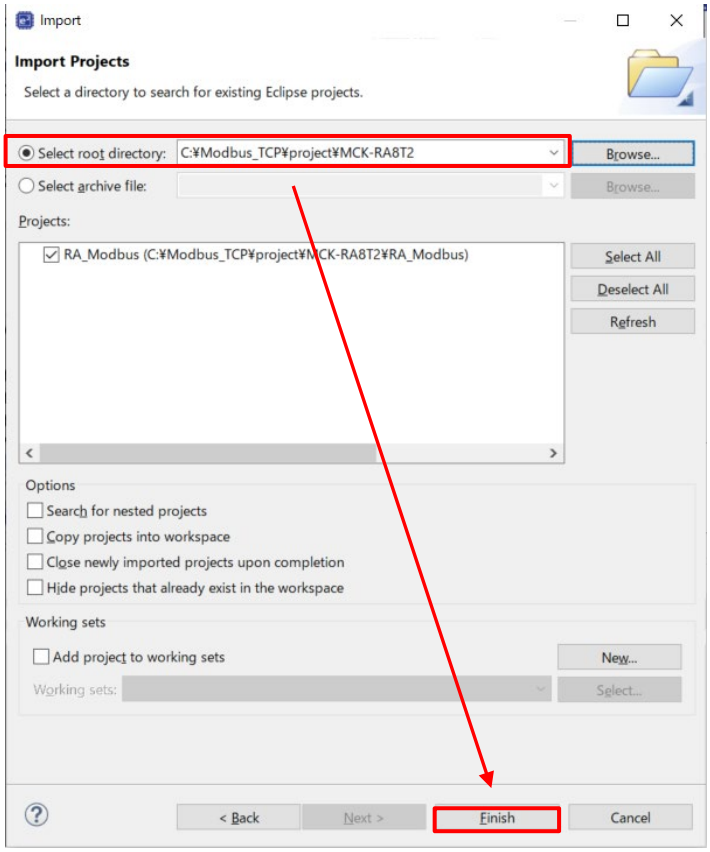
6.1.2 MCK-RA8T2 / EK-RA8D2 / EK-RA8P1 / EK-RA8M2 / EK-RA8T2 Importing Procedures

This section describes the procedures for importing MCK-RA8T2 / EK-RA8D2 / EK-RA8P1 / EK-RA8M2 / EK-RA8T2.

1. Import the sample project. Start e^2 studio, select [File] → [Import], and when the Import window appears, select [General] → [Existing Projects into Workspace].



Check "Select root directory" and select the Modbus sample project folder (“Modbus_TCP/project/[evaluation board]”).



2. Execute the Modbus Sample Project.
   Refer to "**7. Execution of Modbus Sample Project**" and follow the steps.

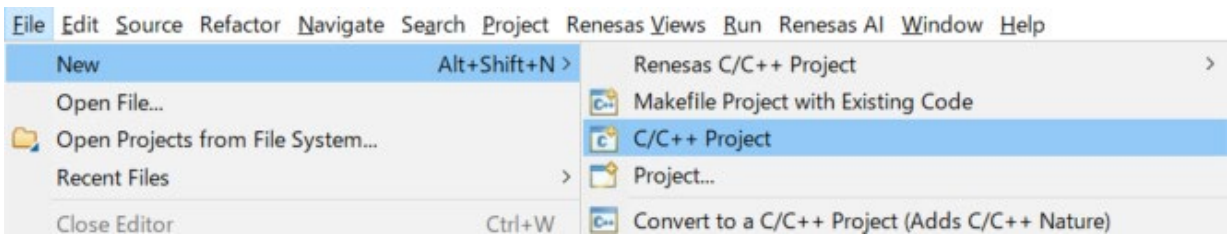
6.2 Creation of New Modbus Project

This section describes the procedure for creating a new Modbus sample project.

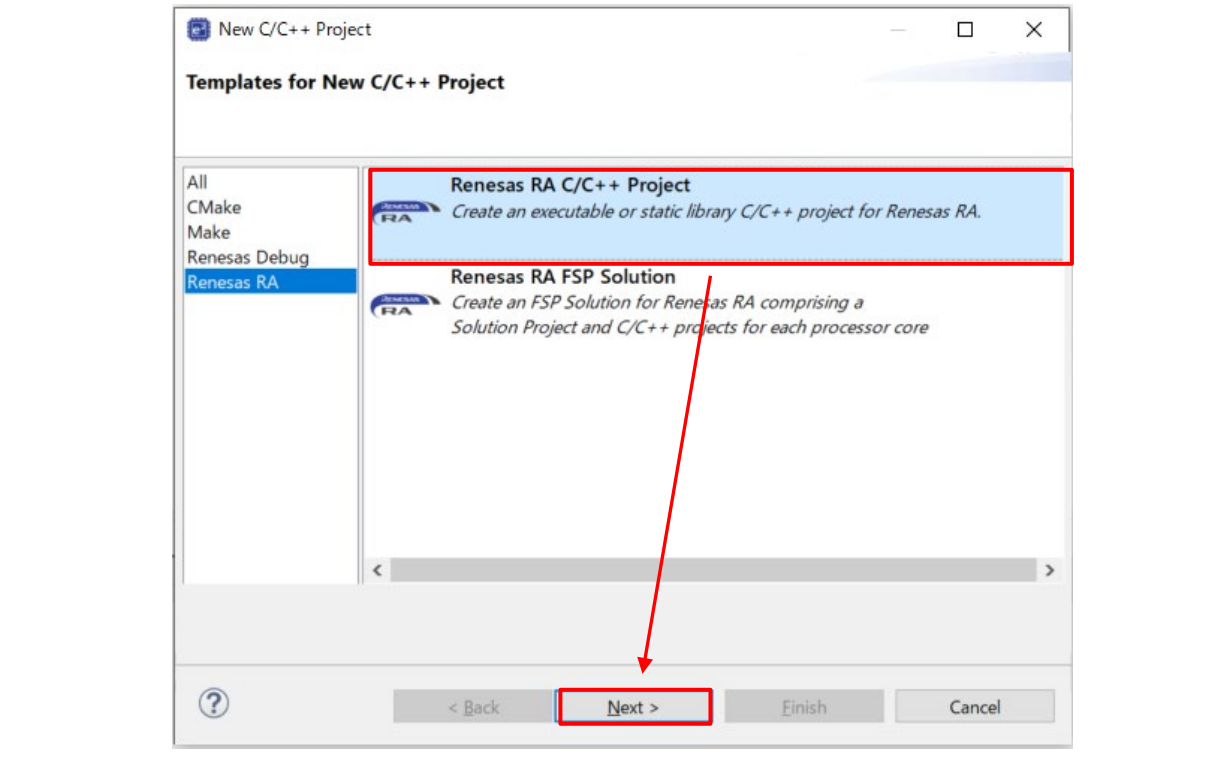
6.2.1 Common Procedures for all Evaluation Boards

This section describes the procedures common to all evaluation boards.

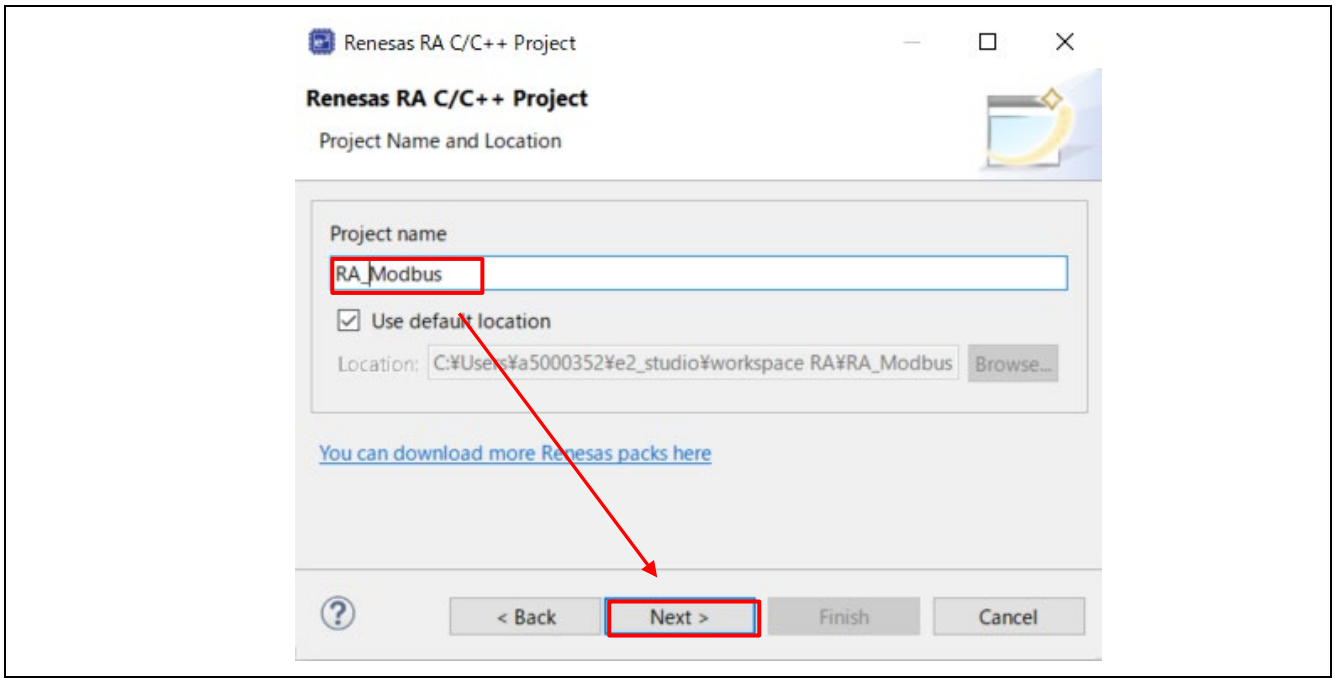
1. Set up a new project. Start e² studio and select [File] → [New] → [C/C++ Project].



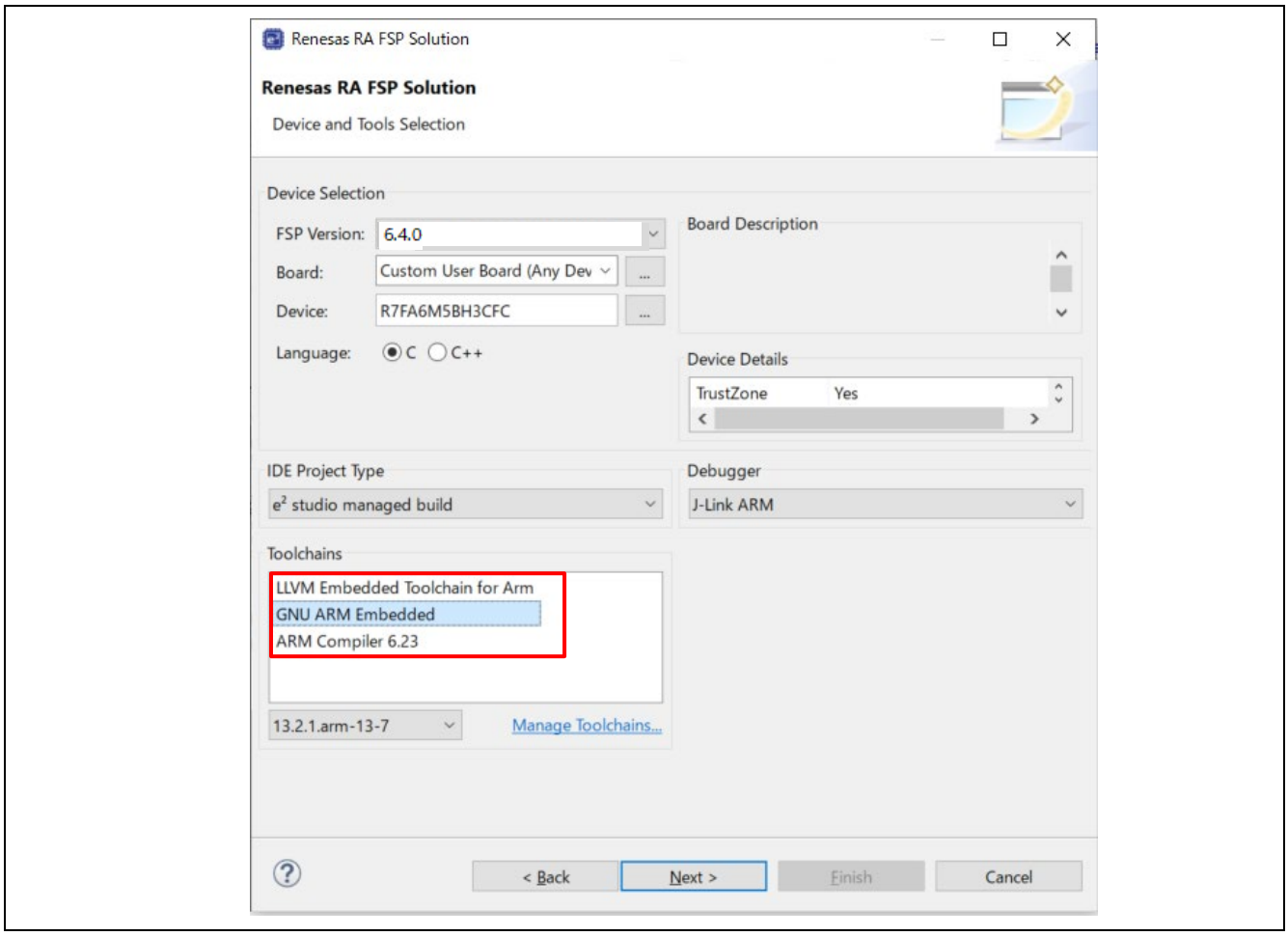
2. Select ”Renesas RA C/C++ Project”



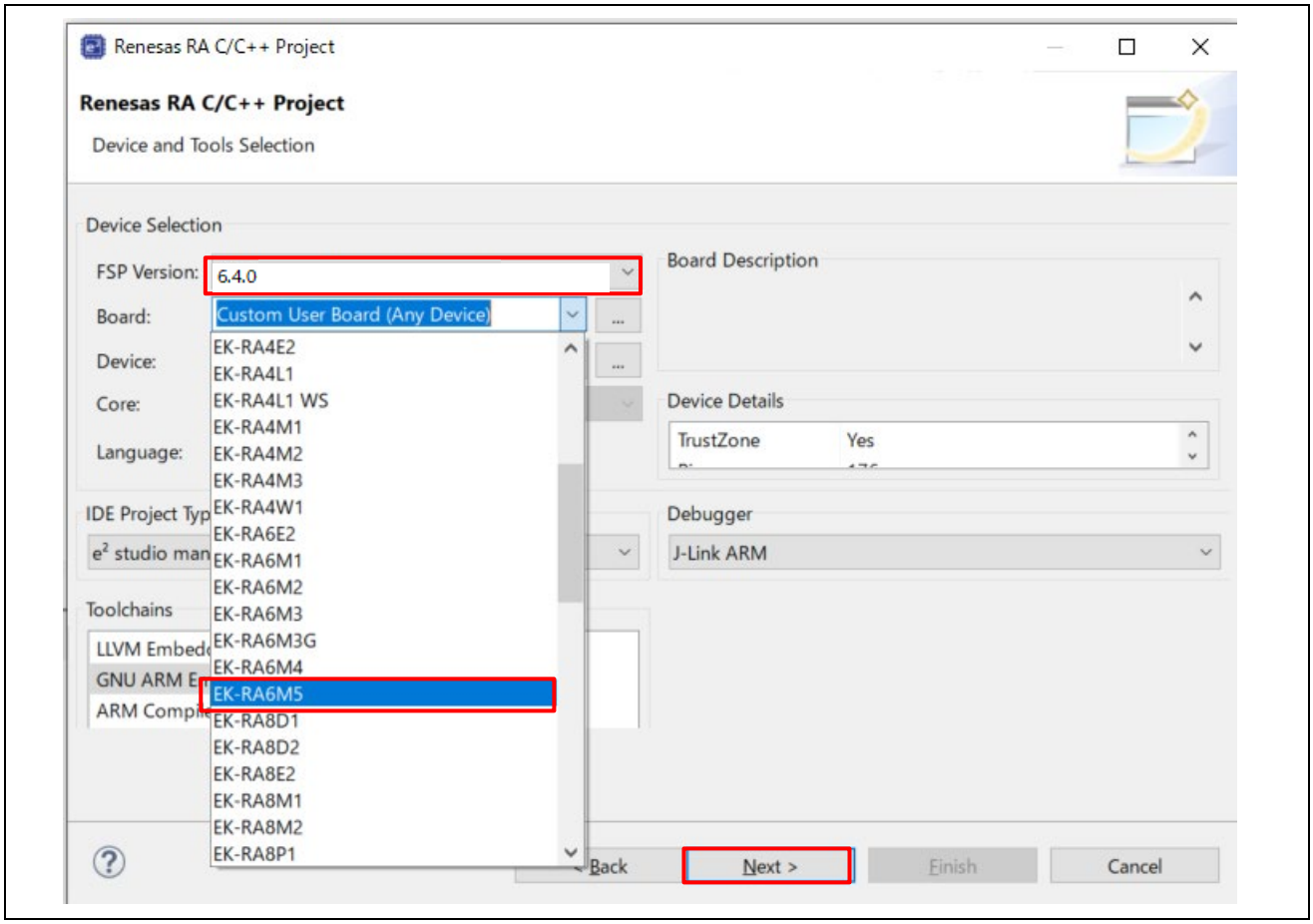
3. Enter any project name.



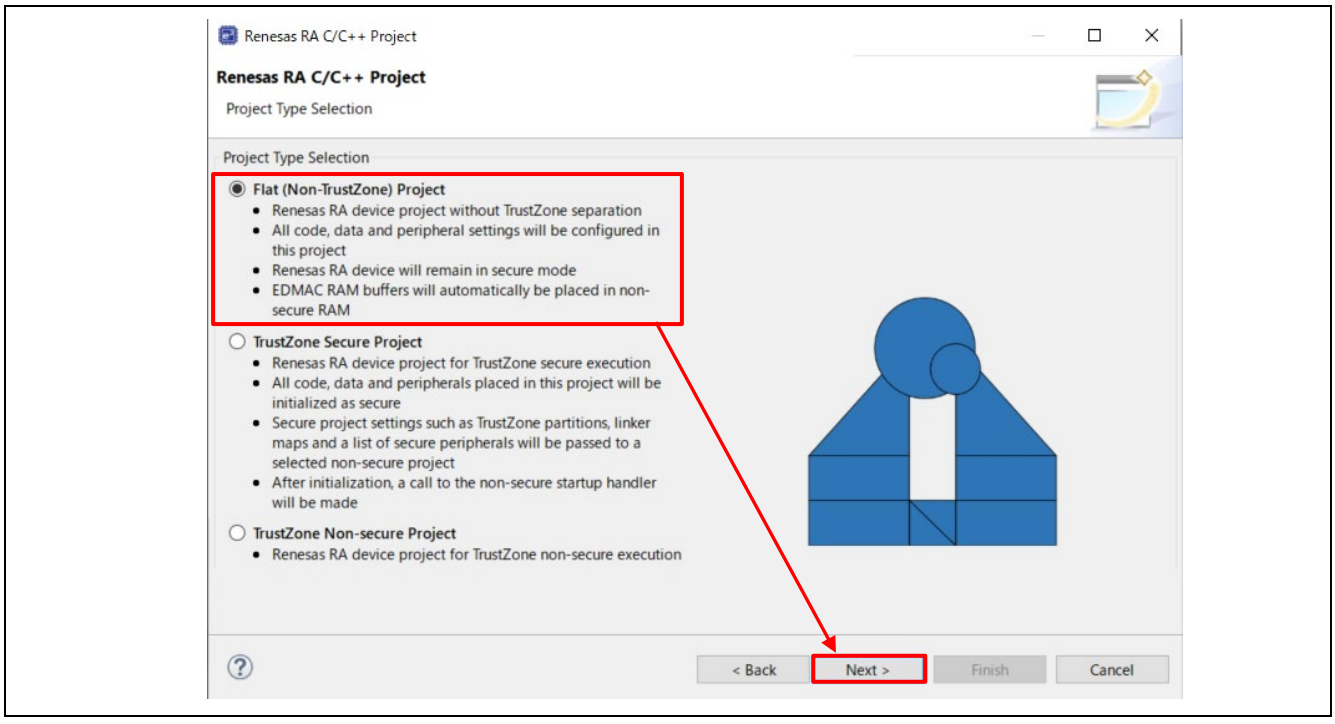
4. Select "Toolchains”



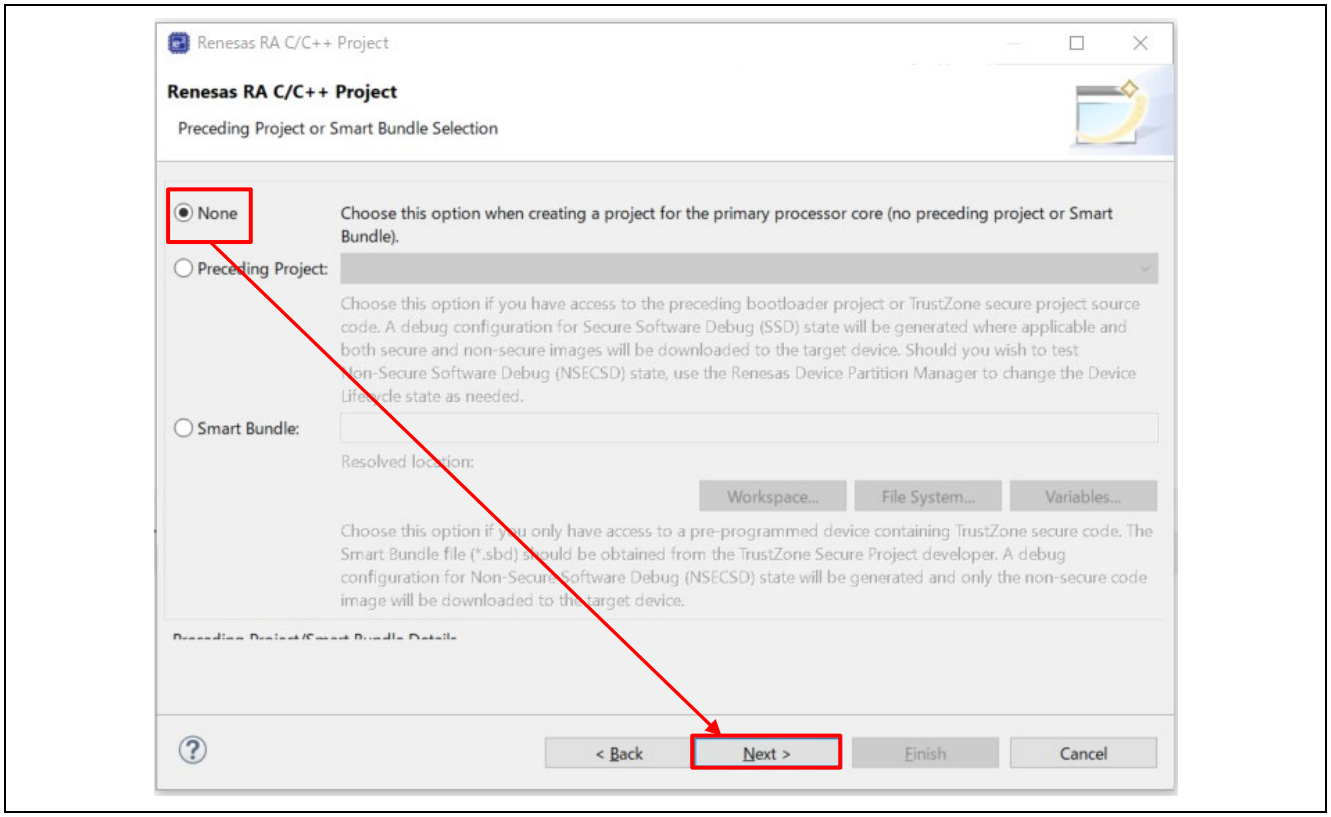
5. Select the FSP Version and Board



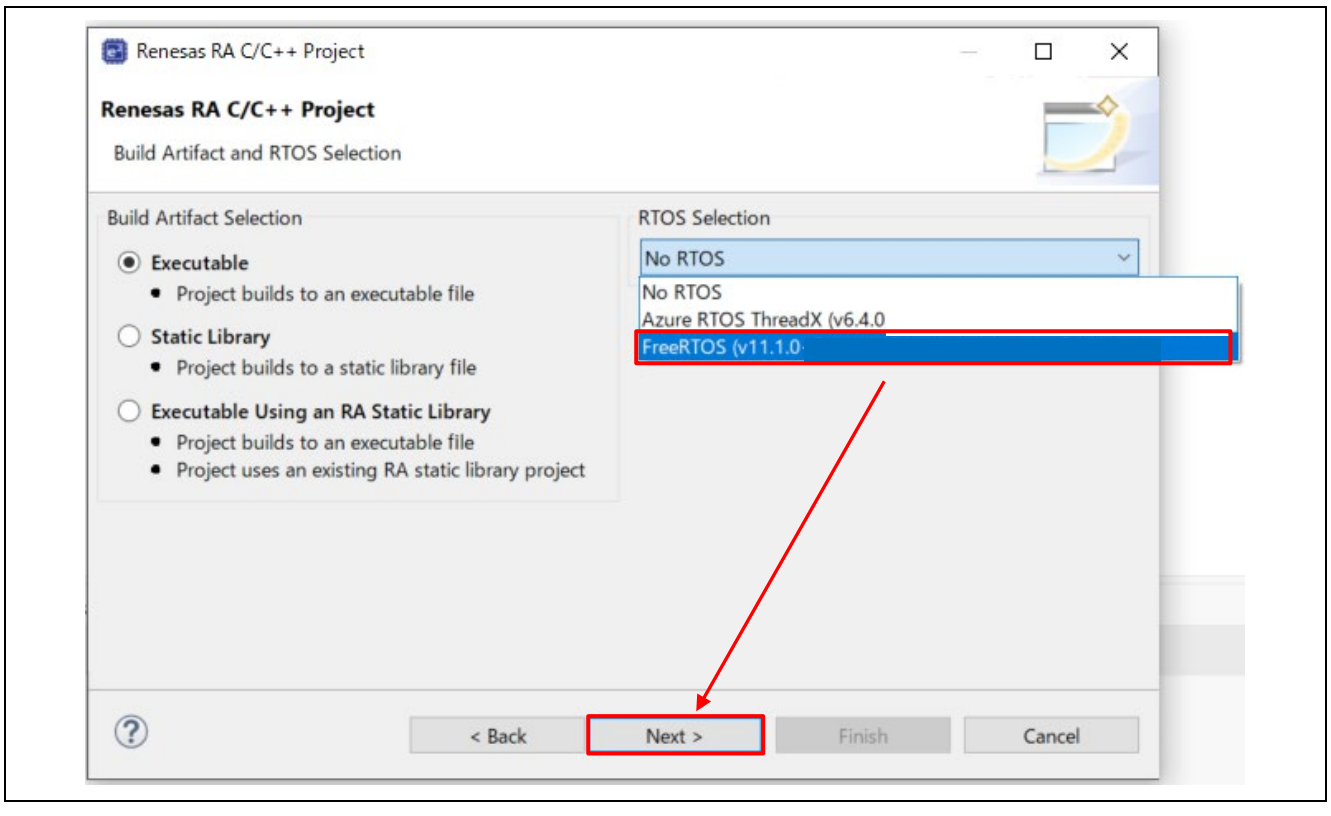
6. Select the project type for “Flat (Non-TrustZone) Project”



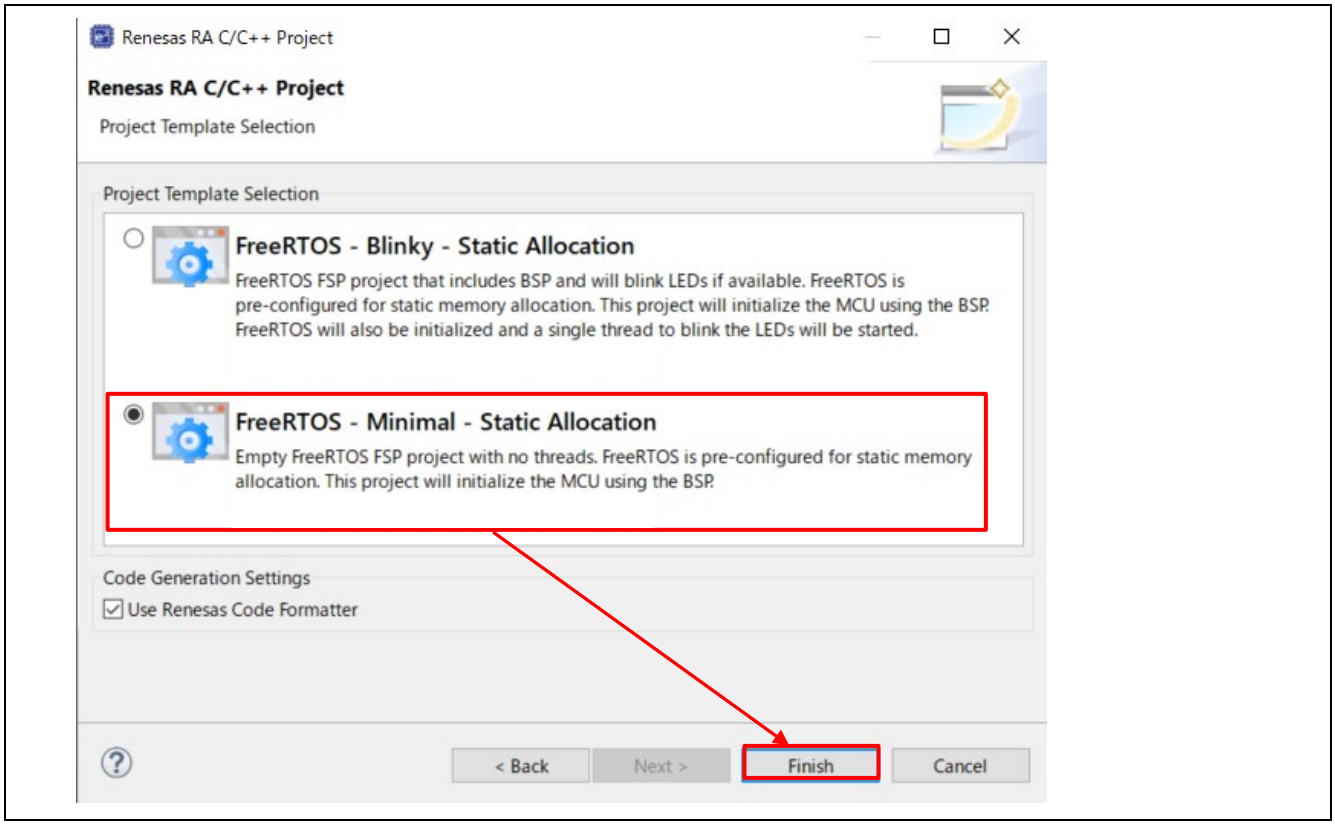
7. Select “None”



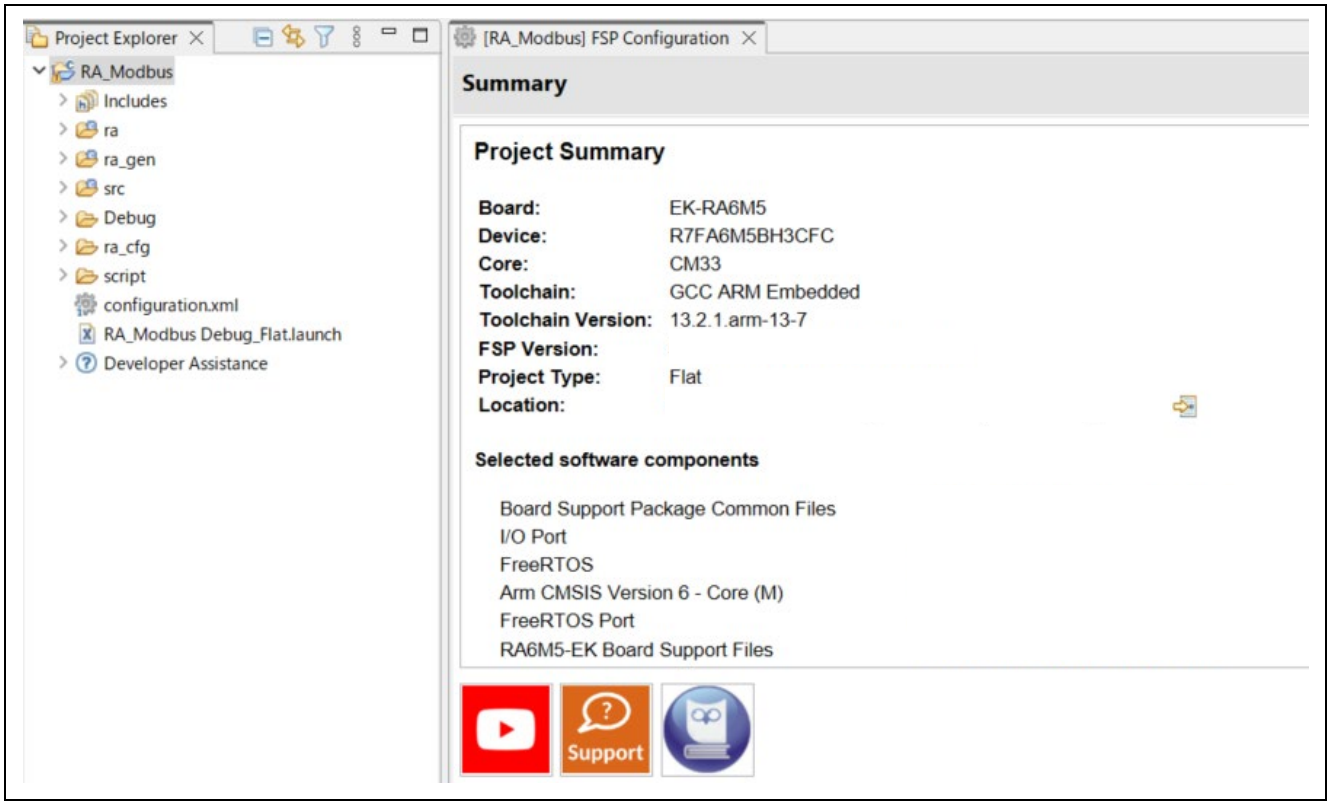
8. Select “FreeRTOS (xxx)”.



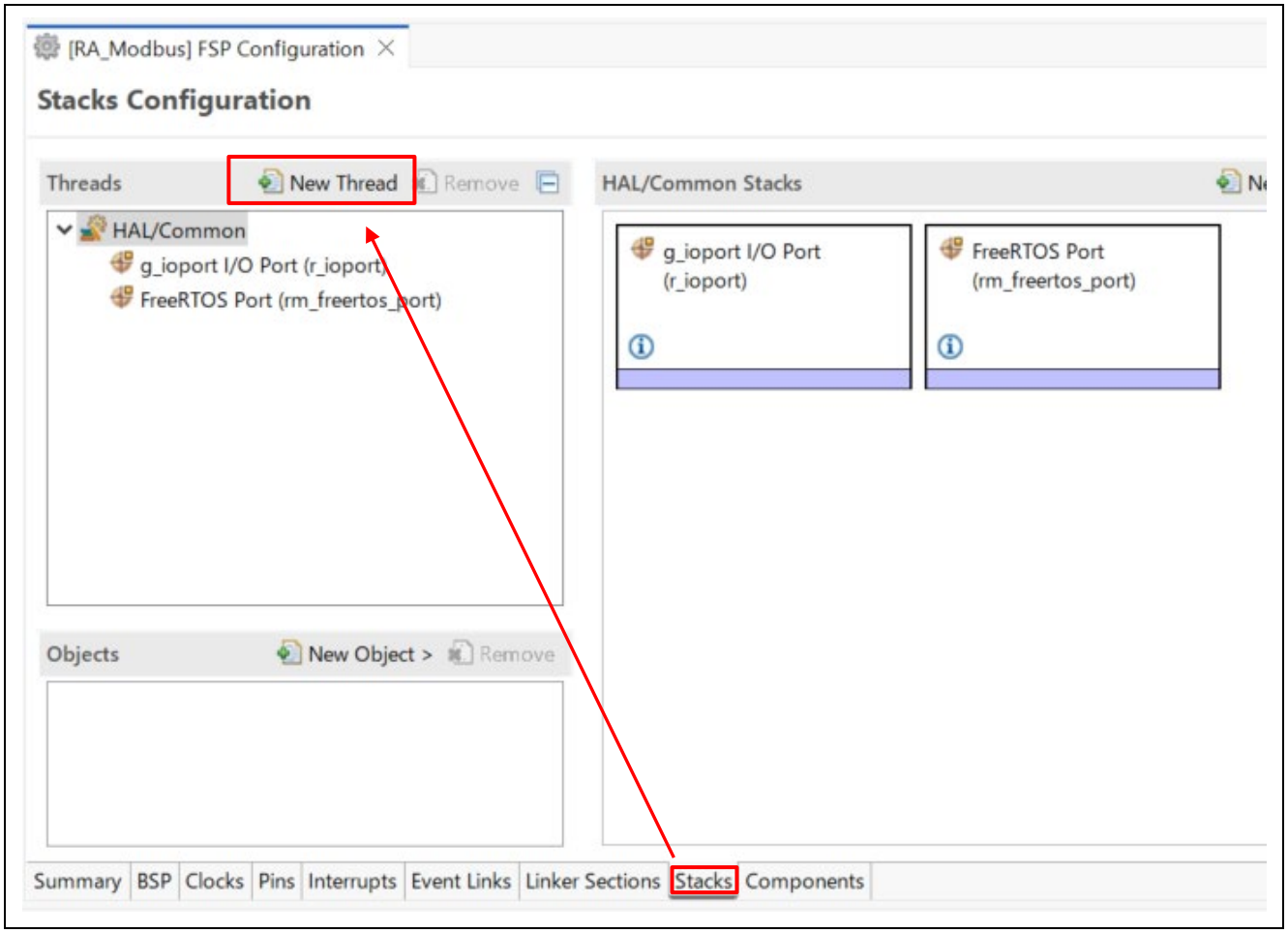
9. Select “FreeRTOS - Minimal - Static Allocation” under Project Template Selection.



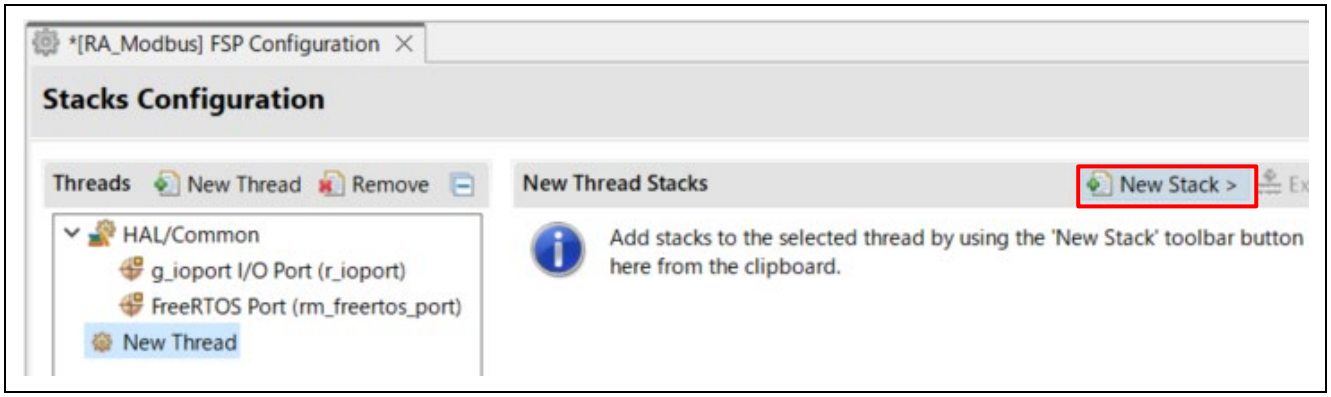
Once the project is created, it appears in the “Project Explorer,” and the “FSP Configuration” tab is displayed.



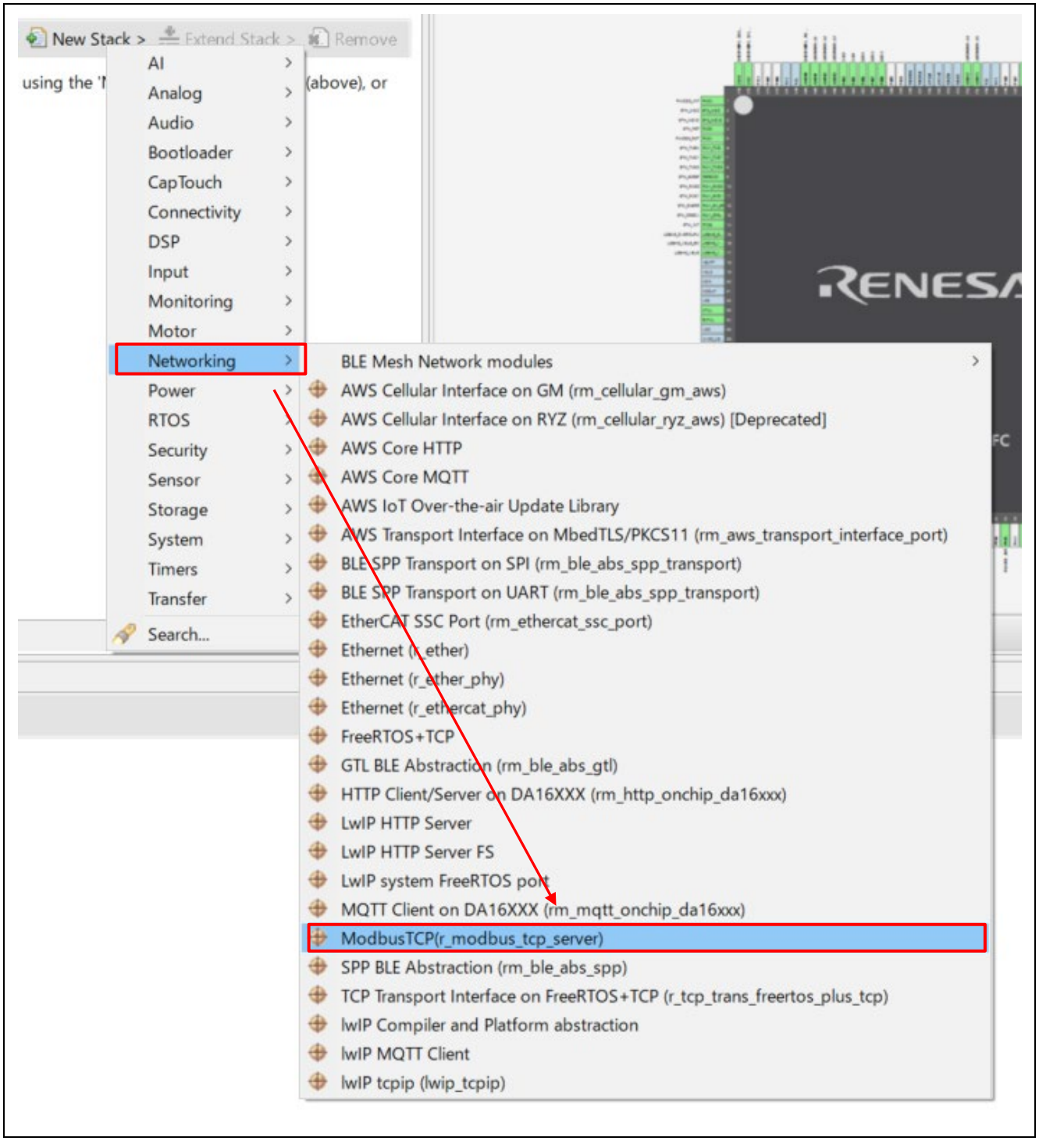
10. Create New Thread
    In the "FSP Configuration", click the "Stacks" tab, select "Threads" → "New Thread". A new thread appears.



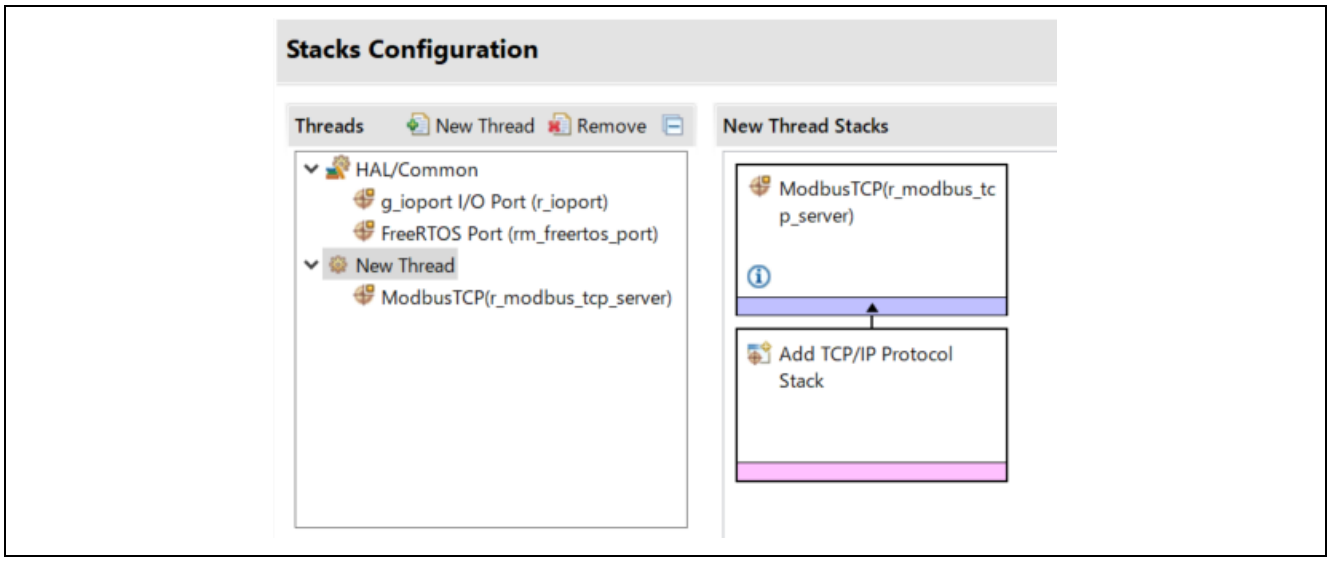
11. Create New Stack
    Select "New Stacks" to be configured.



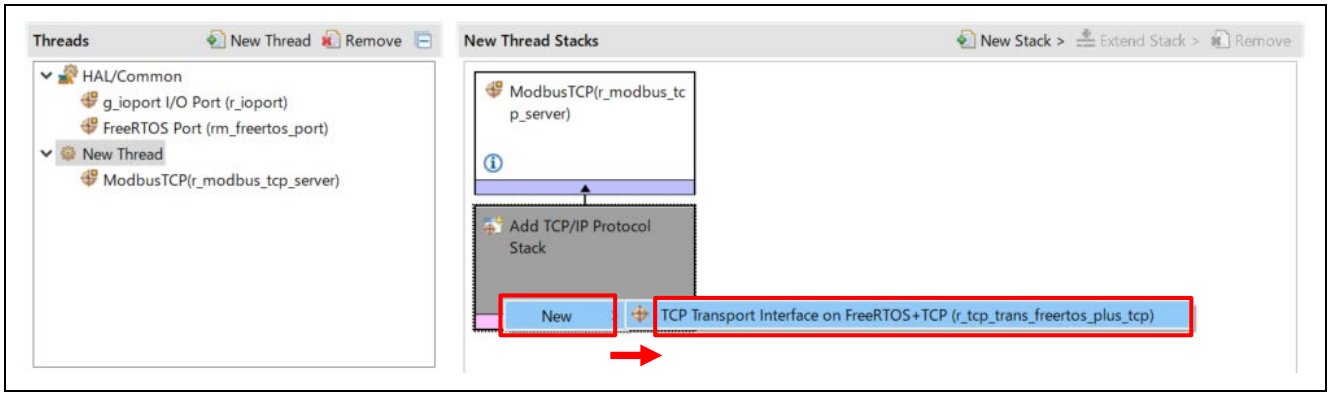
Select “Networking” → ” ModbusTCP(r_modbus_tcp_server)”.



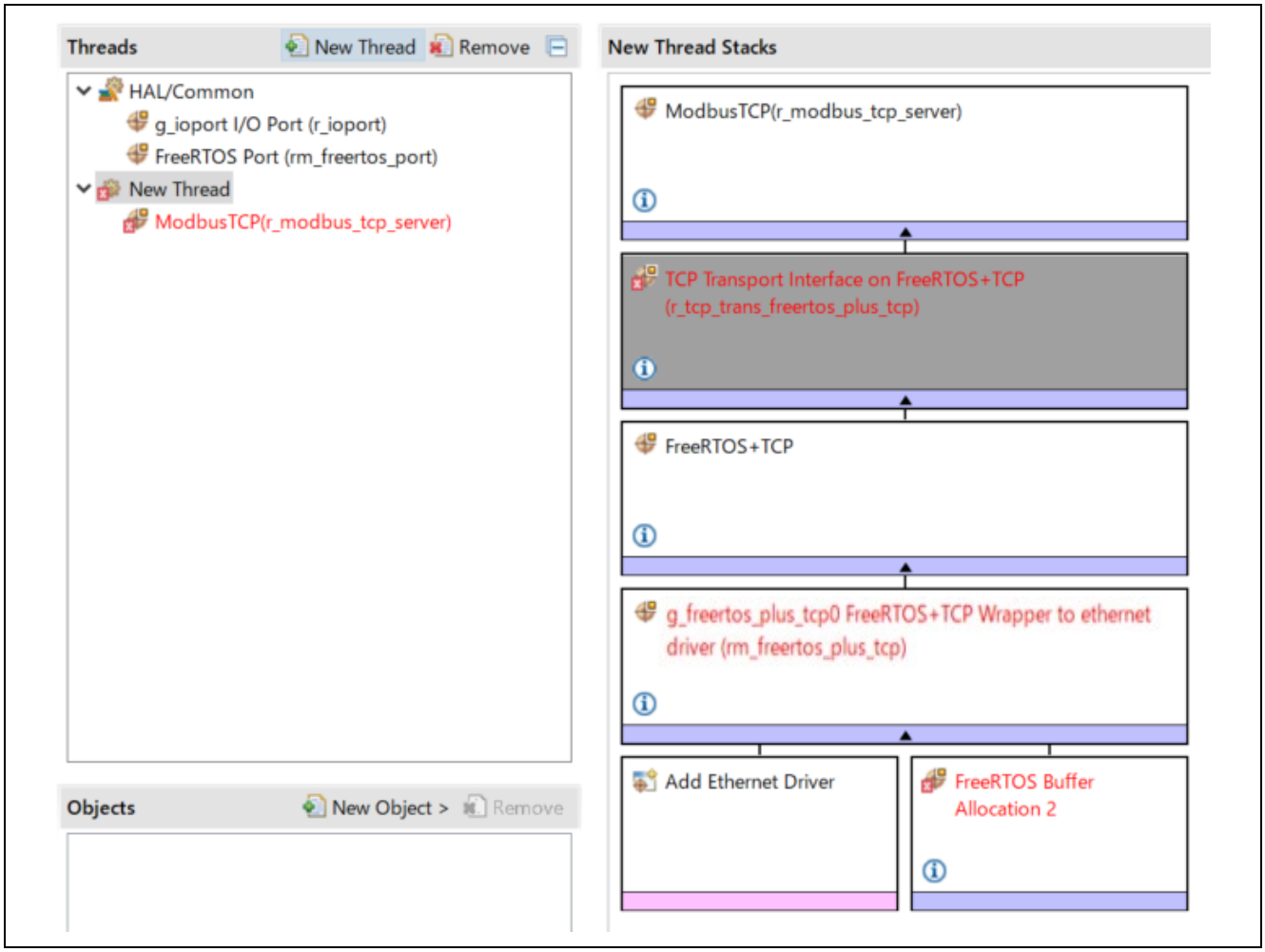
The stack is configured as follows:



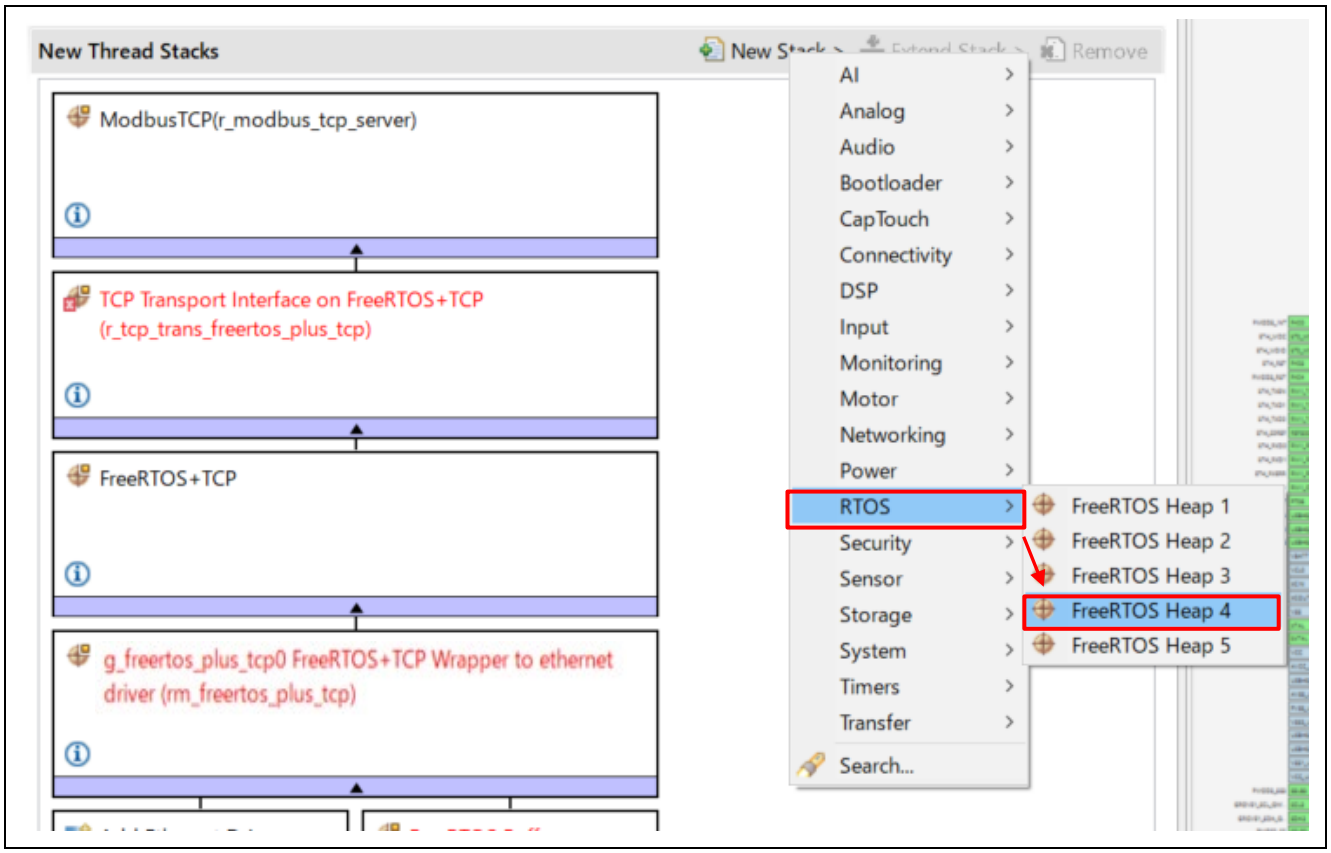
12. Add FreeRTOS+TCP
    Click “New” → “TCP Transport Interface on FreeRTOS+TCP (r_modbus_tcp_server_port_freertos_plus_tcp)” to “Add TCP/IP Protocol Stack”.



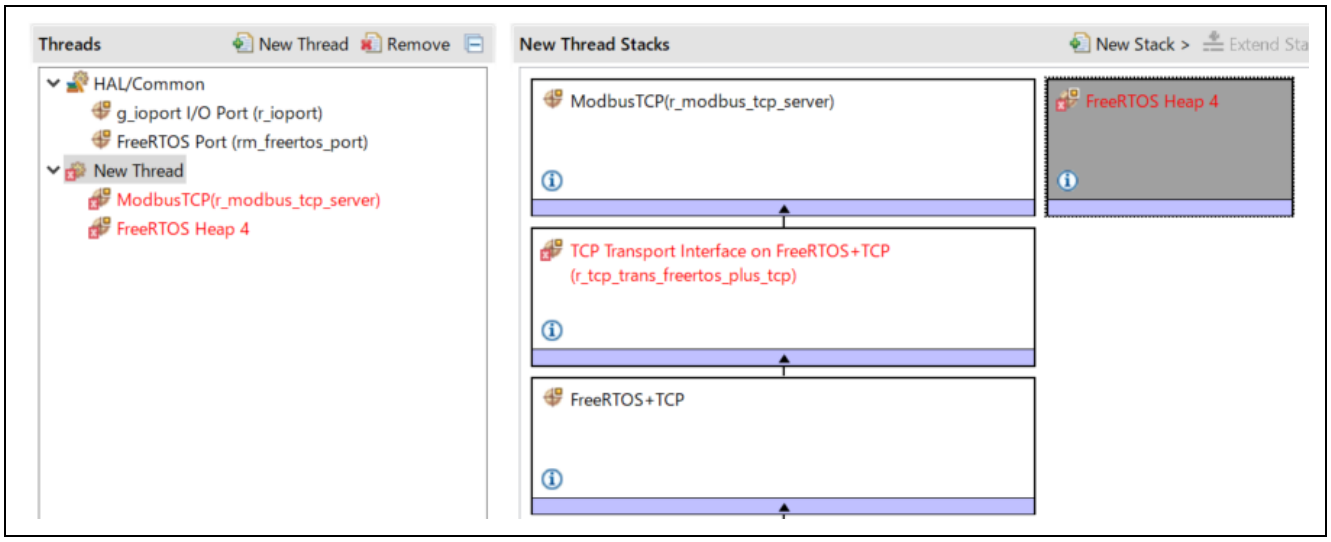
The stack is configured as follows:



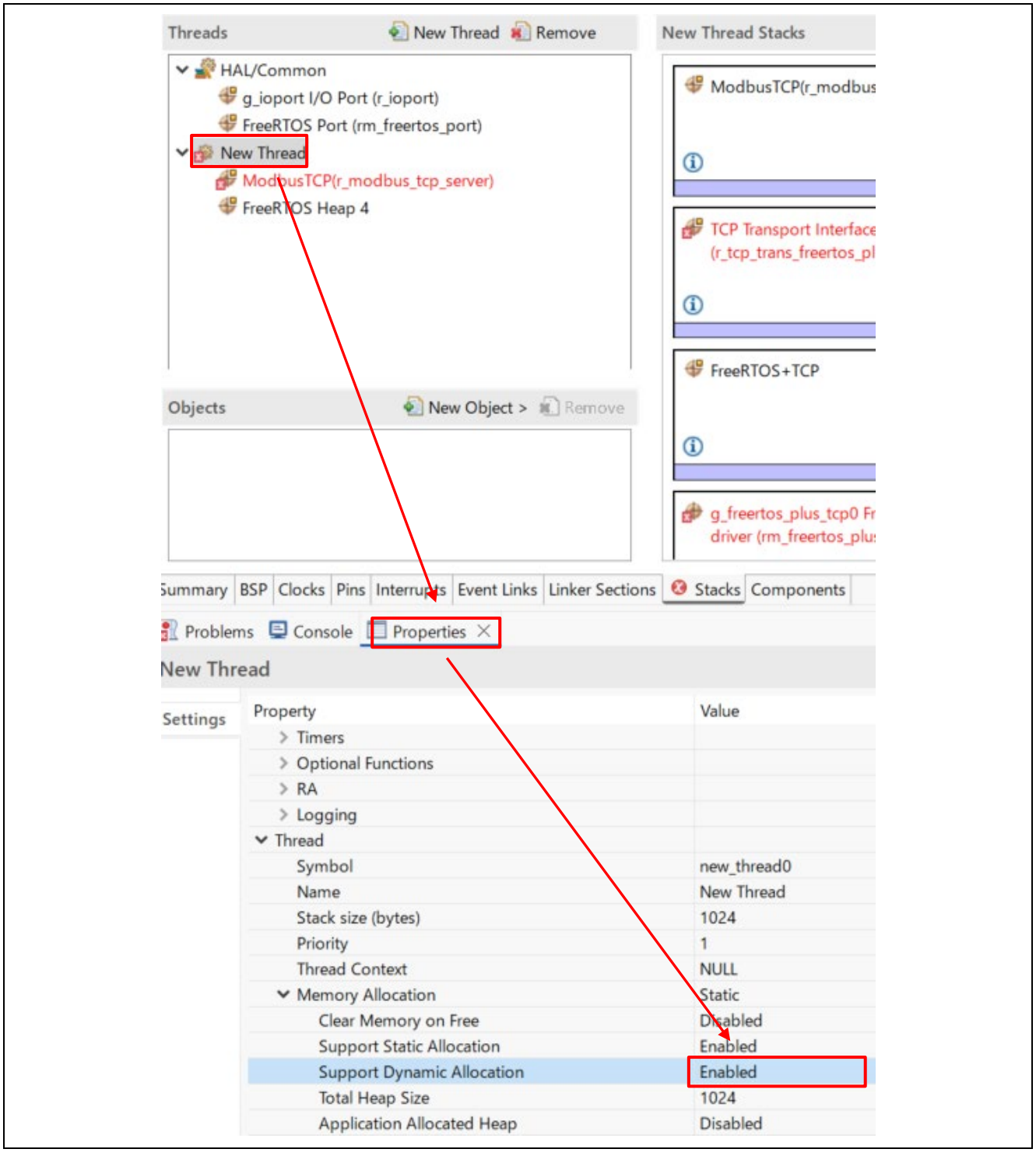
13. Add Heap
    Select “New Stack” → “RTOS” → “FreeRTOS Heap 4”.



The stack will be configured as follows:



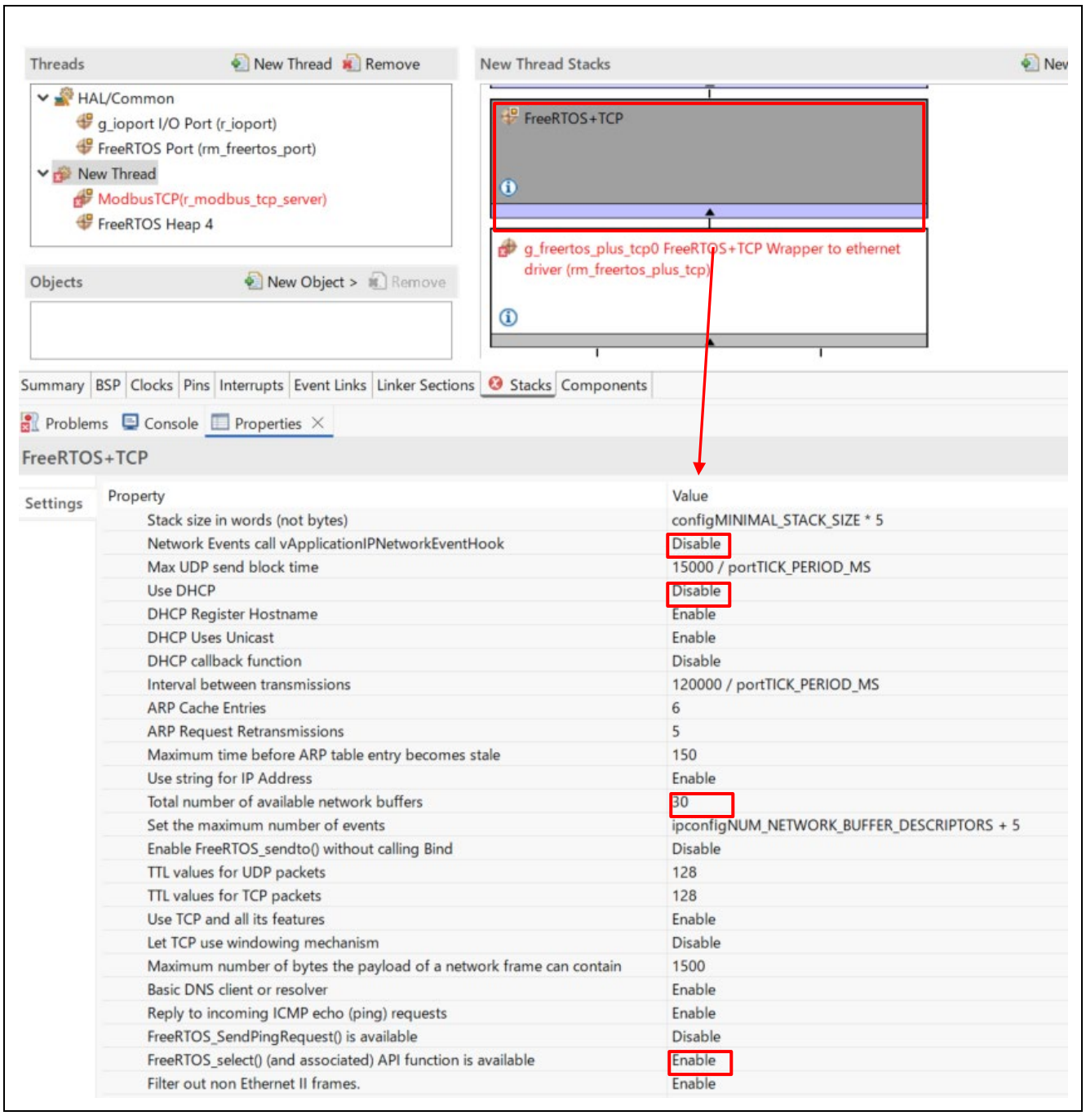
14. Set Support Dynamic Allocation
    Open “Properties” of “New Thread” in “Stacks” and change “Support Dynamic Allocation” inside “Memory Allocation” to “Enabled”.



“FreeRTOS Heap4” stack configuration errors are resolved.

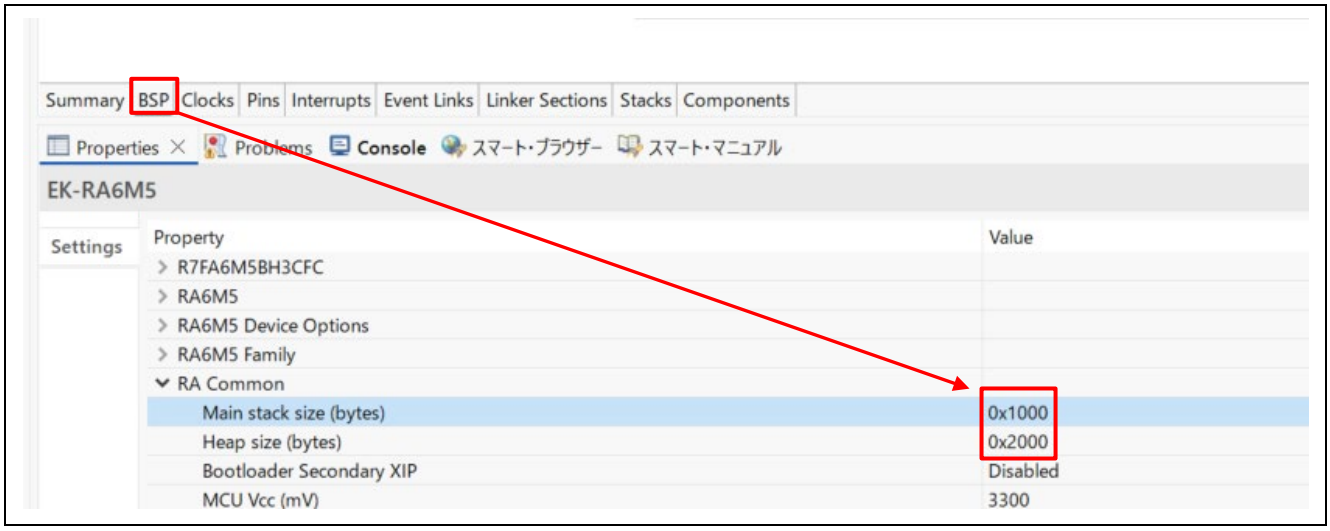
15. Set FreeRTOS+TCP
Open “Properties” of “FreeRTOS+TCP” in “Stacks” and change “Network Events call vApplicationIPNetworkEventHook”, “Use DHCP”, Total number of available network buffers, and “FreeRTOS_Select() (and associated) API function is available” in “Common” to the following values.

Network Events call vApplicationIPNetworkEventHook：**Disable**
Use DHCP：**Disable**
Total number of available network buffers：**30**
FreeRTOS_Select() (and associated) API function is available：**Enable**



16. Set Stack size
    Open “Properties” of “BSP” and change “Main stack size” and “Heap size” in “RA Common” to the following values.

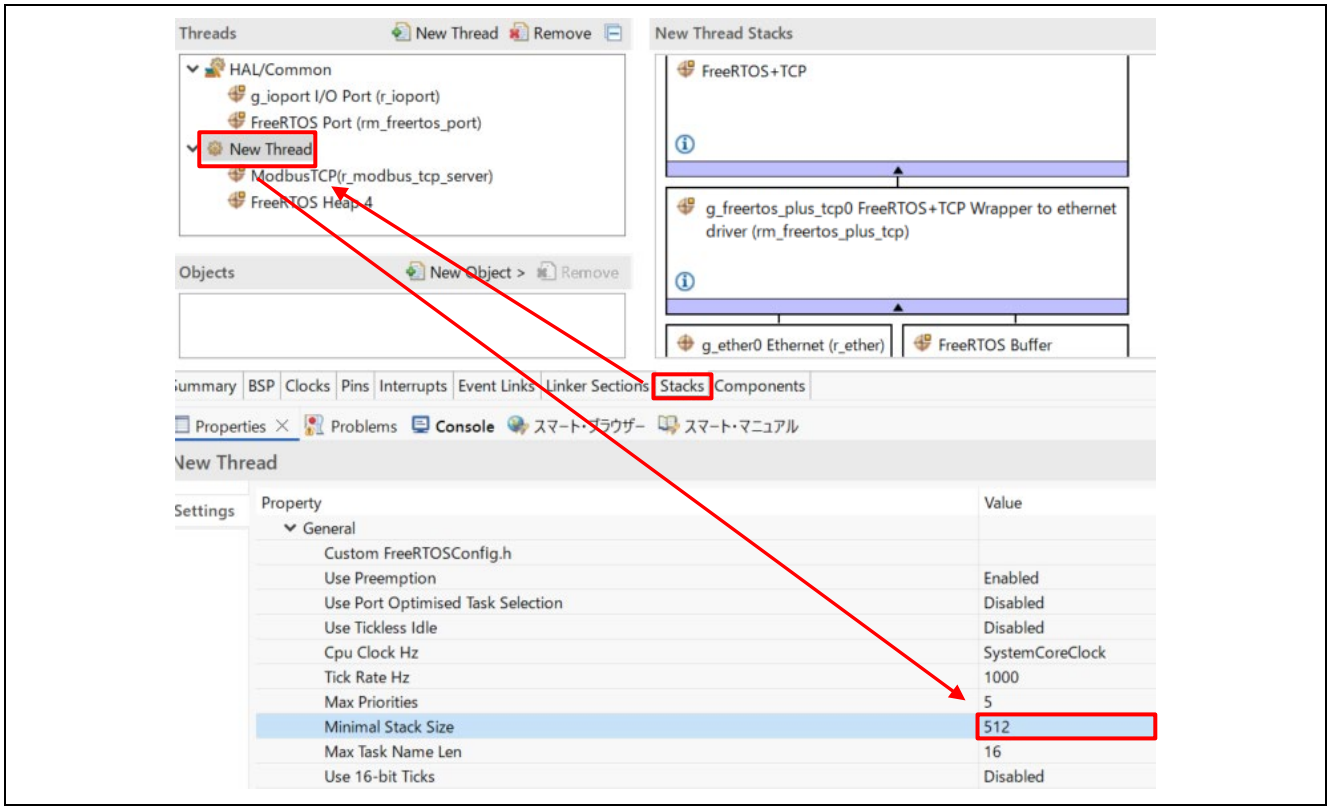
    Main stack size：**0x1000**, Heap size：**0x2000**



The stack configuration error for "ModbusTCP (r_modbus_tcp_server)" is now resolved.

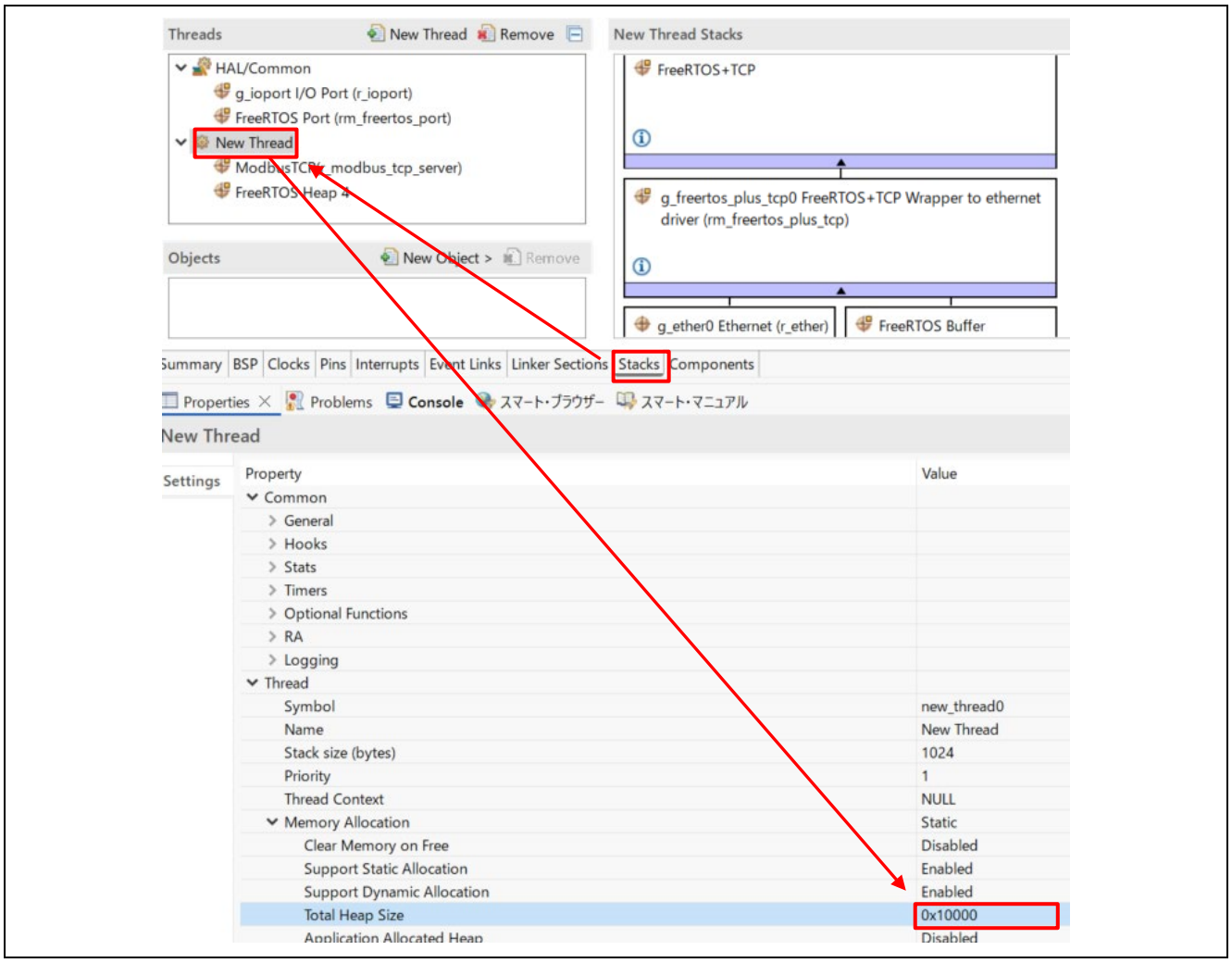
Open “Properties” of “New Thread”, then click on “Stacks” and change “Minimal Stack size” in “General” to the following values.

Minimal Stack size：**512**



Open “Properties” of “New Thread”, then click on “Stacks” and change “Total Heap Size” in “Memory Allocation” to the following values.

Total Heap Size：**0x10000**



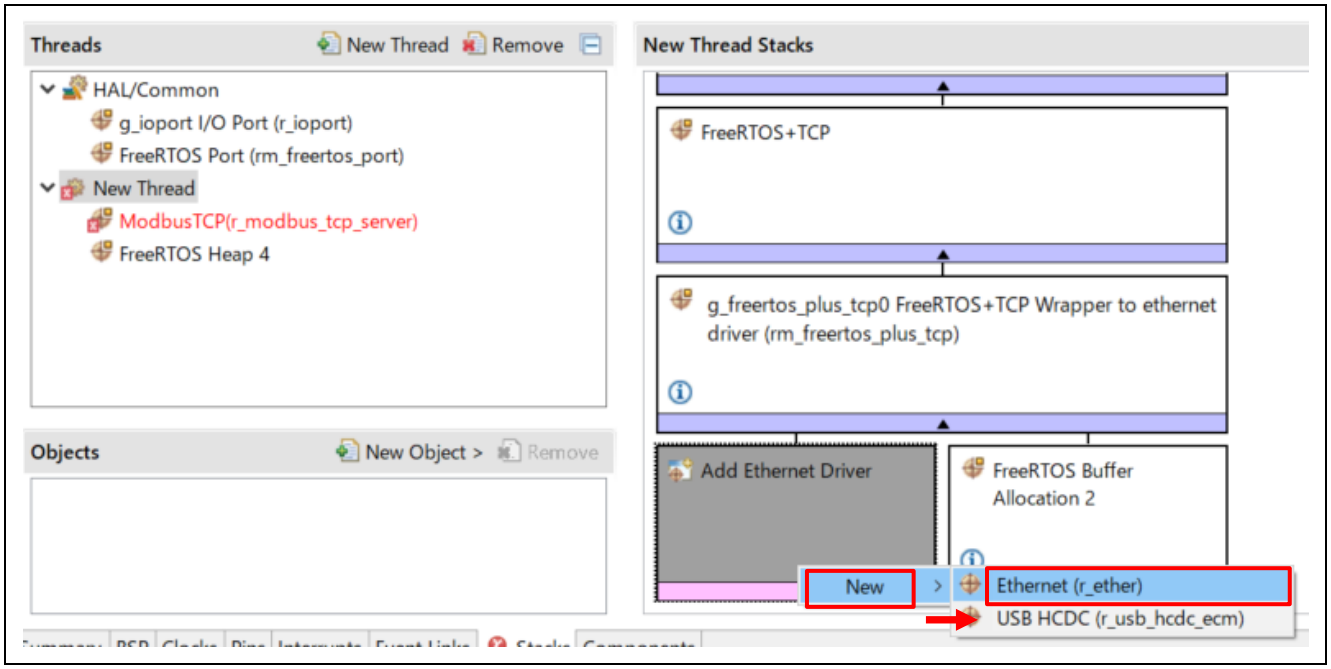
17. Perform the steps for each evaluation board.
    Refer to the following for the evaluation board you are using and follow the steps:

- EK-RA6M3, EK-RA6M4, EK-RA6M5,EK-RA8D1, EK-RA8M1, MCK-RA8T1 :
  6.2.2 EK-RA6Mx / EK-RA8x1 / MCK-RA8T1 Creating Procedures
- MCK-RA8T2 : **6.2.3. MCK-RA8T2 Creating Procedures**
- EK-RA8D2 : **6.2.4. EK-RA8D2 Creating Procedures**
- EK-RA8P1 : **6.2.5. EK-RA8P1 Creating Procedures**
- EK-RA8M2 : **6.2.6. EK-RA8M2 Creating Procedures**
- EK-RA8T2 : **6.2.7. EK-RA8T2 Creating Procedures**

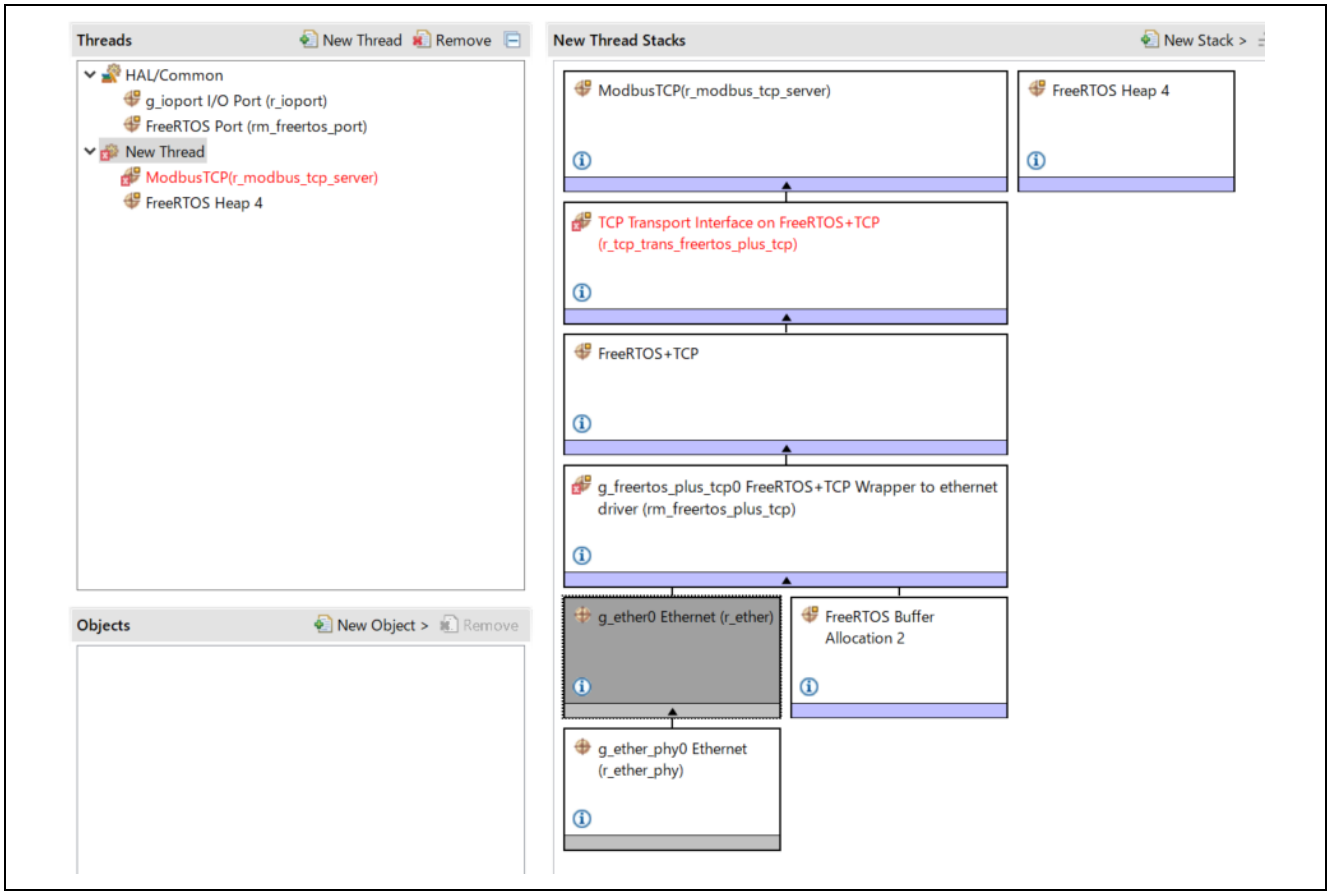
6.2.2 EK-RA6Mx / EK-RA8x1 / MCK-RA8T1 Creating Procedures

This section describes the procedures for creating EK-RA6Mx (EK-RA6M3, EK-RA6M4, EK-RA6M5) / EK-RA8x1 (EK-RA8D1, EK-RA8M1) / MCK-RA8T1.

1. Add Ethernet Driver
   Click “New” → “Ethernet (r_ether)” to “Add Ethernet Driver”.

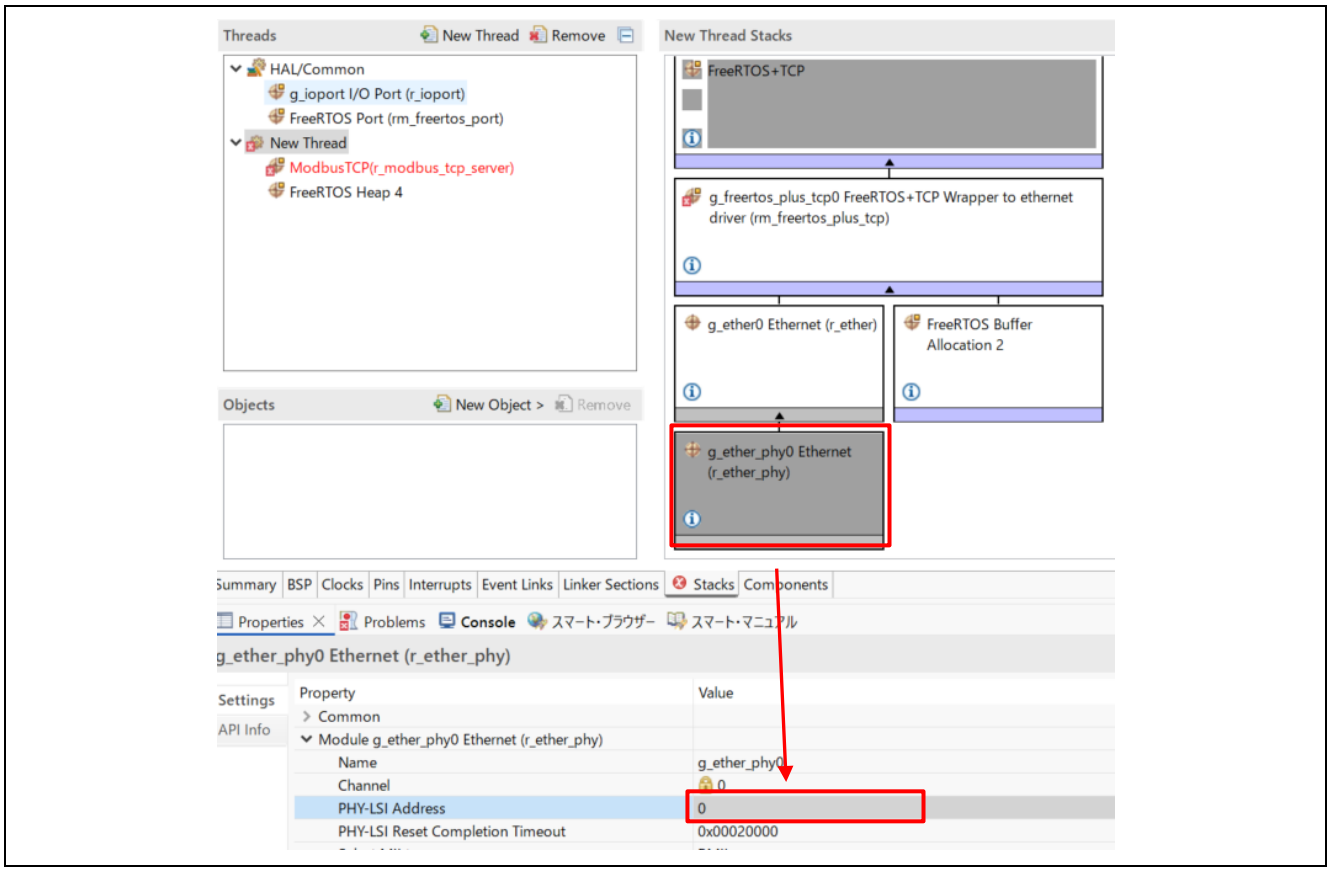


The stack is configured as follows:



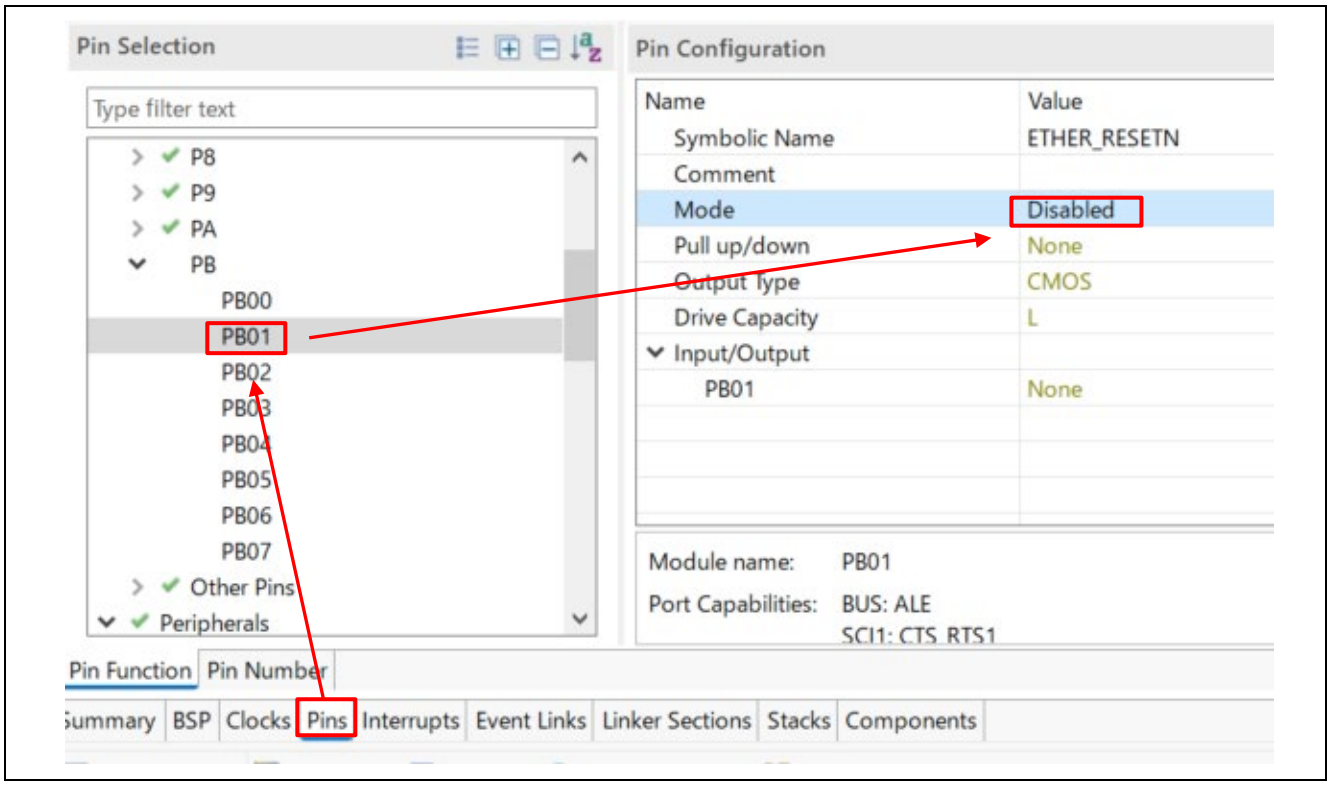
2. Set PHY Address
   Open “Properties” of “g_ether_phy0 Ethernet (r_ether_phy)” in “Stacks” and change “PHY-LSI Address” in “Module g_ether_phy0 Ethernet (r_ether_phy)” to the port0 address configured on the evaluation board.

   RA6xx：PHY Address：**0**, RA8xx：PHY Address：**5**

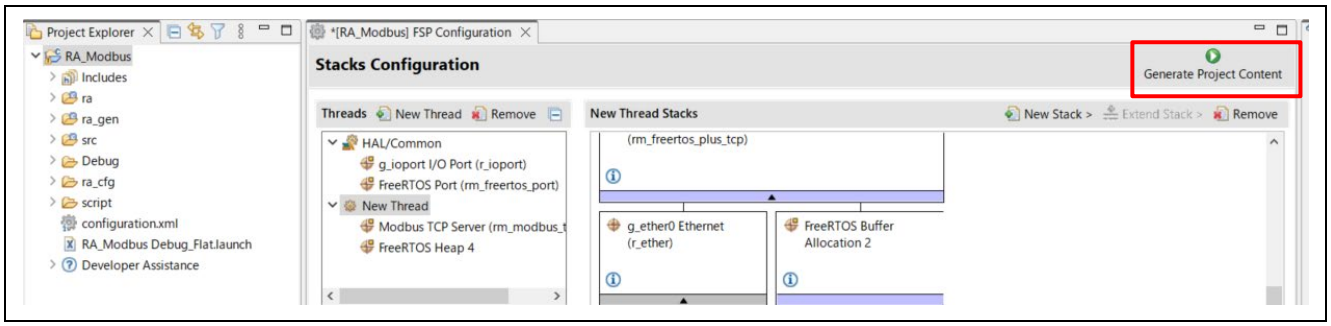


3. Set PHY Reset pin
   The setting of the PHY Reset terminal on the evaluation boards RA8D1 and RA8T1 must be changed. Open “Pin Configuration” of [Reset pin for evaluation board] (see below) in “Pins” and change “Mode” to “Disabled”.

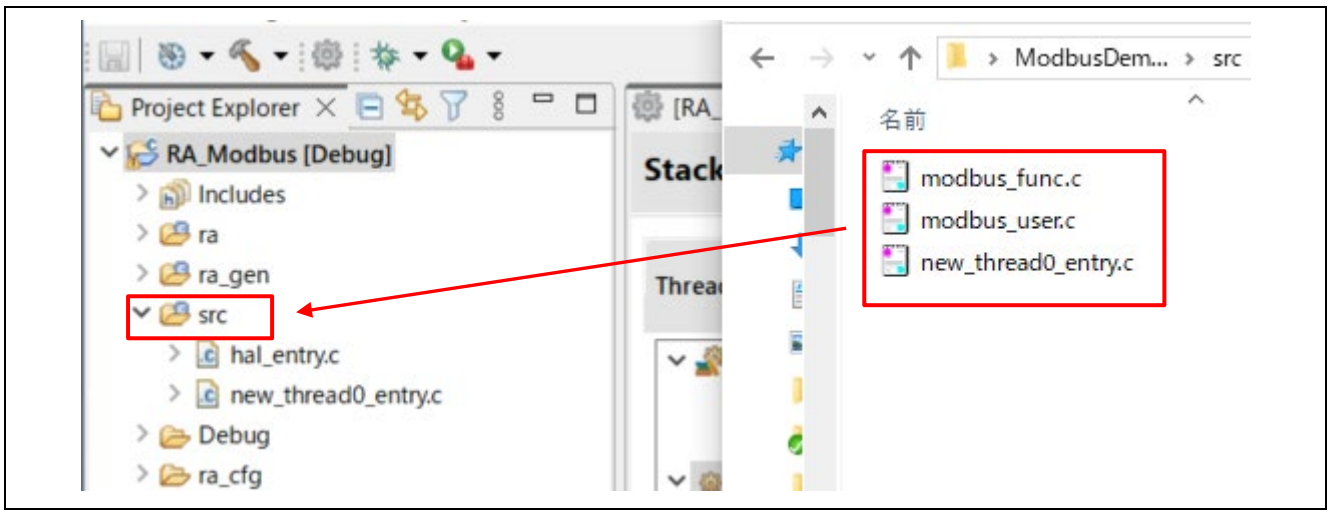
   RA8D1 : **P706**, RA8T1 : **PB01**
   Note: This procedure is not required for evaluation boards other than those listed above.

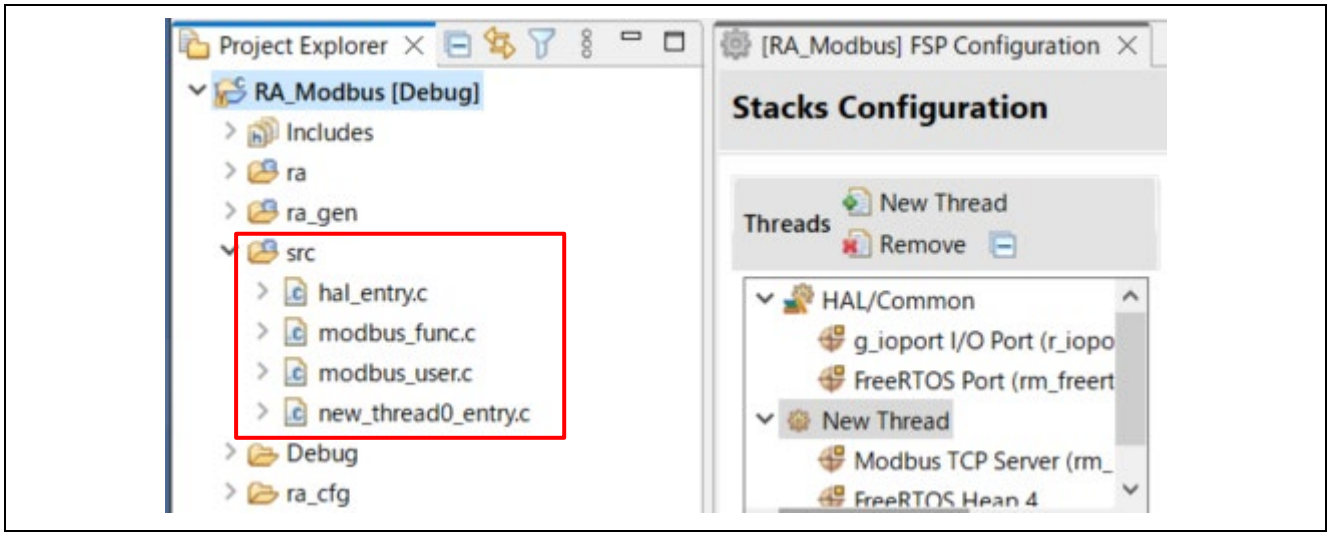


4. Generate the code
   Generate the code with "Generate Project Content".



5. Add Modbus Sample Application
   Copy modbus_func.c, modbus_user.c, and new_thread0_entry.c from the src folder of the sample program package to the src folder of the project and overwrite them.

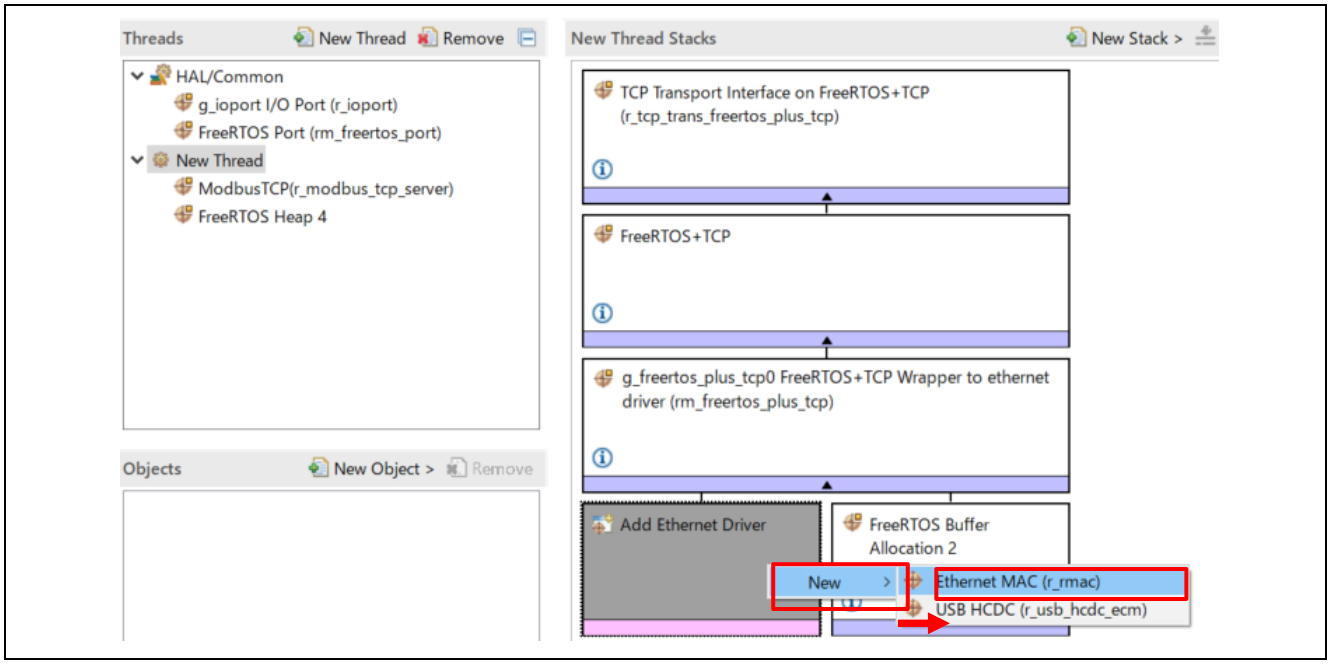




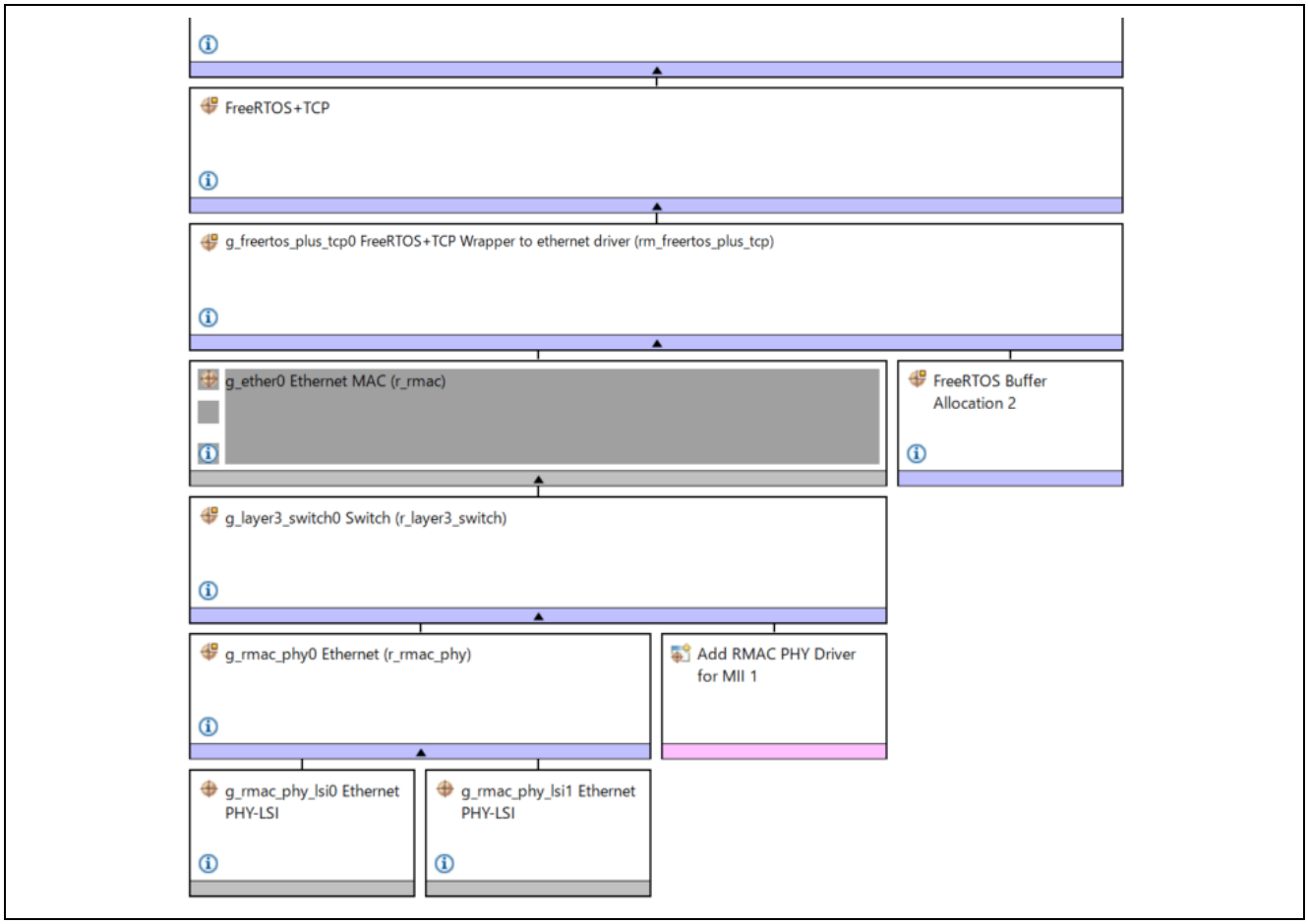
6.2.3 MCK-RA8T2 Creating Procedures

This section describes the procedures for creating MCK-RA8T2.

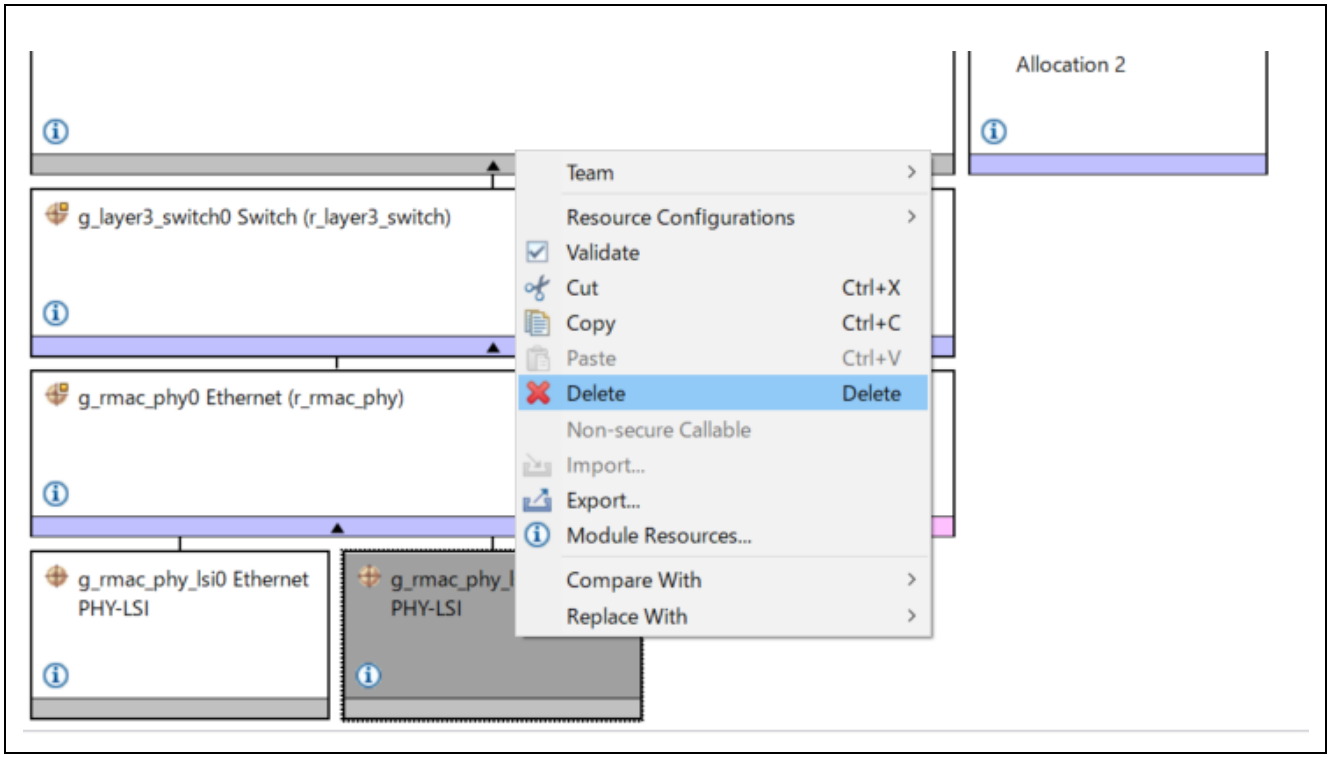
1. Add Ethernet Driver
   Click “New” → “Ethernet (r_rmac)” to “Add Ethernet Driver”.



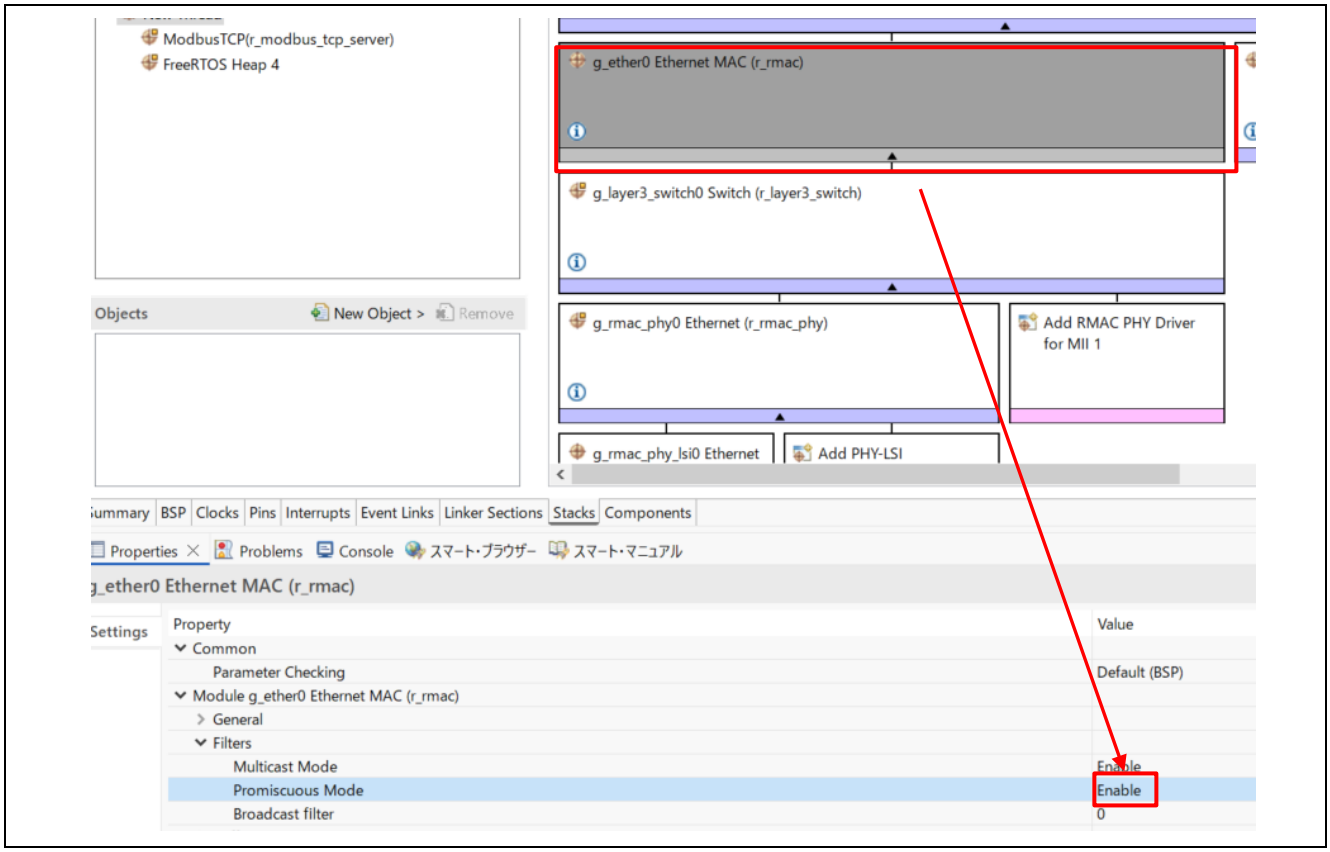
The stack will be configured as follows:



Right-click on “g_rmac_phy_lsi1 Ethernet PHY-LSI”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.

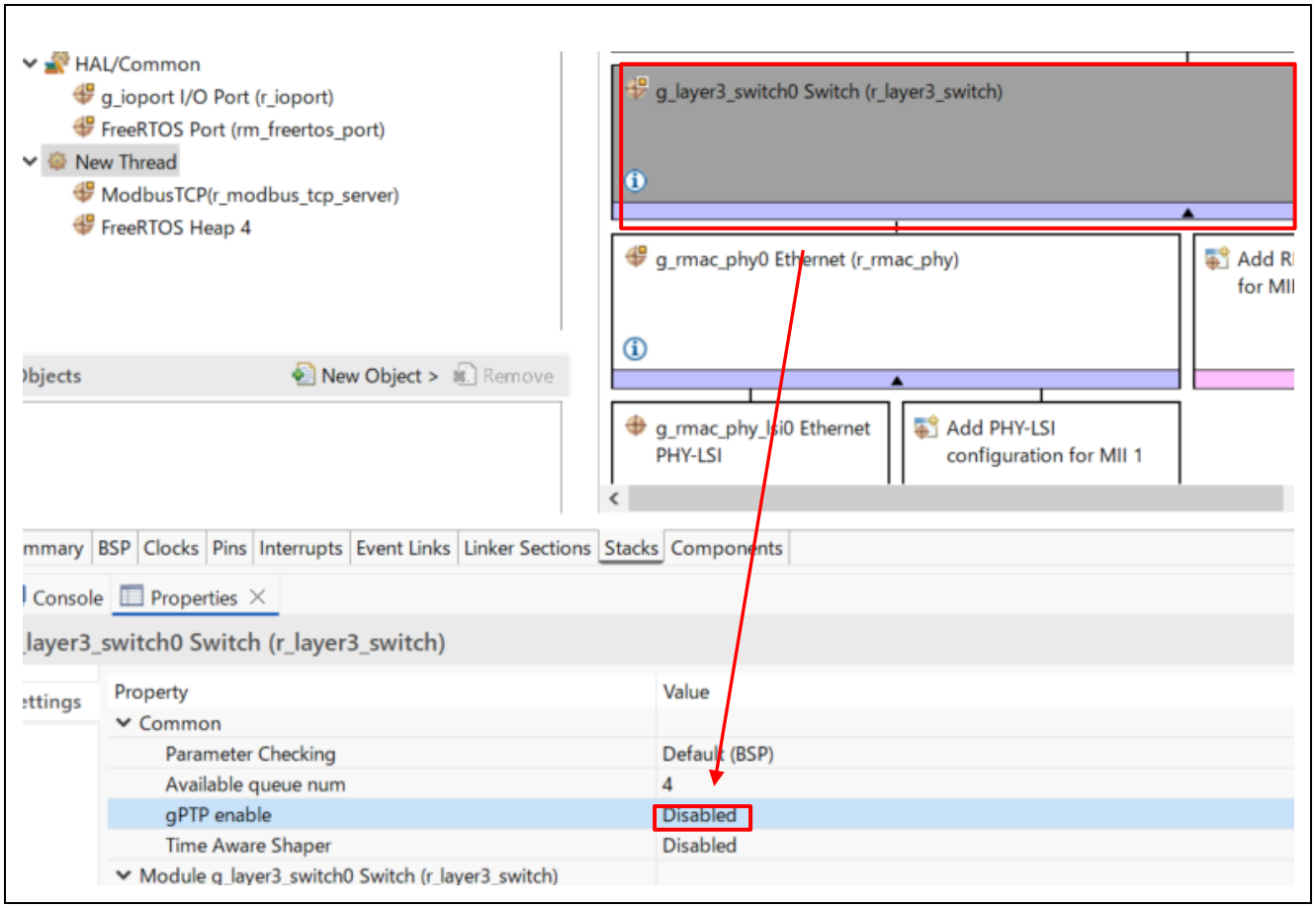


2. Set r_rmac
Change the “Stacks” → ”g_ether0 Ethernet MAC (r_rmac)” → ”Module g_ether0 Ethernet MAC (r_rmac)” → “Promiscuous Mode” in “Filters” to “Enable”.



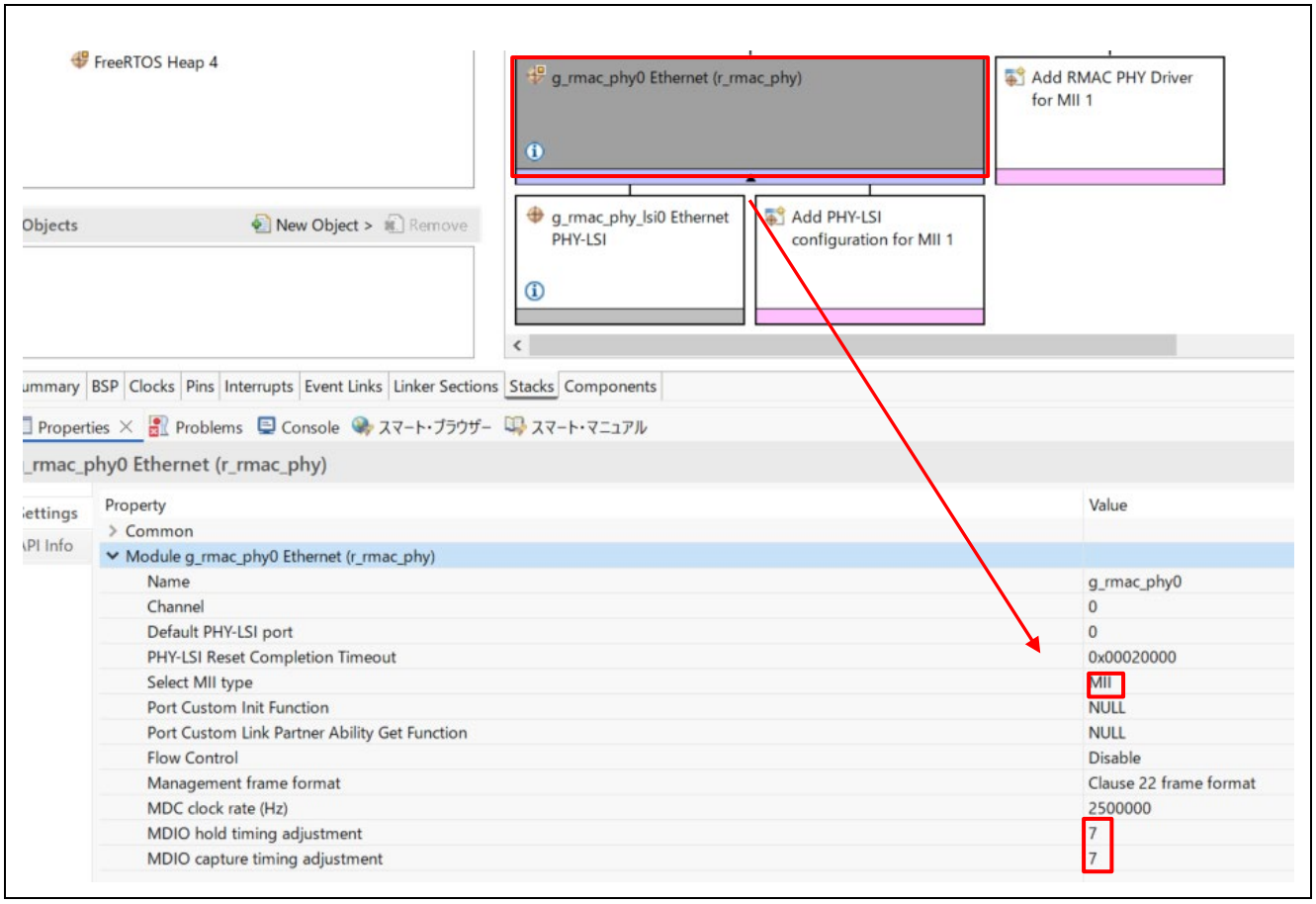
3. Set r_layer3_switch
   Open “Properties” of “g_layer3_switch0 Switch (r_layer3_switch)” in “Stacks” and change “gPTP enable” to the following values.

   gPTP enable：**Disabled**

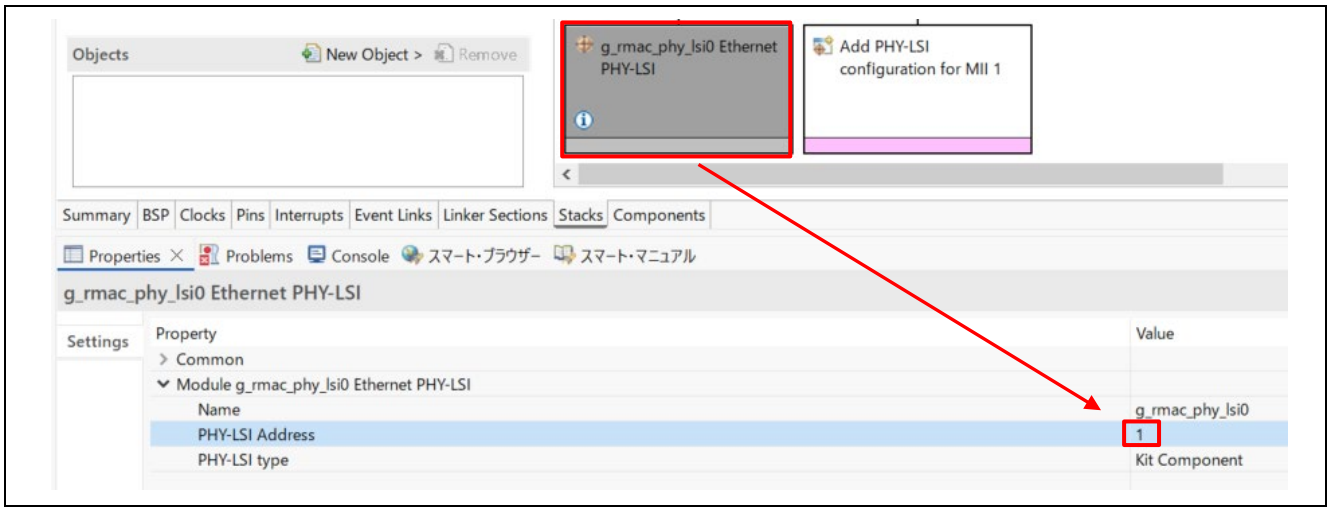


4. Set r_rmac_phy
Open “Properties” of “g_mac_phy0 Ethernet (r_rmac_phy)” in “Stacks” and change “Select MII type”, “MDIO hold timing adjustment”, and “MDIO capture timing adjustment” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

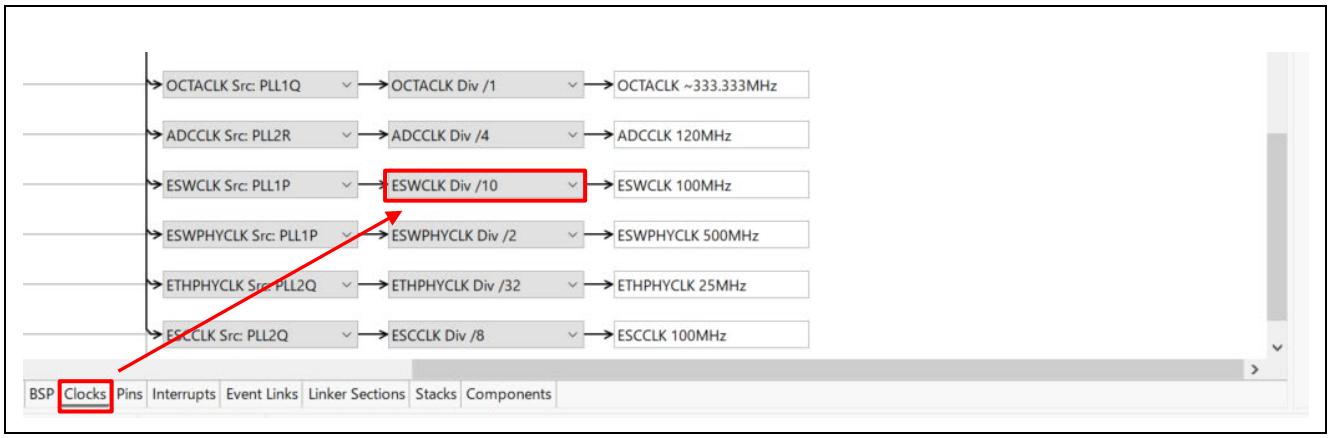
Select MII type：**MII**
MDIO holds timing adjustment：**7**
MDIO capture timing adjustment：**7**



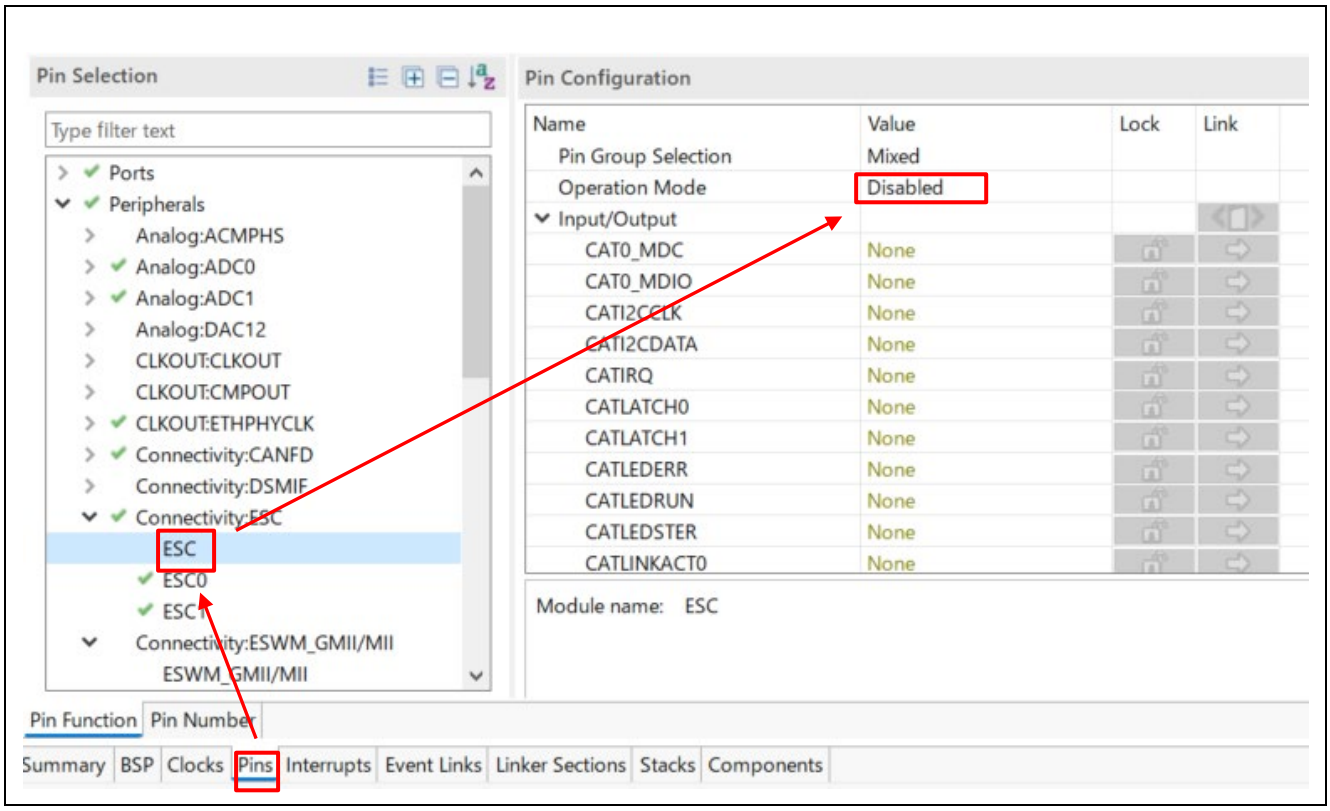
5. Set PHY Address
Open “Properties” of “g_mac_phy_lsi0 Ethernet PHY LSI” in “Stacks” and change “PHY-LSI Address” in “Module g_mac_phy_lsi0 Ethernet PHY LSI” to “1”.



6. Set ESW Clock
   Change the “ESWCLK Div” at the bottom of “Clocks” to “ESWCLK Div /10”.

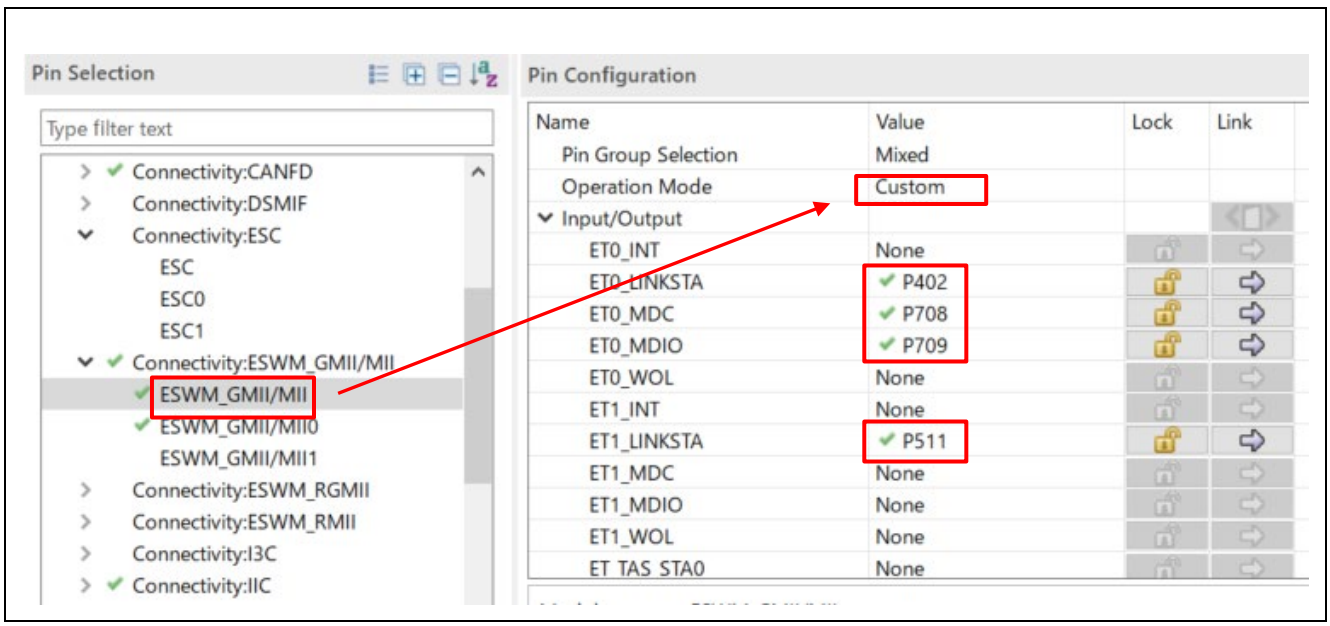


7. Set ESWM Terminals
   Change the "Operation Mode" of “Pins” → ”Peripherals” → ”Connectivity: ESC” → "ESC" to "Disabled".
   Change the "Operation Mode" of "ESC0" and "ESC1" to "Disabled" as well.



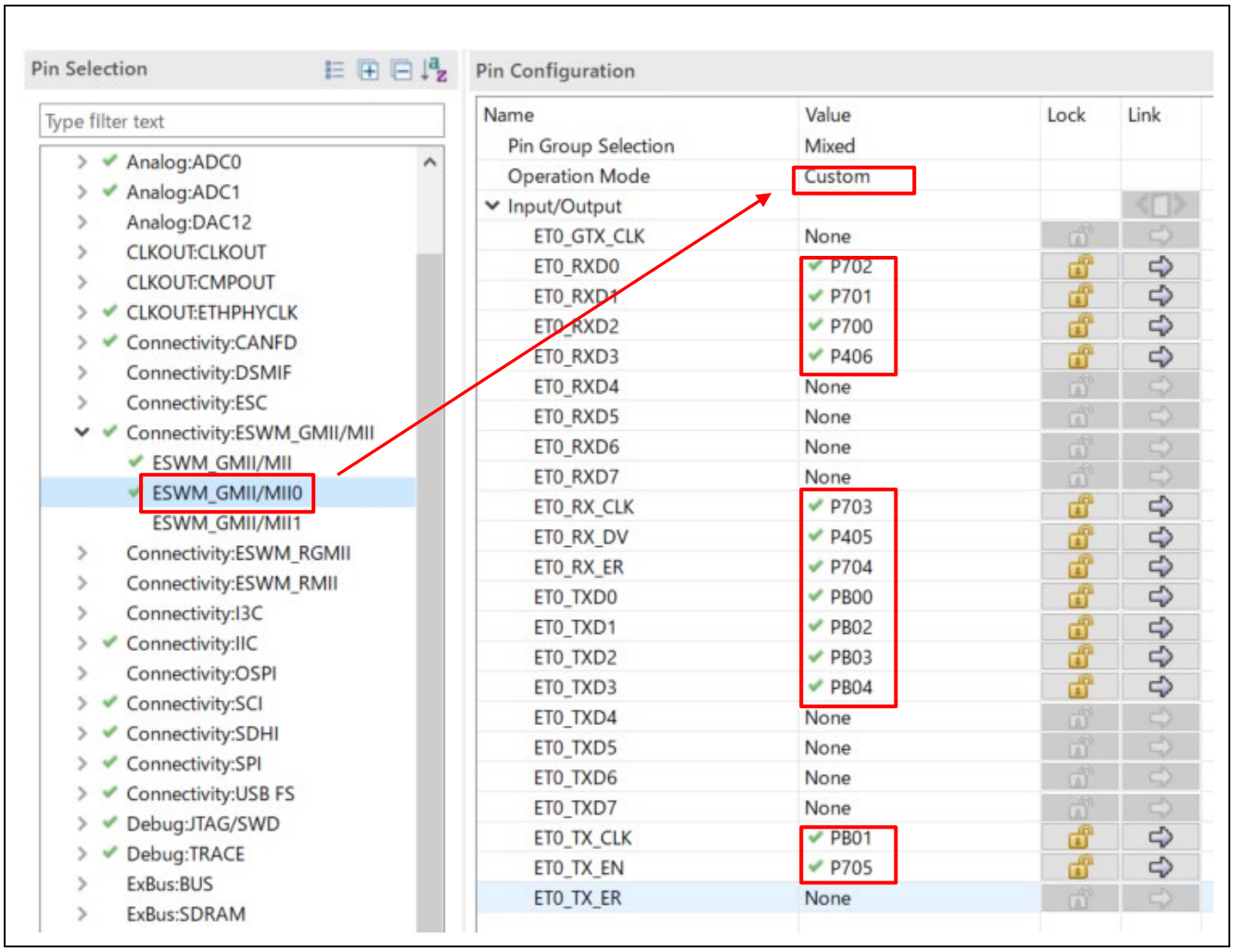
After changing the "Operation Mode" of "Pins" → "Peripherals" → "Connectivity: ESWM_GMII/MII" → "ESWM_GMII/MII" to "Custom", change the pins as follows:

ET0_LINKSTA : **P402**
ET0_MDC : **P708**
ET0_MDIO : **P709**
ET1_LINKSTA : **P511**

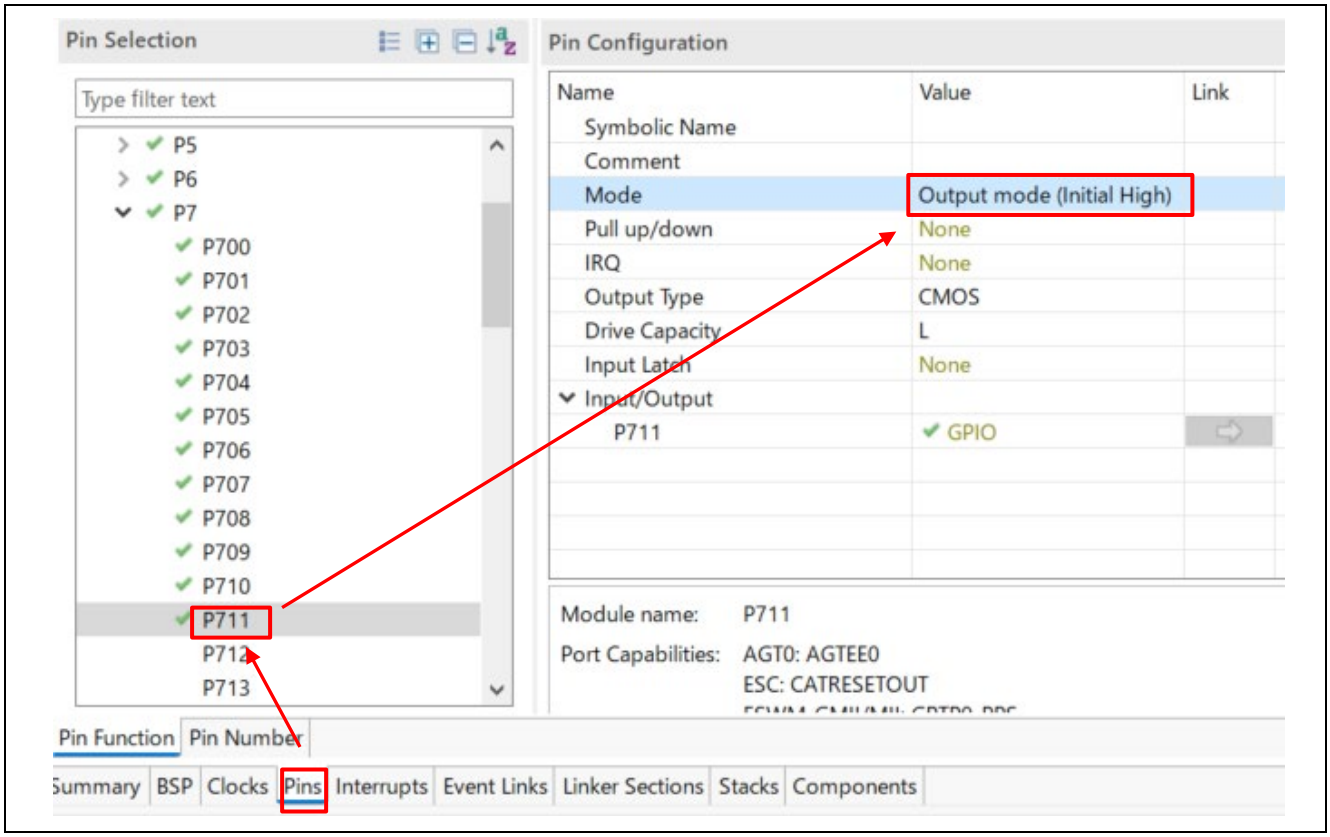


After changing the "Operation Mode" of "Pins" → "Peripherals" → "Connectivity: ESWM_GMII/MII" → "ESWM_GMII/MII0" to "Custom", change the pins as follows:

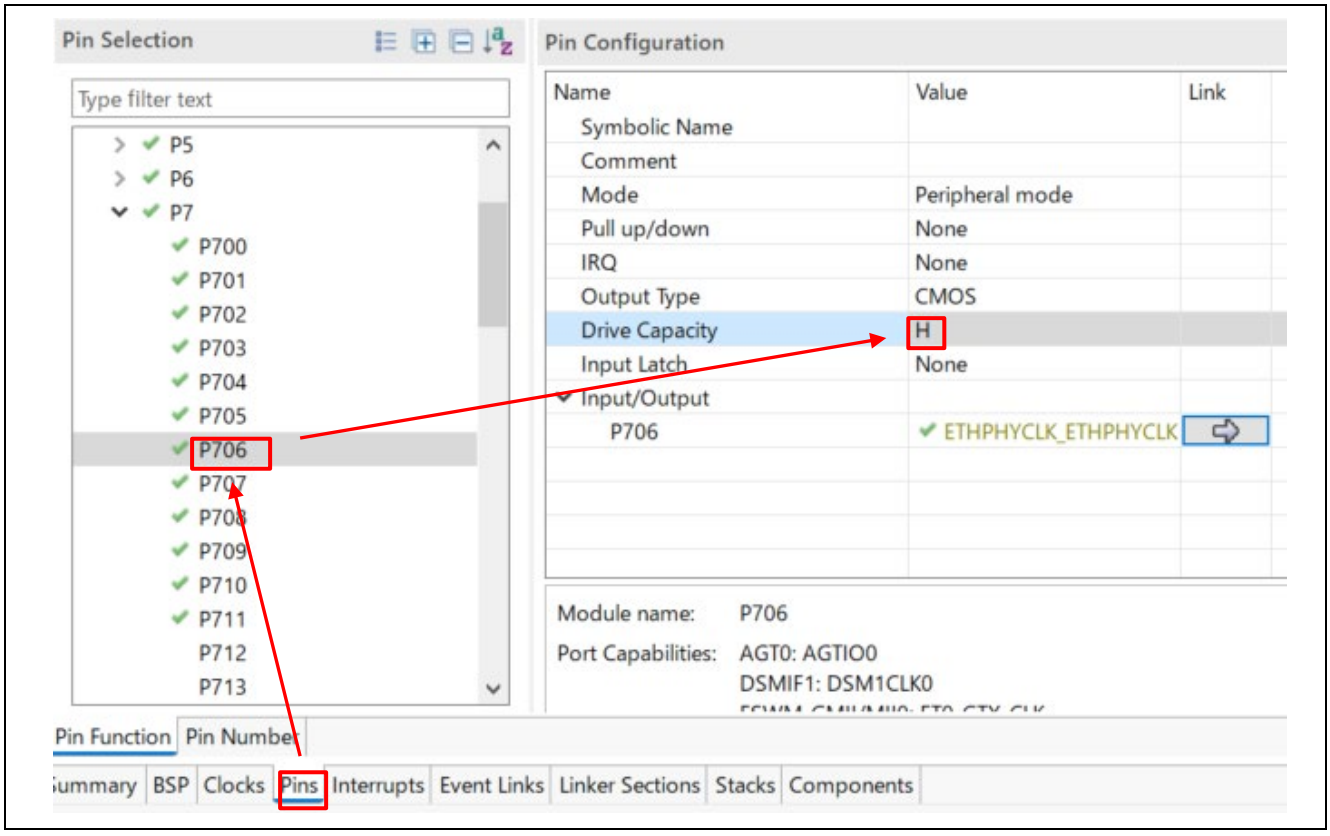
ET0_RXD0 : **P702**
ET0_RXD1 : **P701**
ET0_RXD2 : **P700**
ET0_RXD3 : **P406**
ET0_RX_CLK : **P703**
ET0_RX_DV : **P405**
ET0_RX_ER : **P704**
ET0_TXD0 : **PB00**
ET0_TXD1 : **PB02**
ET0_TXD2 : **PB03**
ET0_TXD3 : **PB04**
ET0_TX_CLK : **PB01**
ET0_TX_EN : **P705**



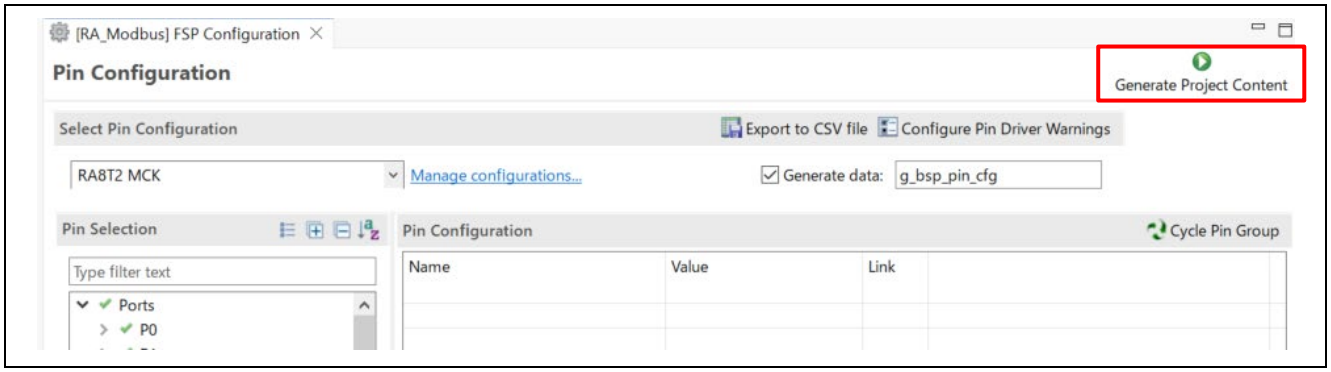
8. Set PHY Reset Terminals
Change the "Mode" of “Pins” → ”Ports” → ”P7” → "P711" to "Output mode (Initial High)".



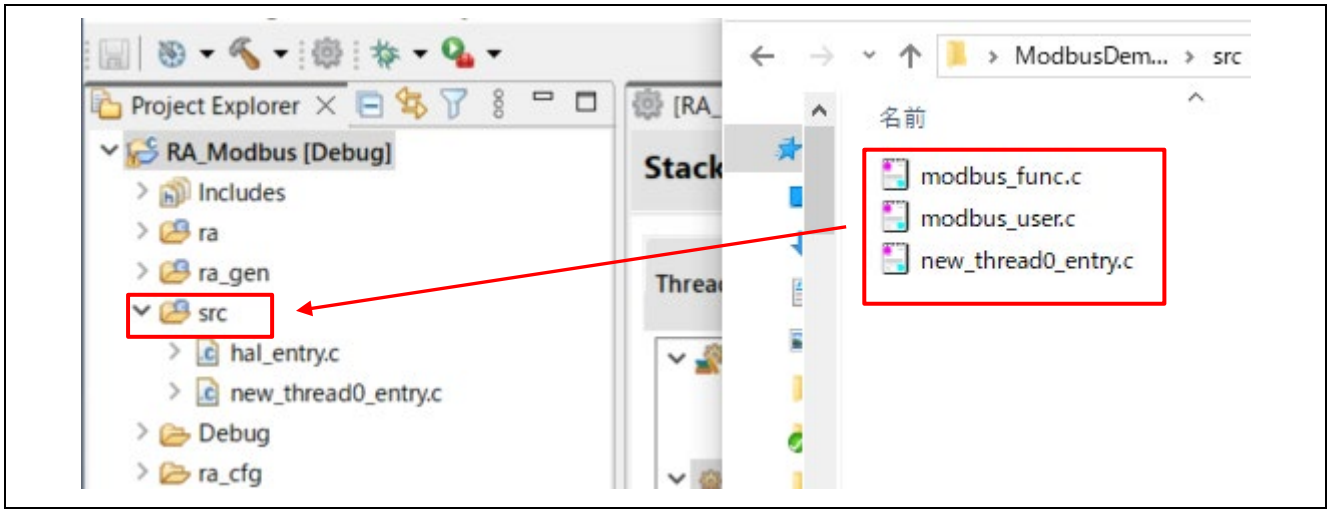
9. Set PHY CLK
Change the "Drive Capacity" of “Pins” → ”Ports” → ”P7” → "P706" to "H".

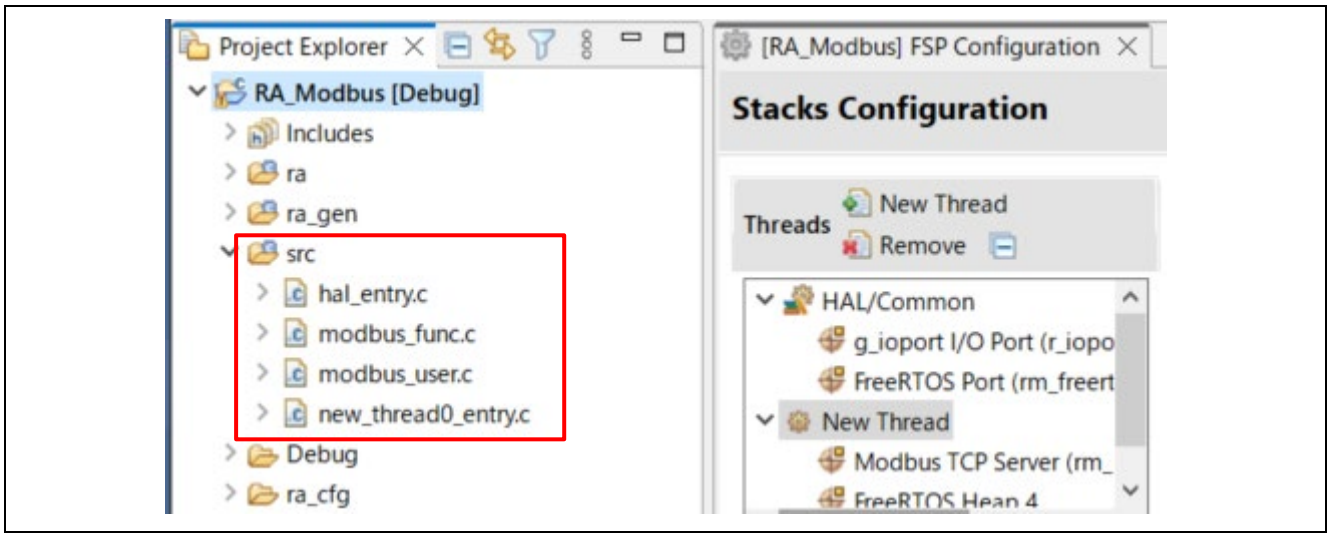


10. Generate the code
    Generate the code with "Generate Project Content".



11. Add Modbus Sample Application
    Copy modbus_func.c, modbus_user.c, and new_thread0_entry.c from the src folder of the sample program package to the src folder of the project and overwrite them.

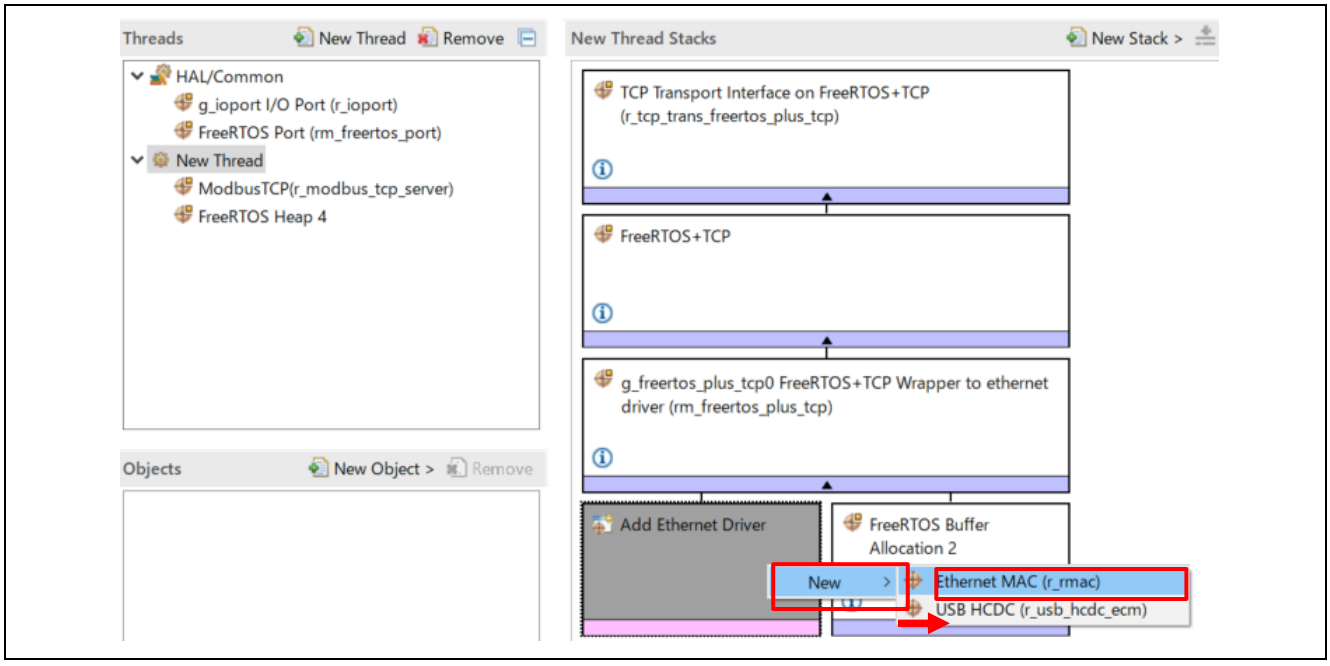




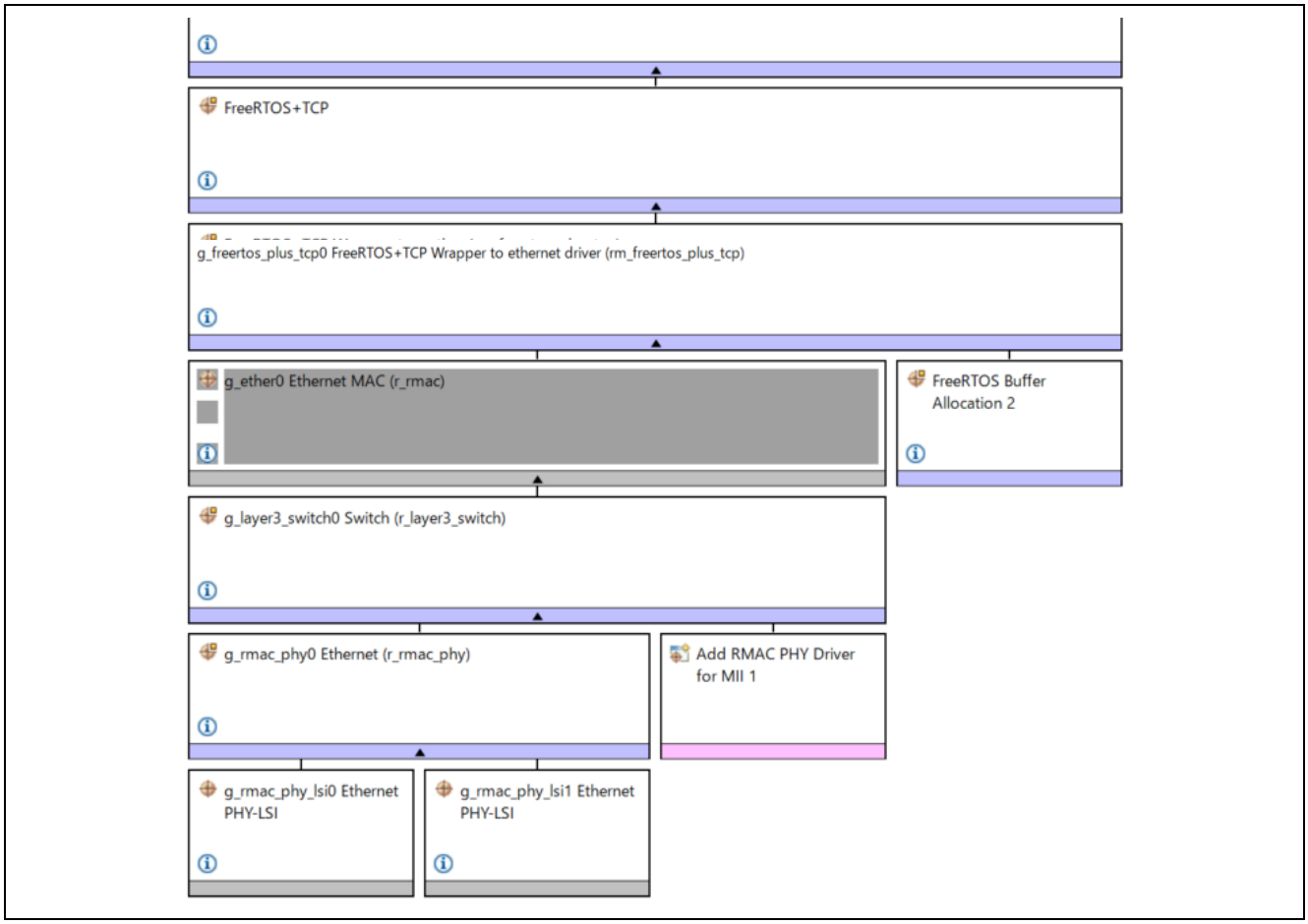
6.2.4 EK-RA8D2 Creating Procedures

This section describes the procedures for creating EK-RA8D2.

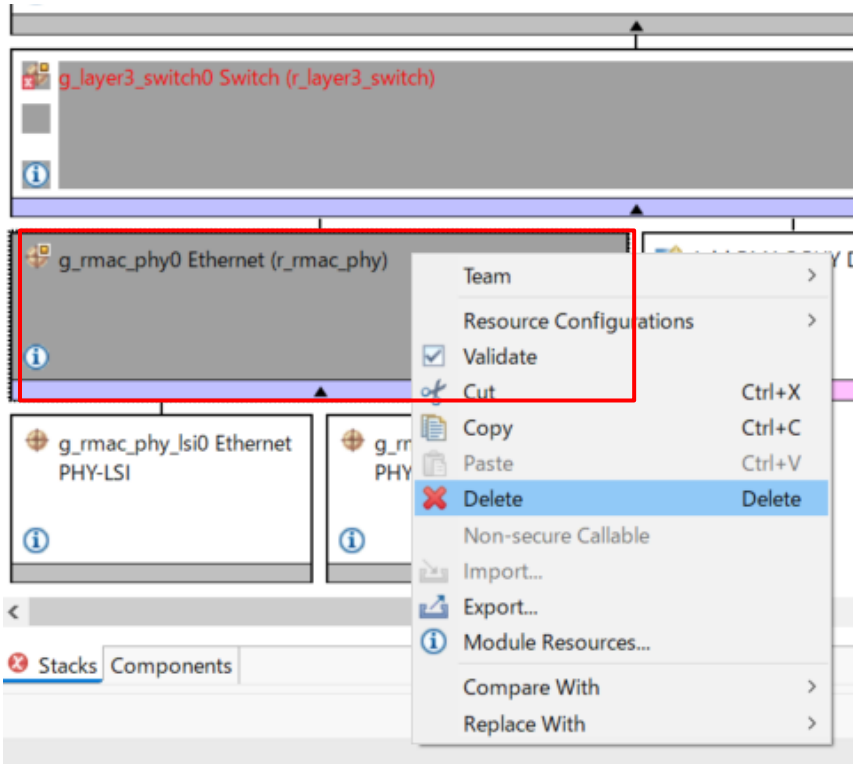
1. Add Ethernet Driver
   Click “New” → “Ethernet (r_rmac)” to “Add Ethernet Driver”.



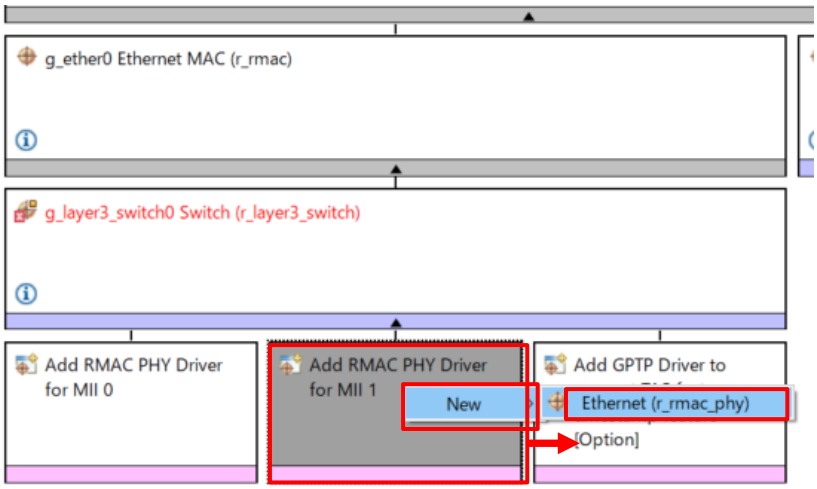
The stack is configured as follows:



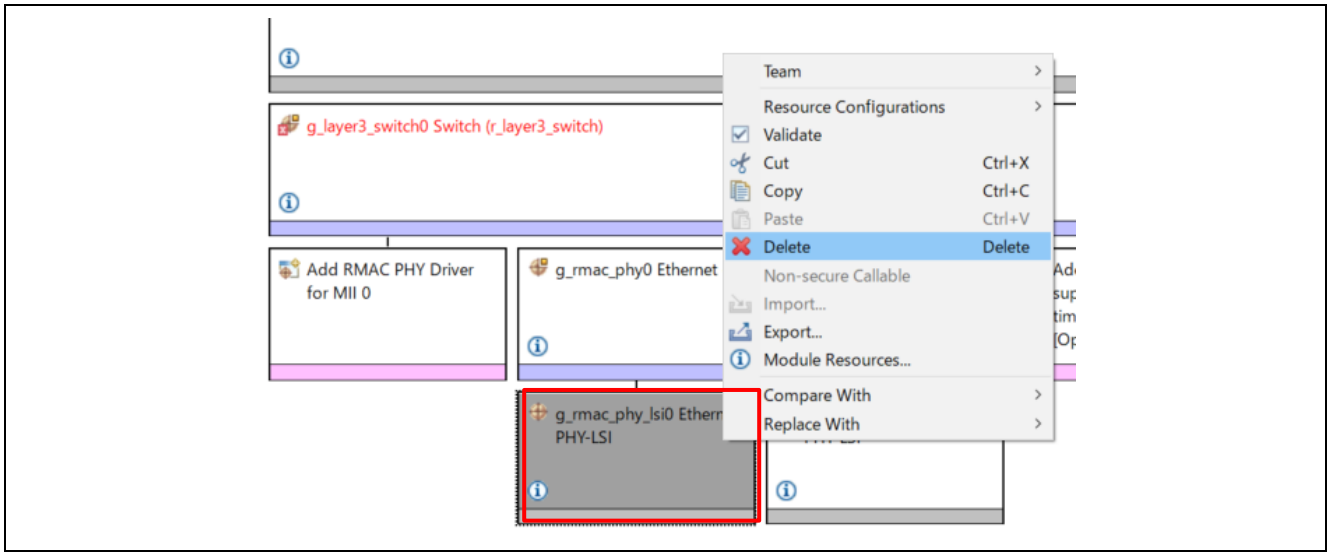
Right-click on “g_mac_phy0 Ethernet (r_rmac_phy)”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.



Click “New” → “Ethernet (r_rmac_phy)” to “Add RMAC PHY Driver for MII1”.

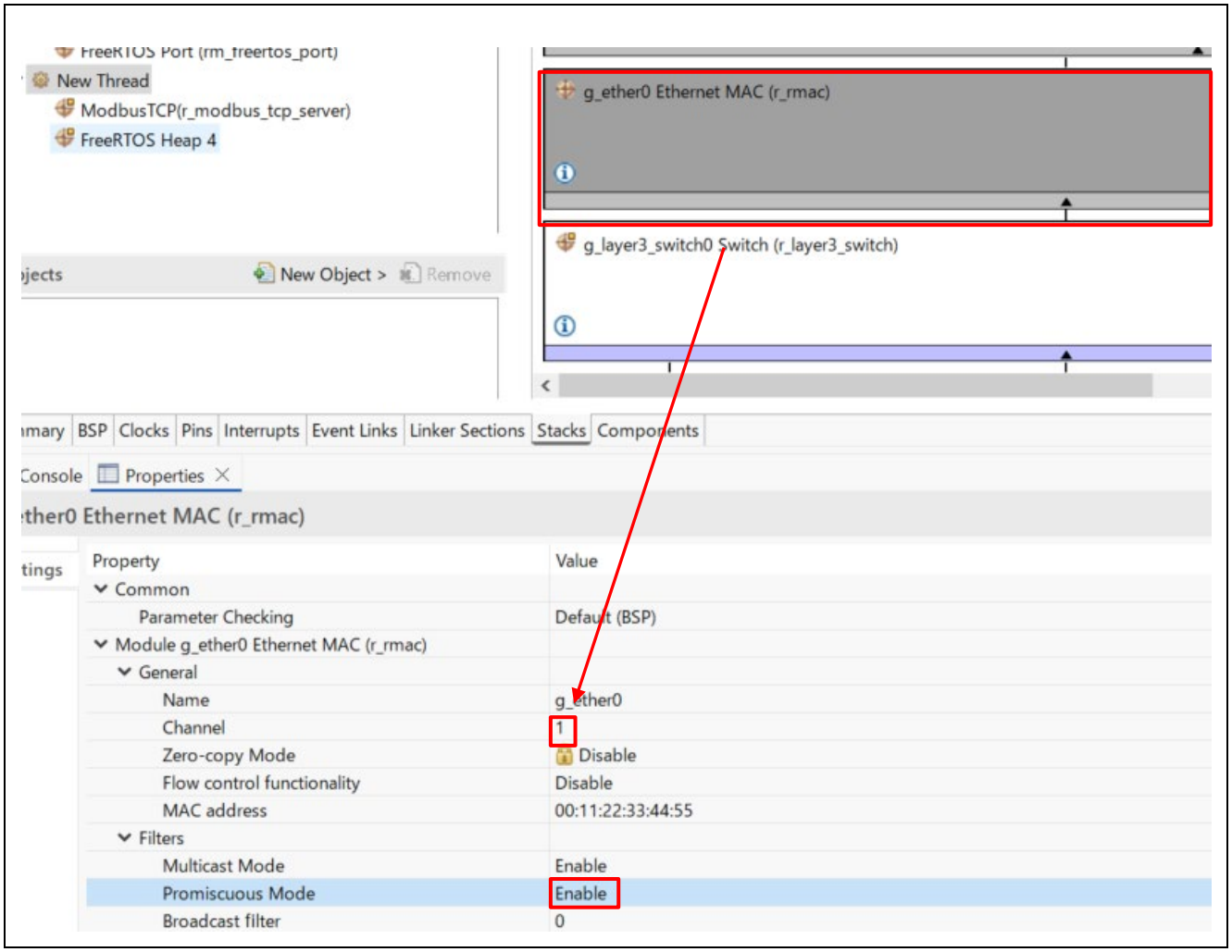


Right-click on “g_rmac_phy_lsi0 Ethernet PHY-LSI”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.



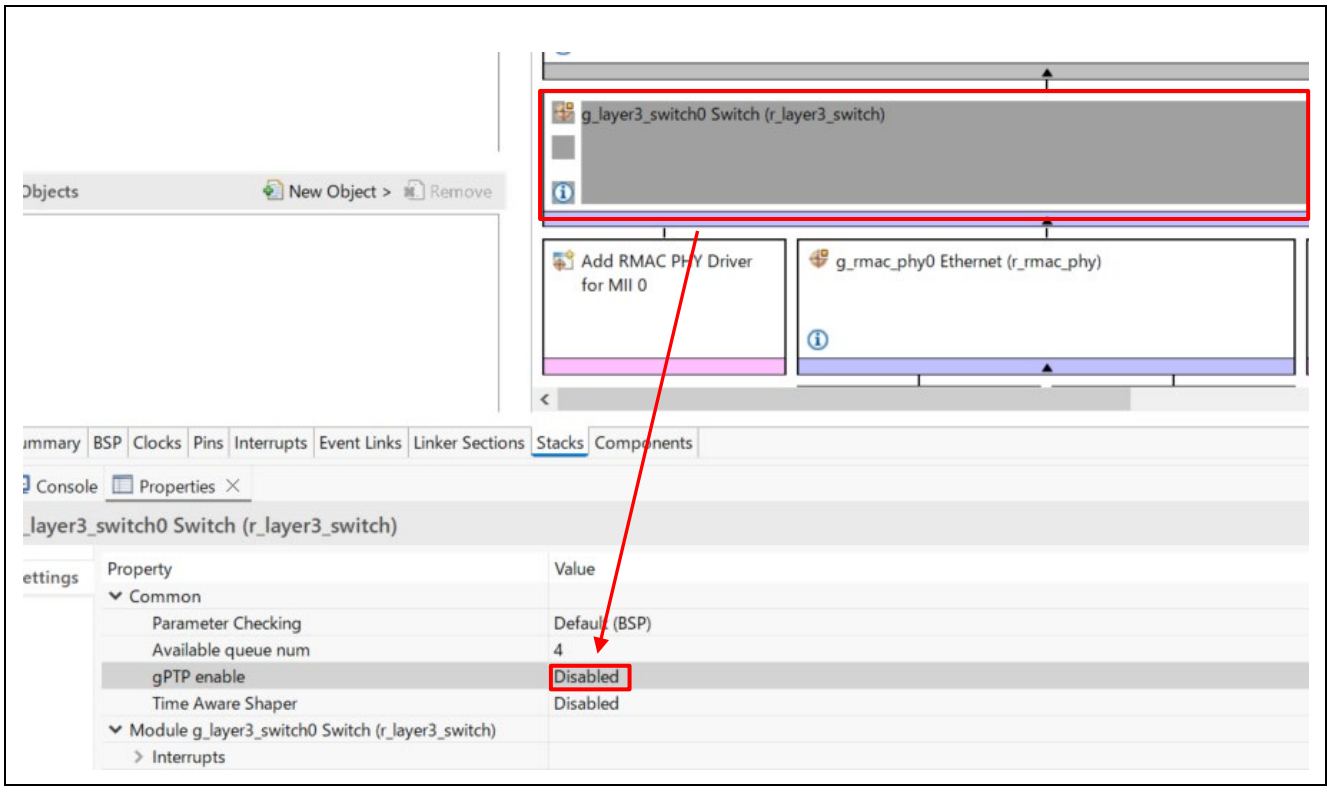
2. Set r_rmac
Open “Properties” of “g_ether0 Ethernet MAC (r_rmac)” in “Stacks” and change “Channel” and “Promiscuous Mode” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

Channel：**1**
Promiscuous Mode：**Enable**



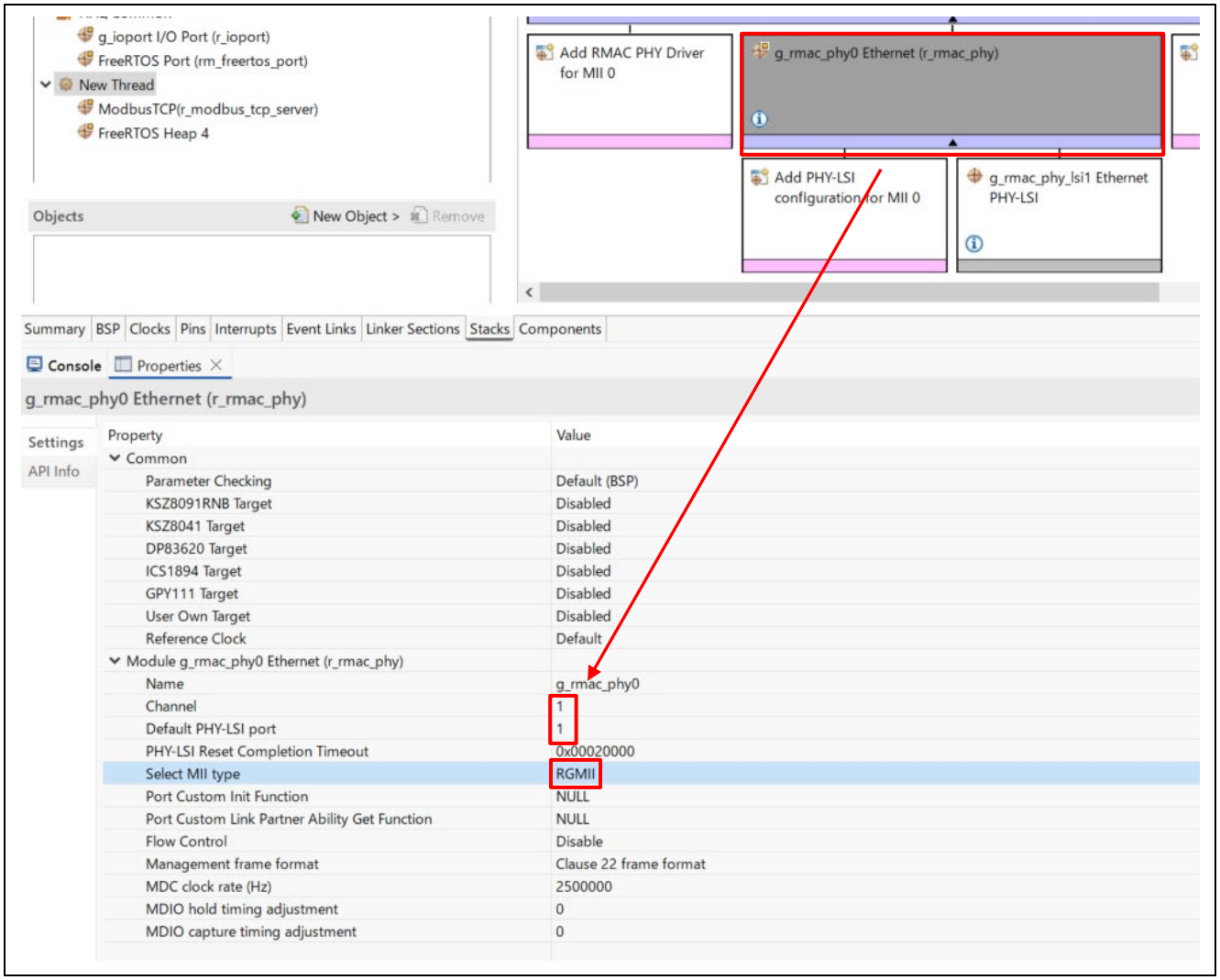
3. Set r_layer3_switch
   Open “Properties” of “g_layer3_switch0 Switch (r_layer3_switch)” in “Stacks” and change “gPTP enable” to the following values.

   gPTP enable：**Disabled**

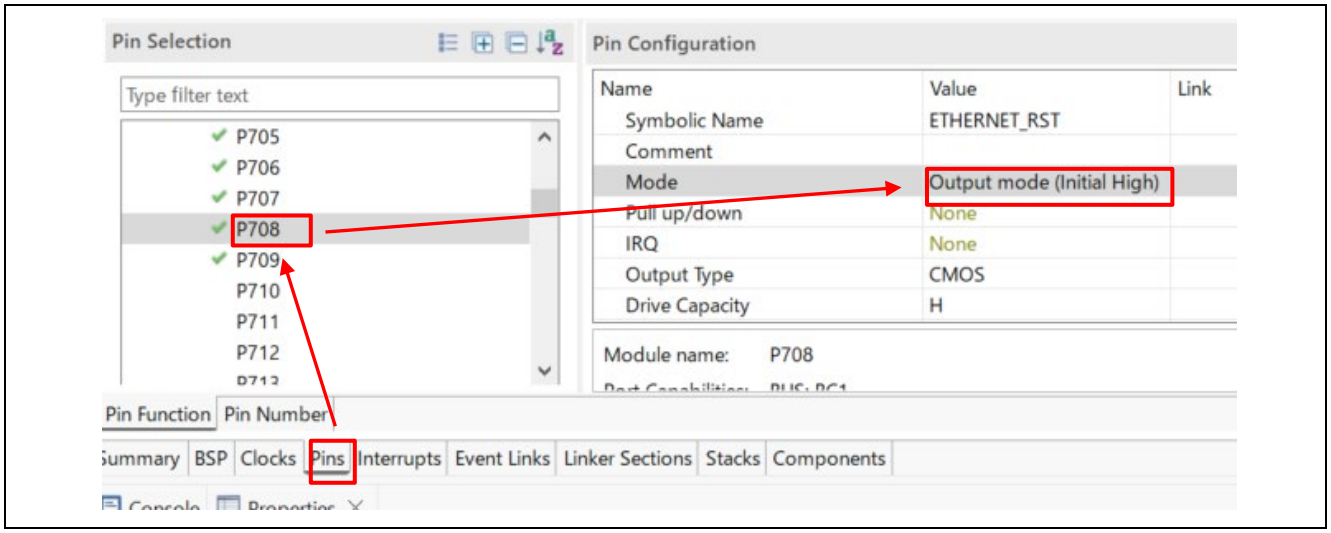


4. Set r_rmac_phy
   Open “Properties” of “g_mac_phy0 Ethernet (r_rmac_phy)” in “Stacks” and change “Channel”, “Default PHY-LSI port”, and “Select MII type” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

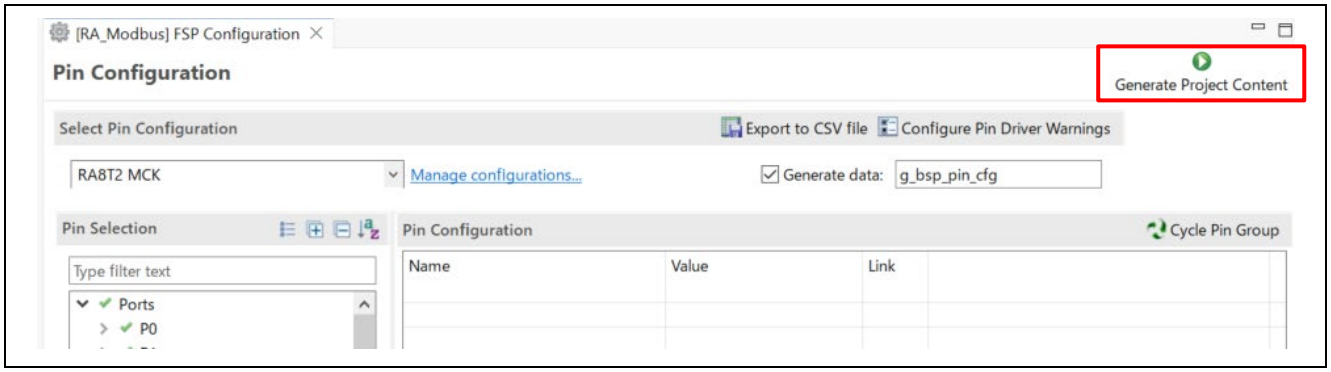
   Channel：**1**
   Default PHY-LSI port：**1**
   Select MII type：**RGMII**



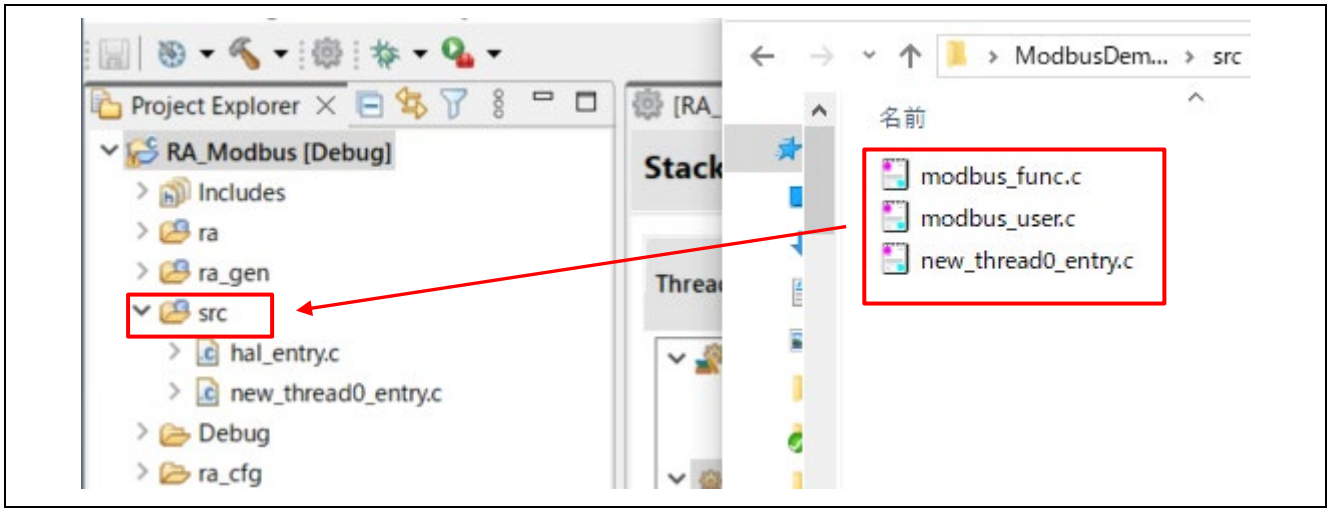
5. Set PHY Reset Terminals
   Change the "Mode" of “Pins” → ”Ports” → ”P7” → "P708" to "Output mode (Initial High)".

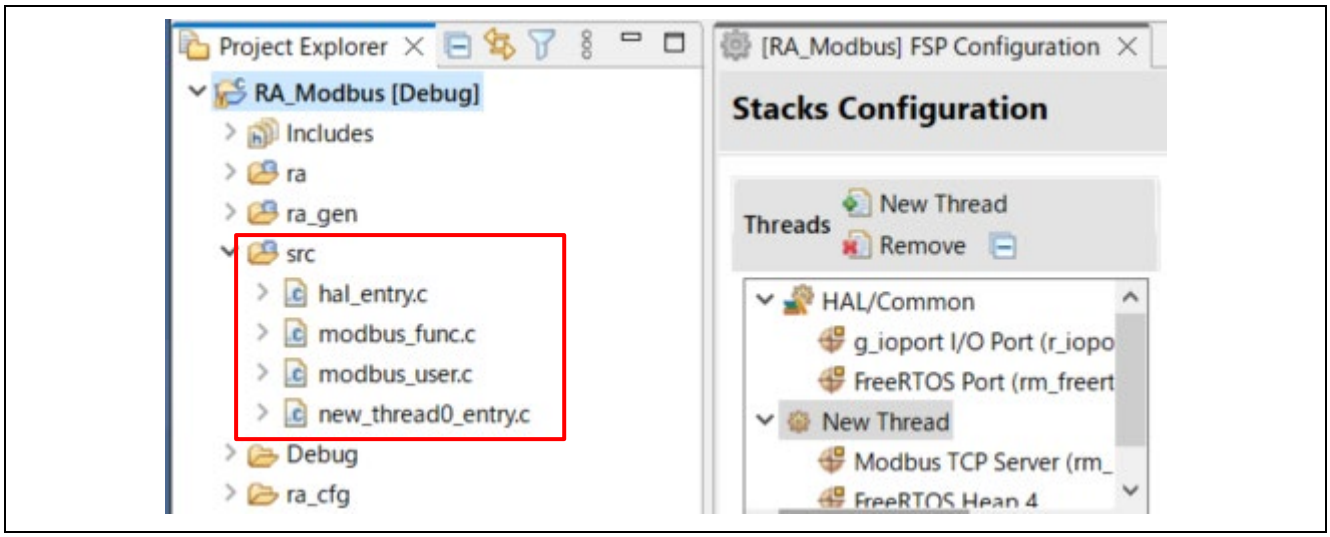


6. Generate the code
   Generate the code with "Generate Project Content".



7. Add Modbus Sample Application
   Copy modbus_func.c, modbus_user.c, and new_thread0_entry.c from the src folder of the sample program package to the src folder of the project and overwrite them.

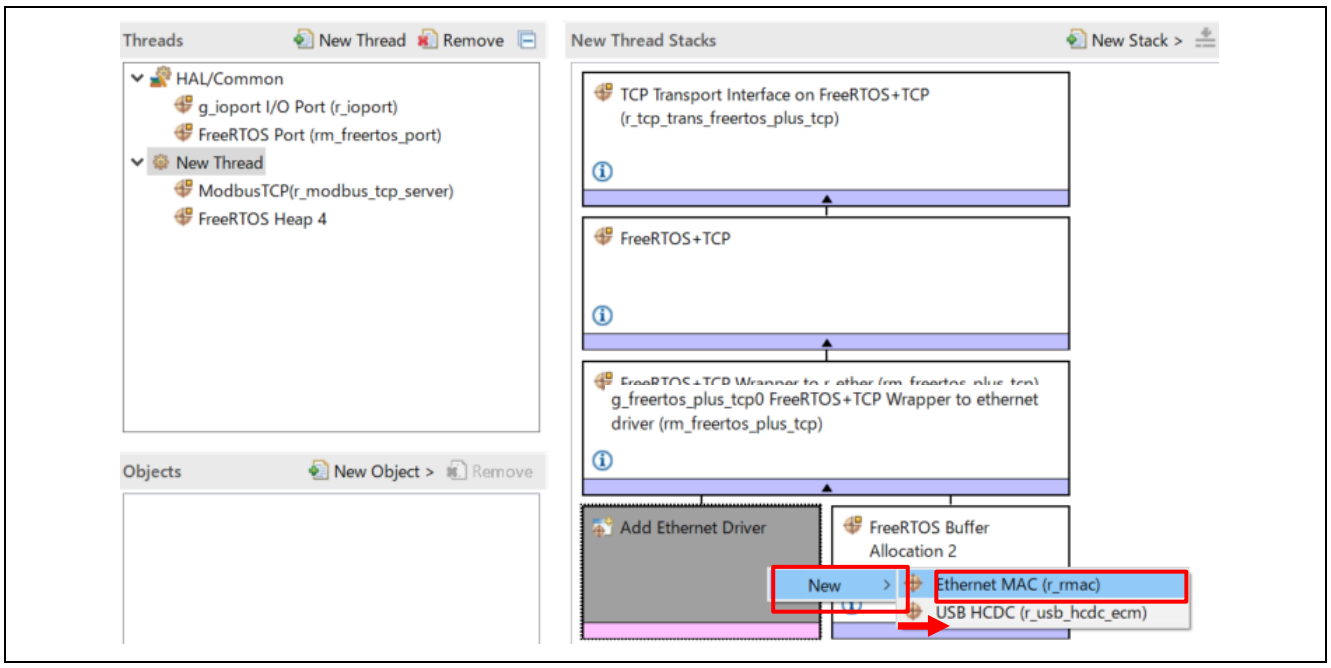




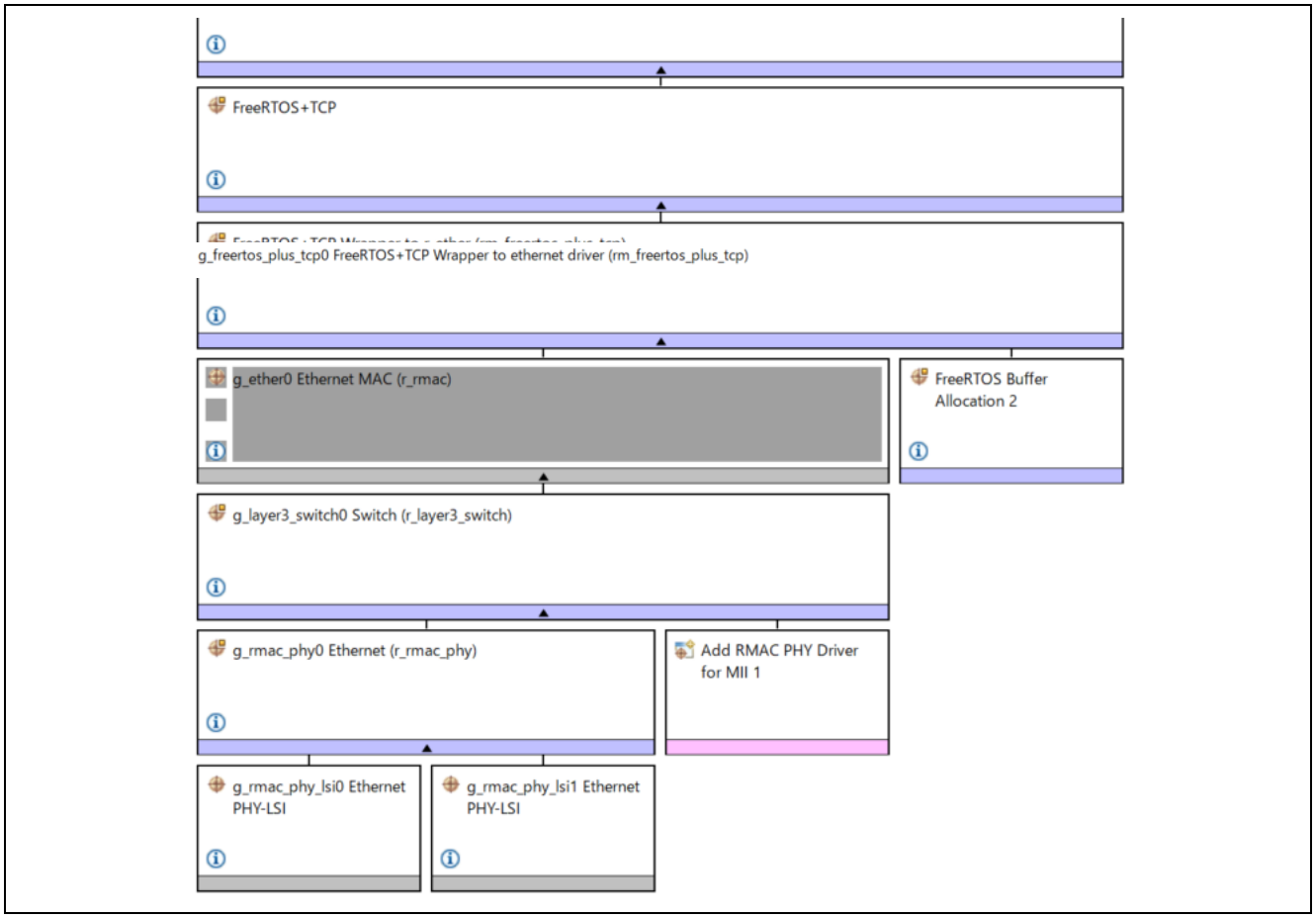
6.2.5 EK-RA8P1 Creating Procedures

This section describes the procedures for creating EK-RA8P1.

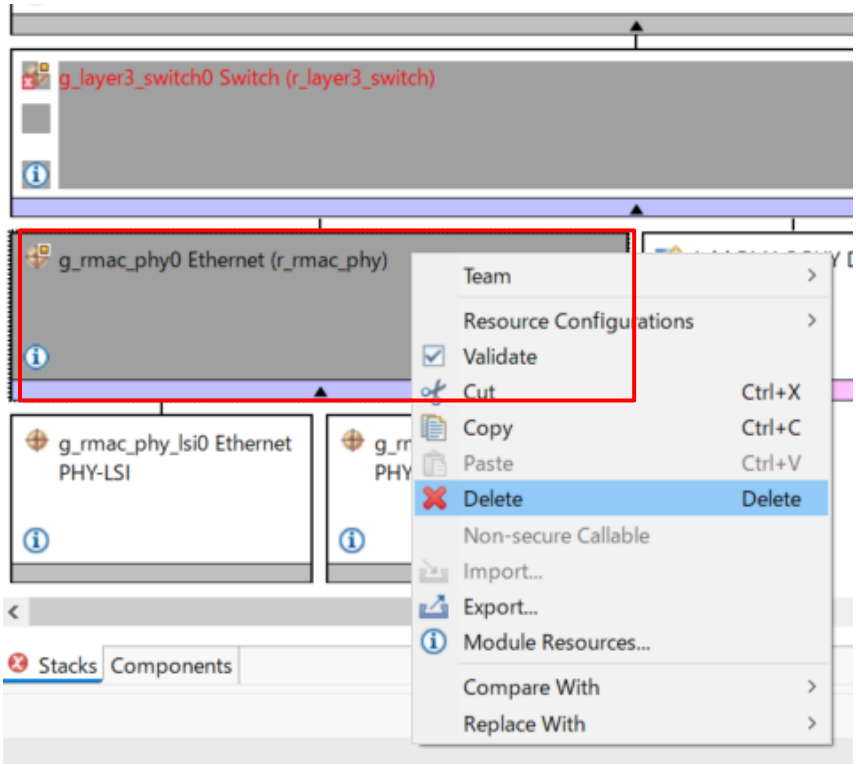
1. Add Ethernet Driver
   Click “New” → “Ethernet (r_rmac)” to “Add Ethernet Driver”.



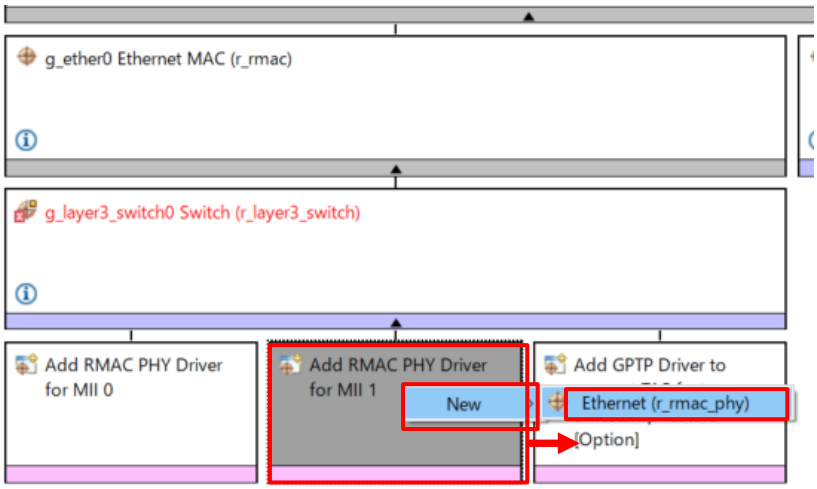
The stack is configured as follows:



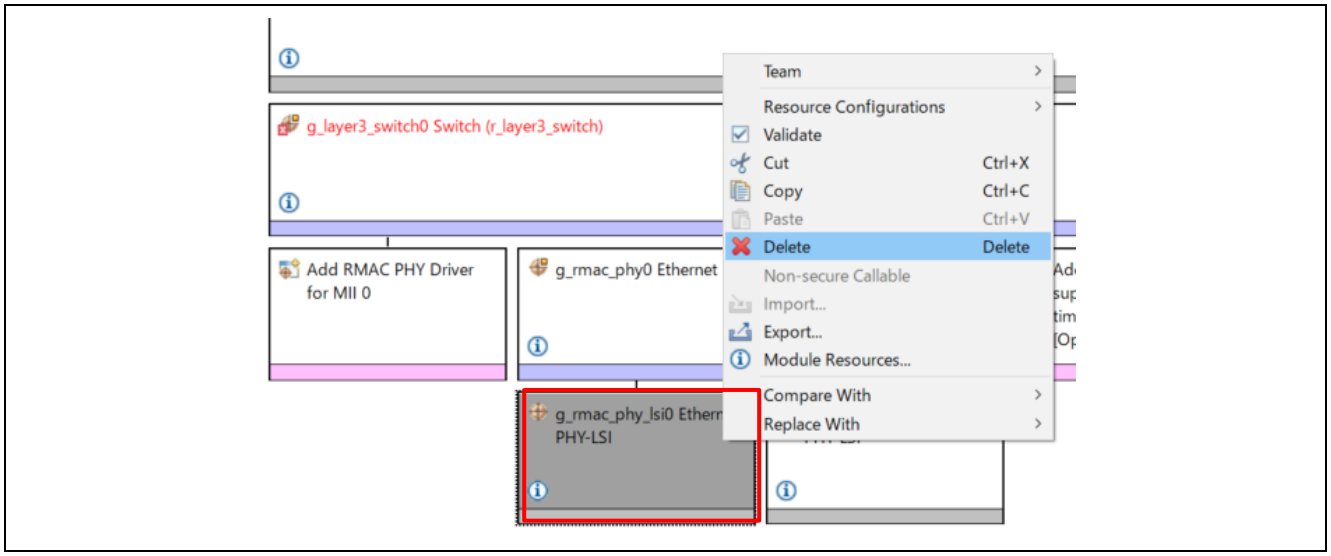
Right-click on “g_mac_phy0 Ethernet (r_rmac_phy)”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.



Click “New” → “Ethernet (r_rmac_phy)” to “Add RMAC PHY Driver for MII1”.

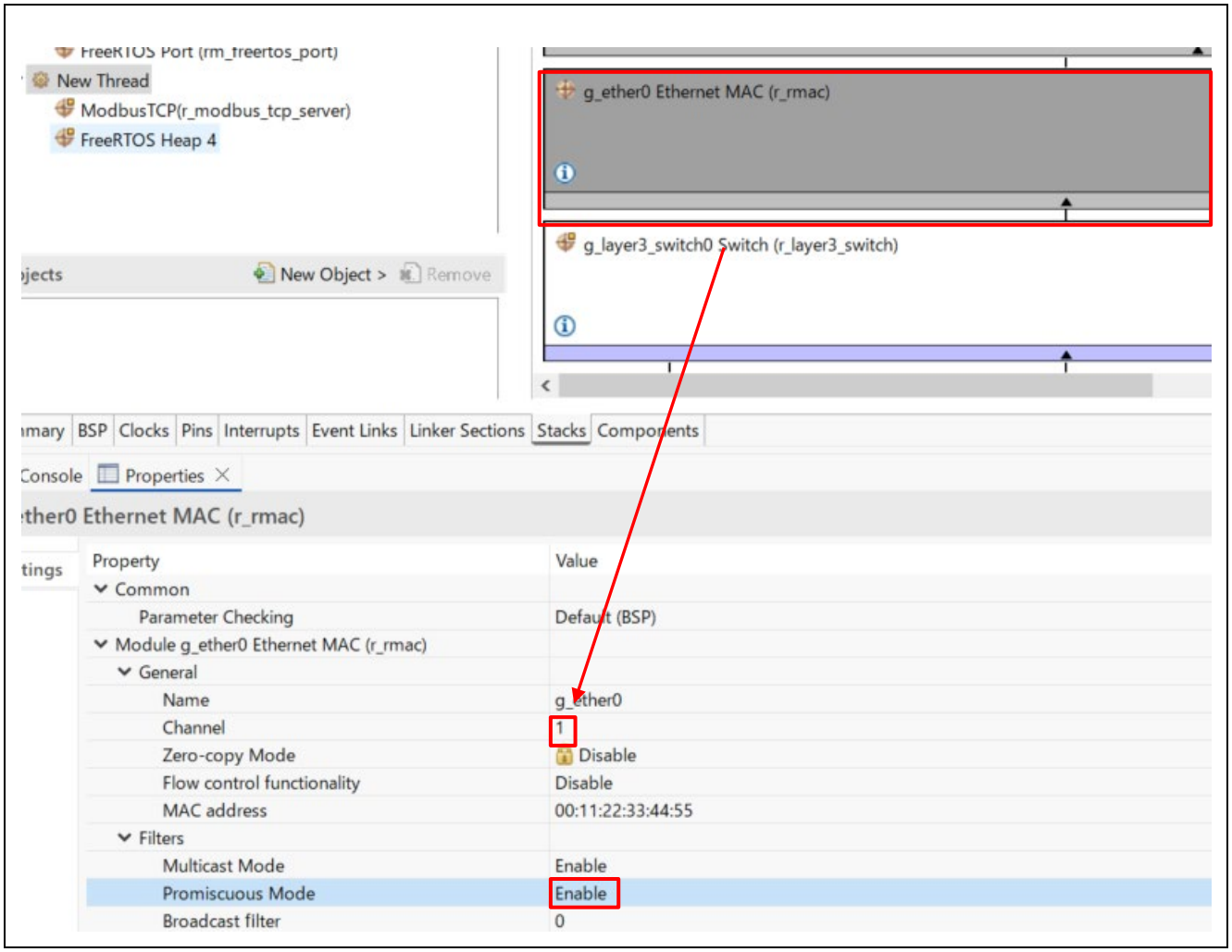


Right-click on “g_rmac_phy_lsi0 Ethernet PHY-LSI”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.



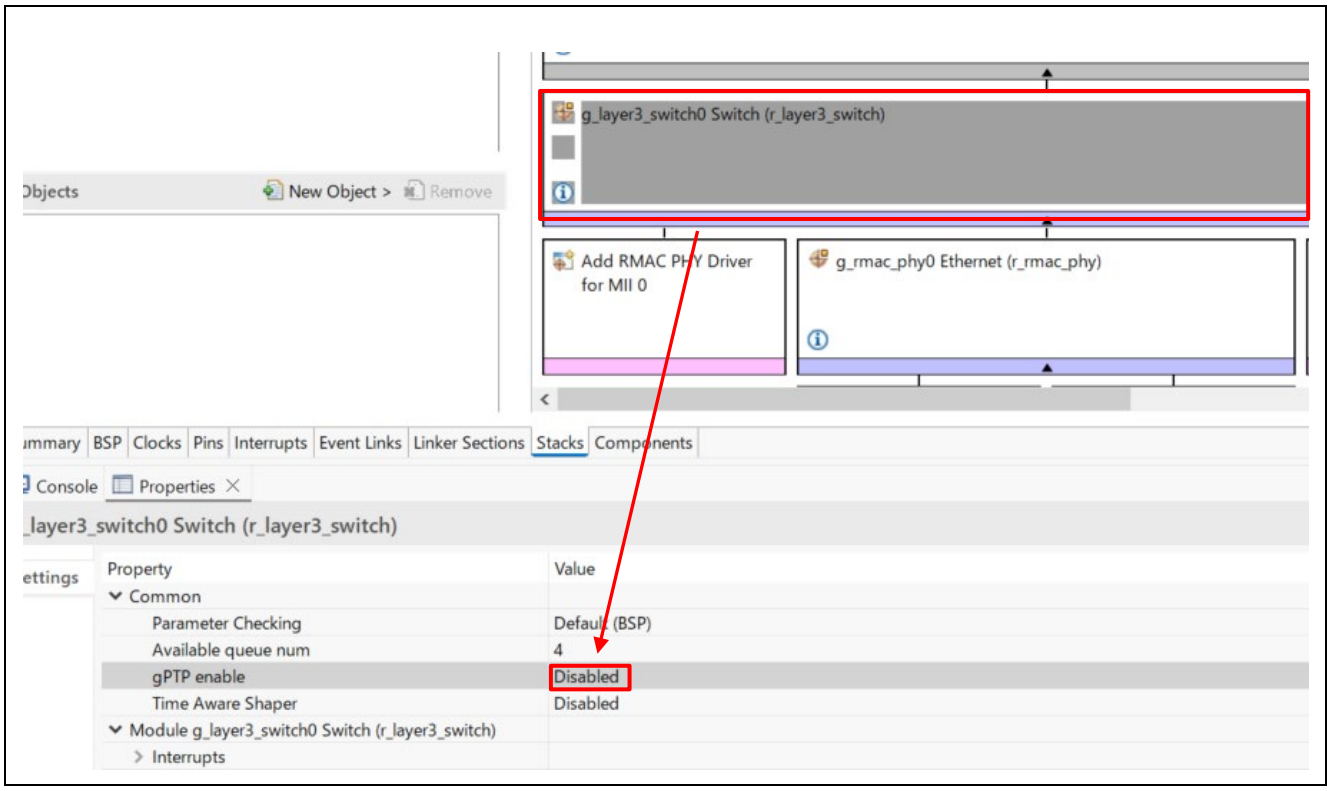
2. Set r_rmac
   Open “Properties” of “g_ether0 Ethernet MAC (r_rmac)” in “Stacks” and change “Channel” and “Promiscuous Mode” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

   Channel：**1**
   Promiscuous Mode：**Enable**



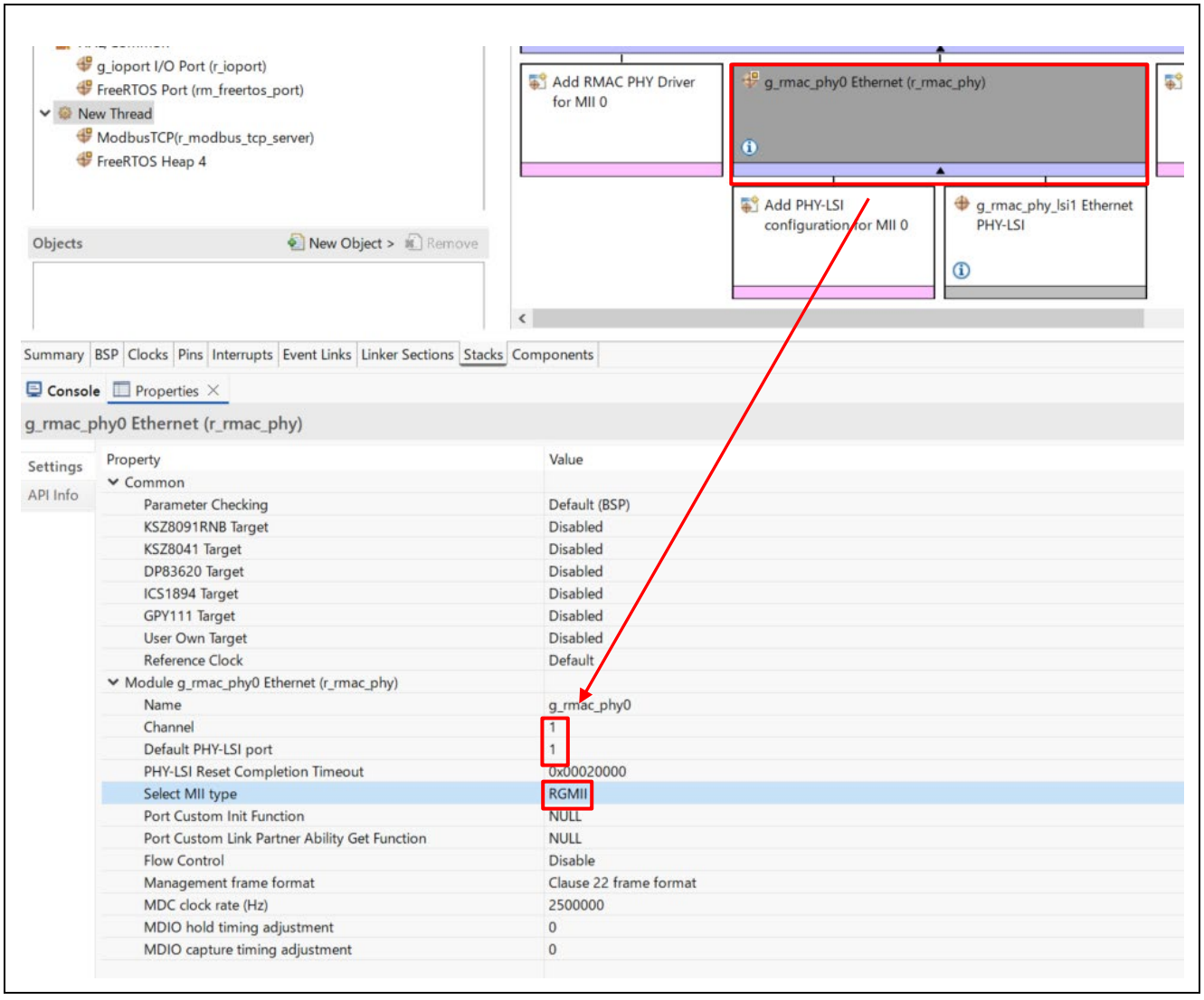
3. Set r_layer3_switch
   Open “Properties” of “g_layer3_switch0 Switch (r_layer3_switch)” in “Stacks” and change “gPTP enable” to the following values.

   gPTP enable：**Disabled**

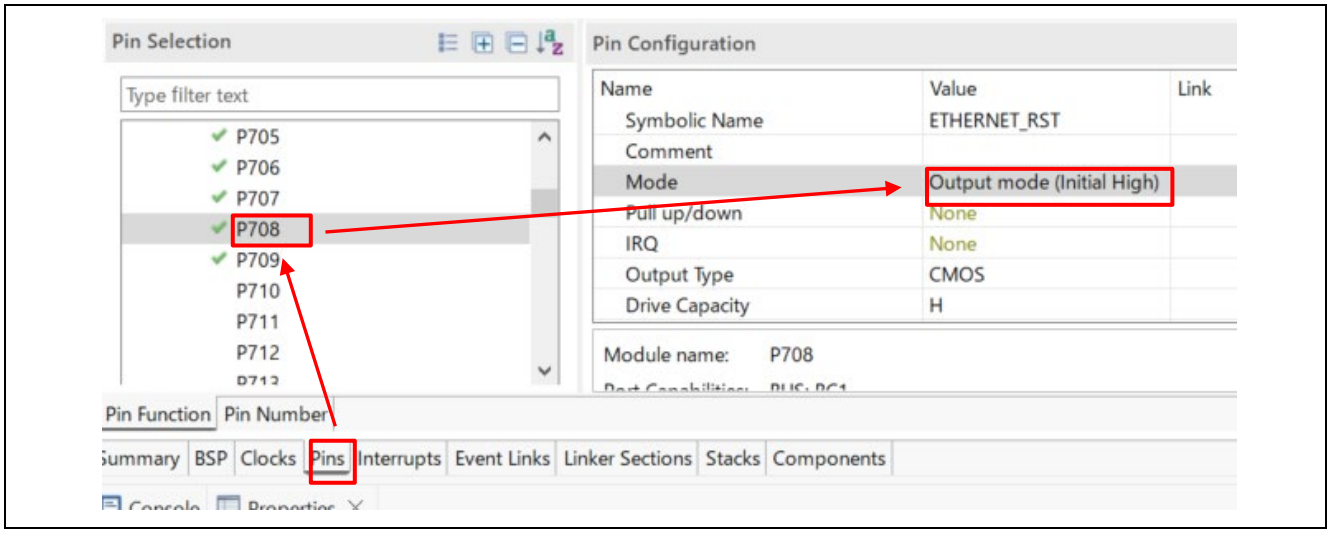


4. Set r_rmac_phy
   Open “Properties” of “g_mac_phy0 Ethernet (r_rmac_phy)” in “Stacks” and change “Channel”, “Default PHY-LSI port”, and “Select MII type” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

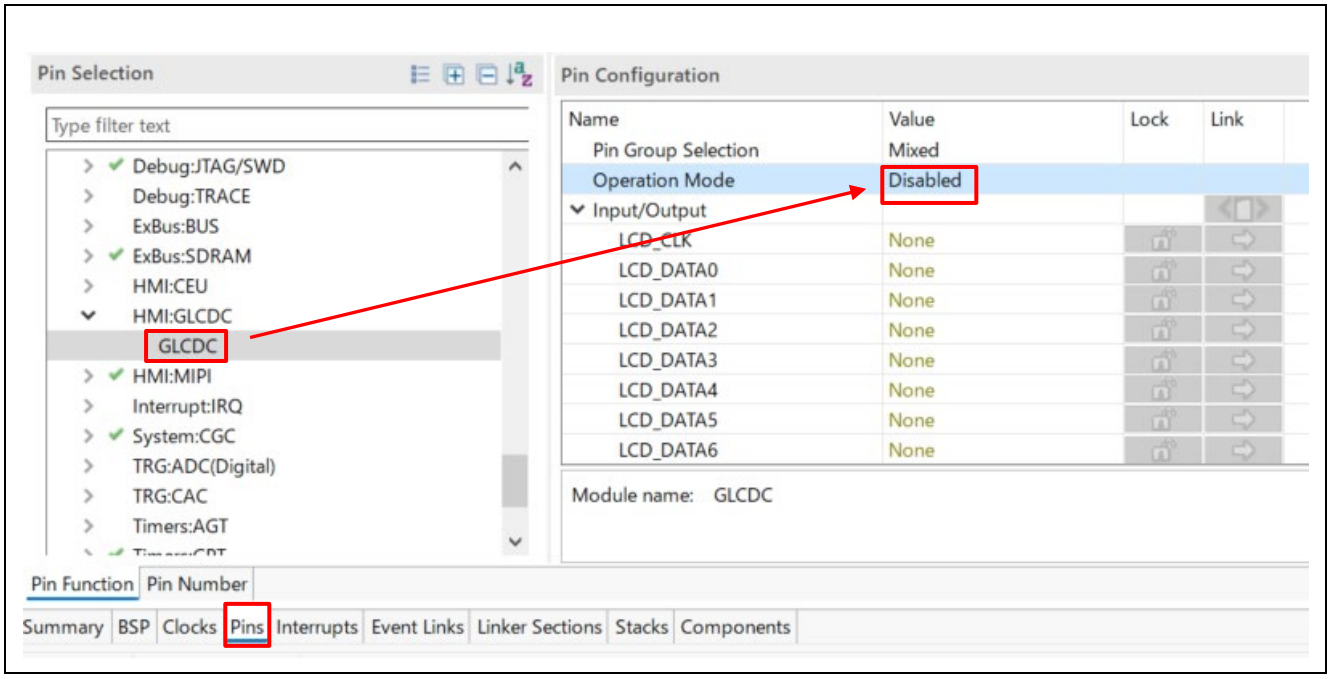
   Channel：**1**
   Default PHY-LSI port：**1**
   Select MII type：**RGMII**



5. Set PHY Reset Terminals
   Change the "Mode" of “Pins” → ”Ports” → ”P7” → "P708" to "Output mode (Initial High)".

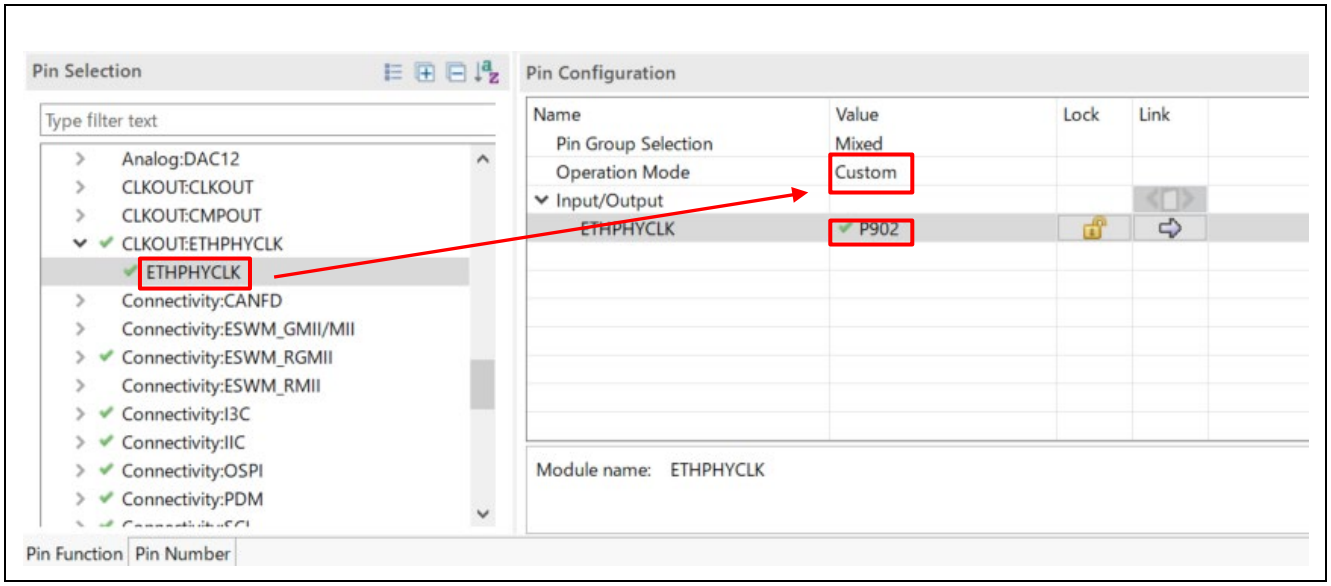


6. Set PHY Clock Terminals
Change the "Operation Mode" of “Pins” → ”Peripherals” → ” HMI: GLCDC” → " GLCDC " to "Disabled".

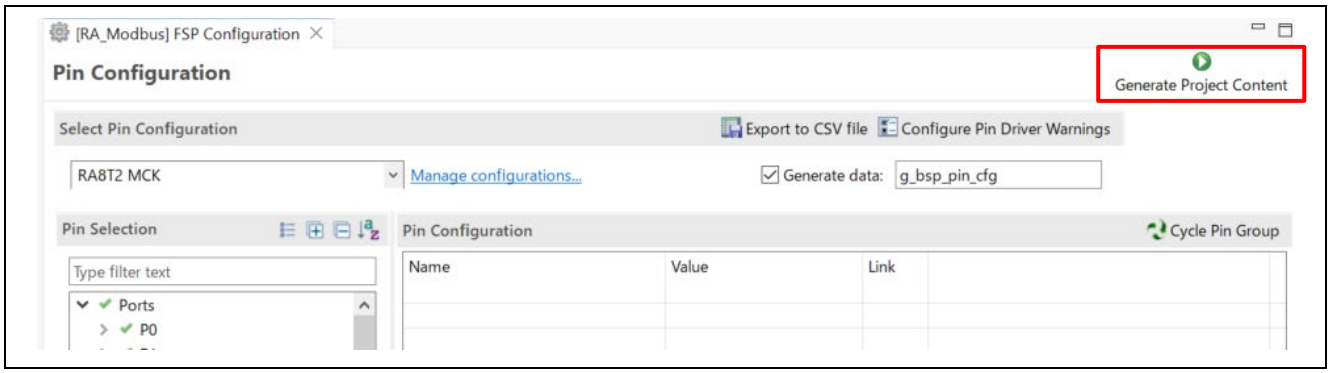


After changing the "Operation Mode" of "Pins" → "Peripherals" → " CLKOUT: ETHPHYCLK " → " ETHPHYCLK " to "Custom", change the pins as follows:

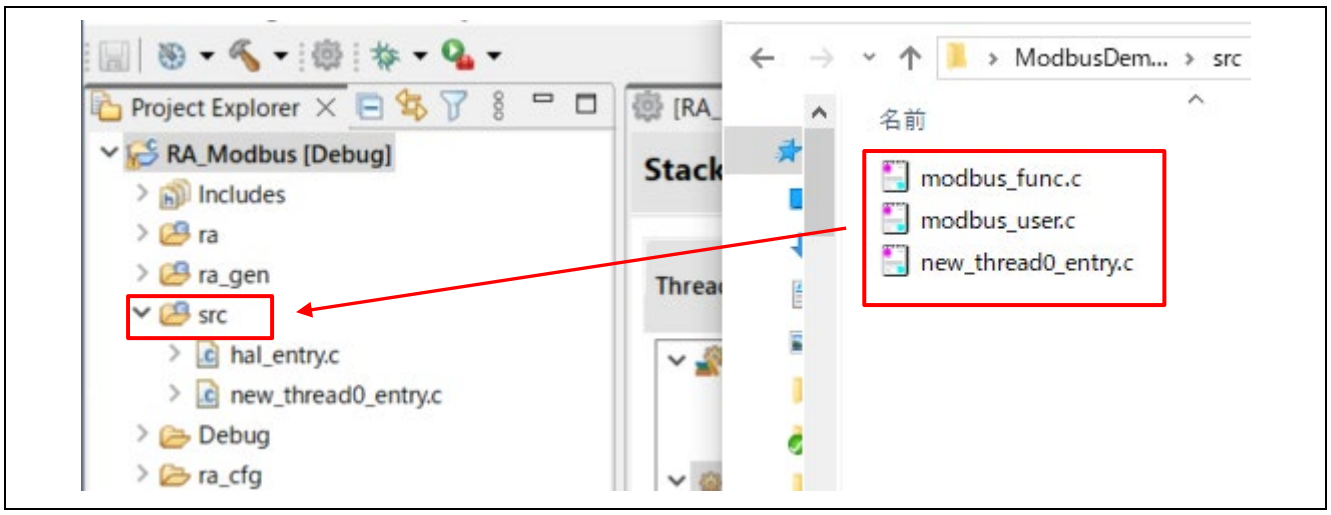
ETHPHYCLK：**P902**

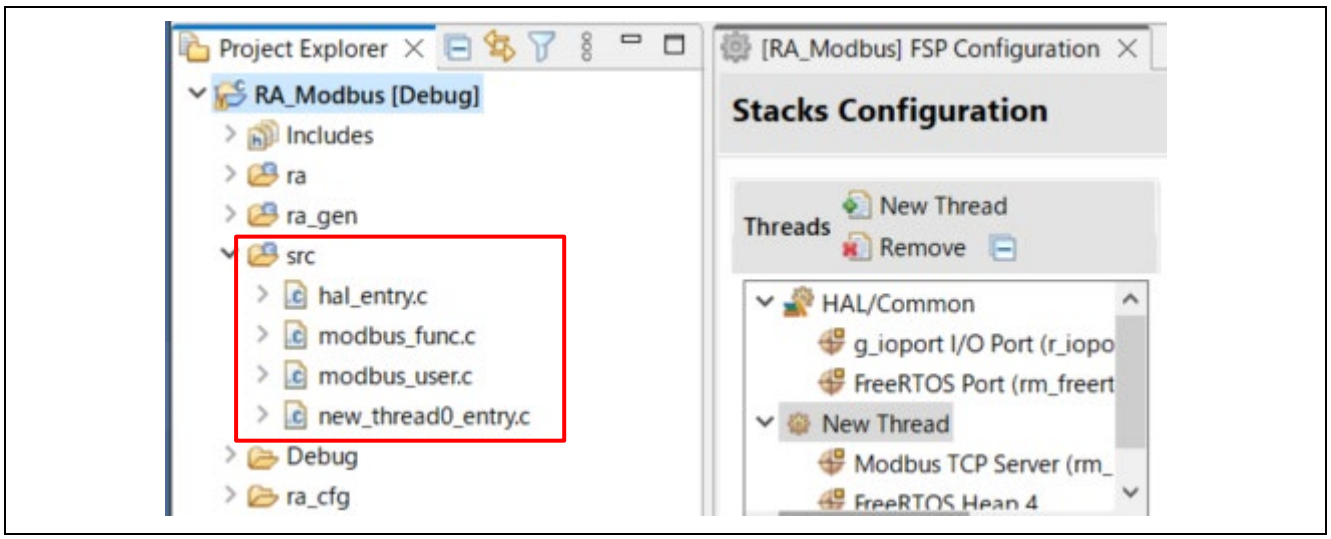


7. Generate the code
   Generate the code with "Generate Project Content".



8. Add Modbus Sample Application
   Copy modbus_func.c, modbus_user.c, and new_thread0_entry.c from the src folder of the sample program package to the src folder of the project and overwrite them.

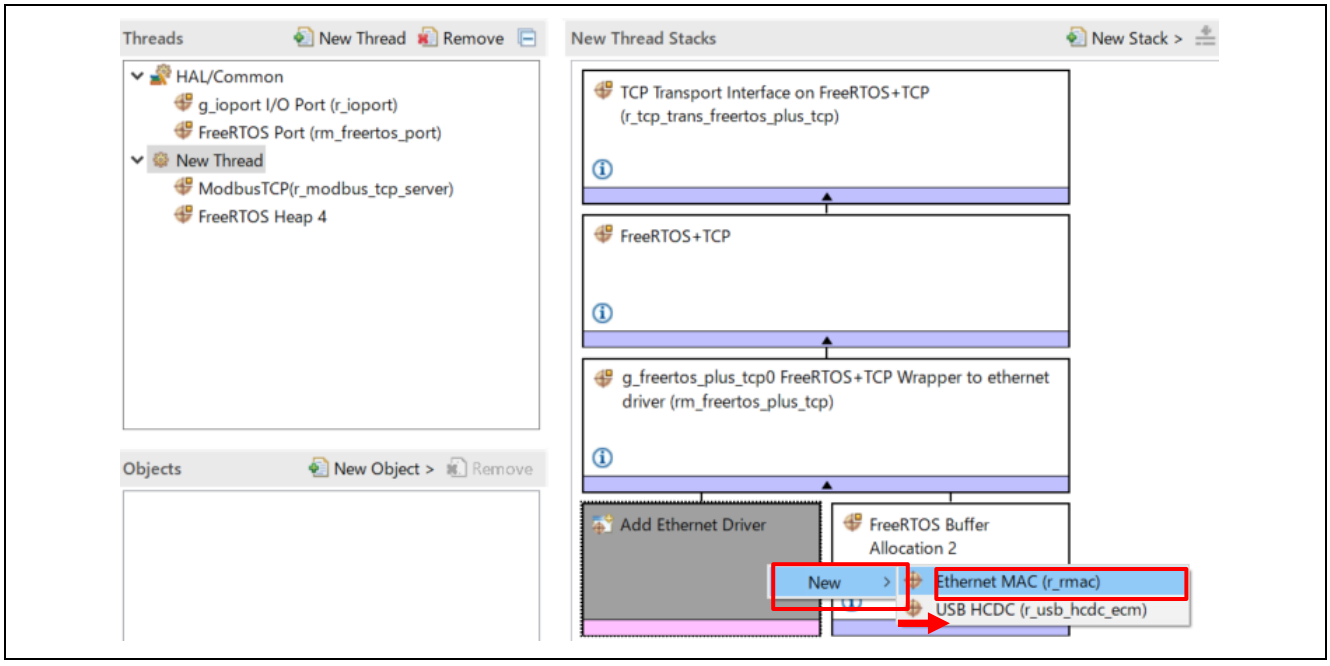




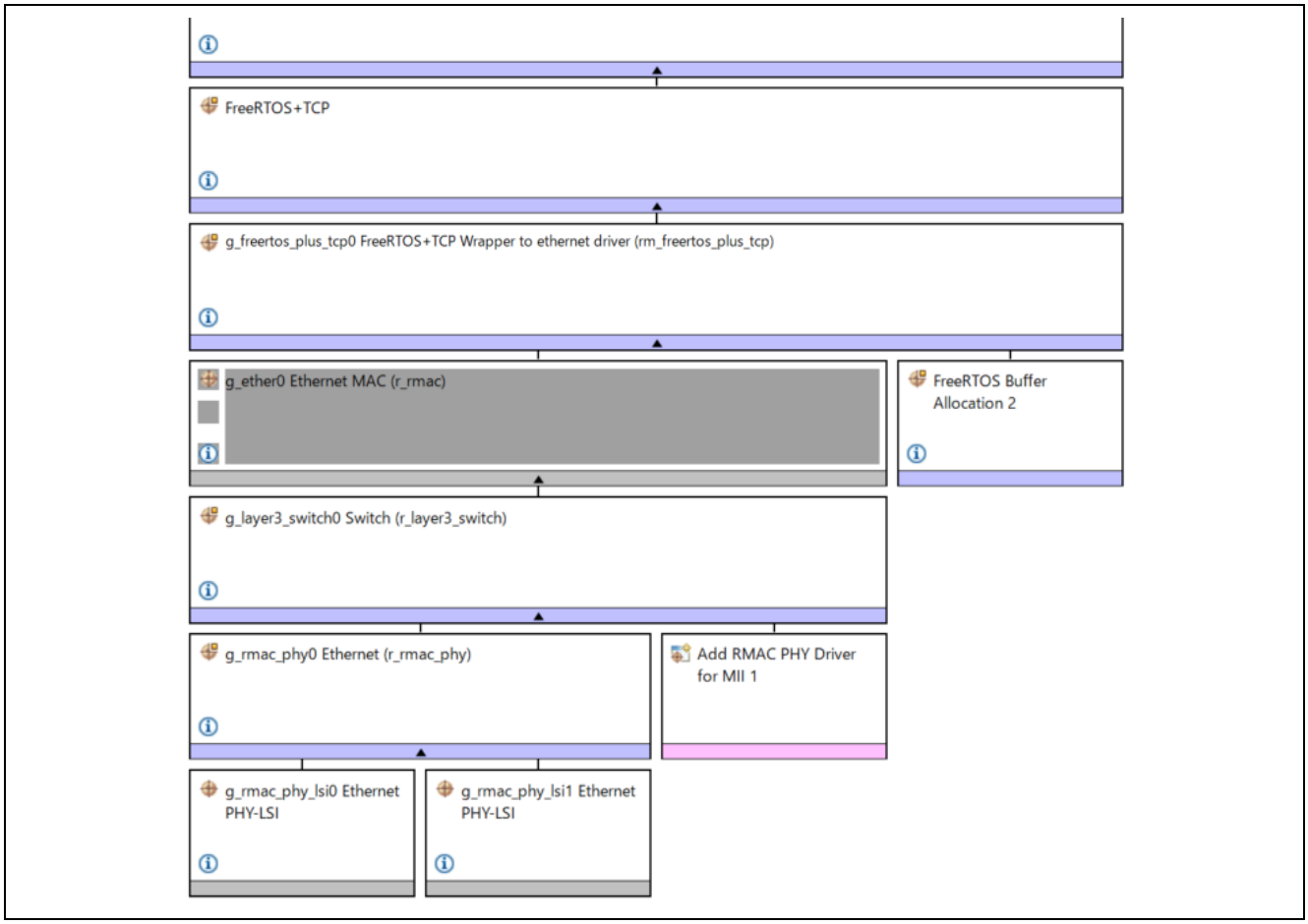
6.2.6 EK-RA8M2 Creating Procedures

This section describes the procedures for creating EK-RA8M2.

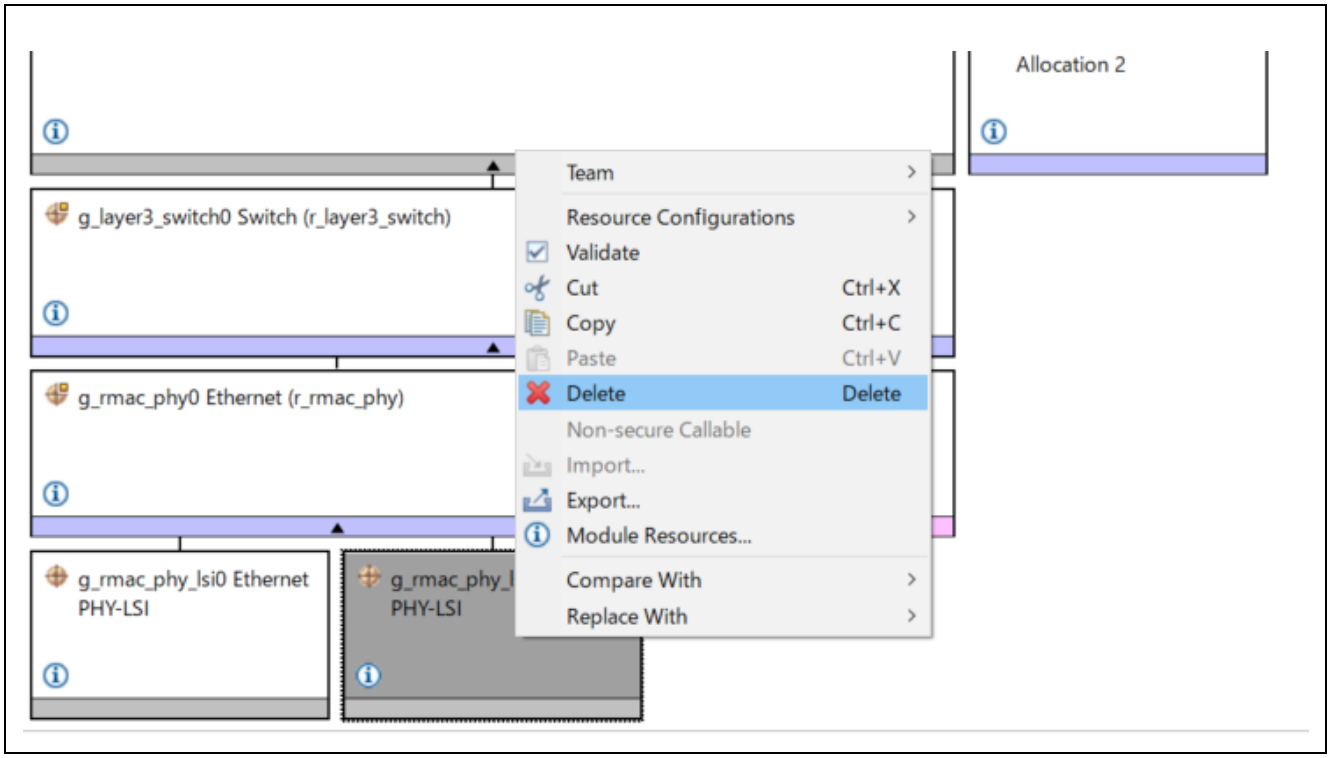
1. Add Ethernet Driver
   Click “New” → “Ethernet (r_rmac)” to “Add Ethernet Driver”.



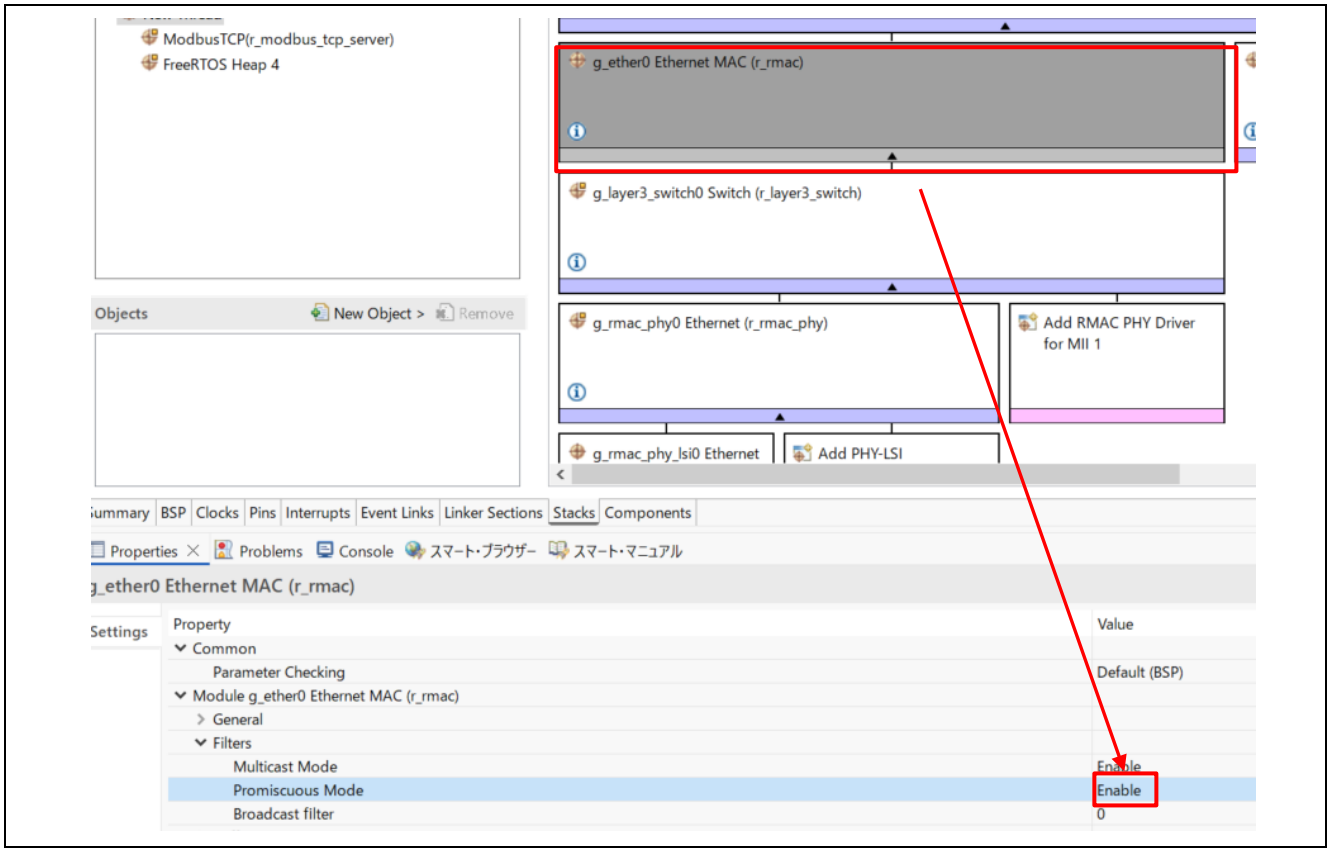
The stack is configured as follows:



Right-click on “g_rmac_phy_lsi1 Ethernet PHY-LSI”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.

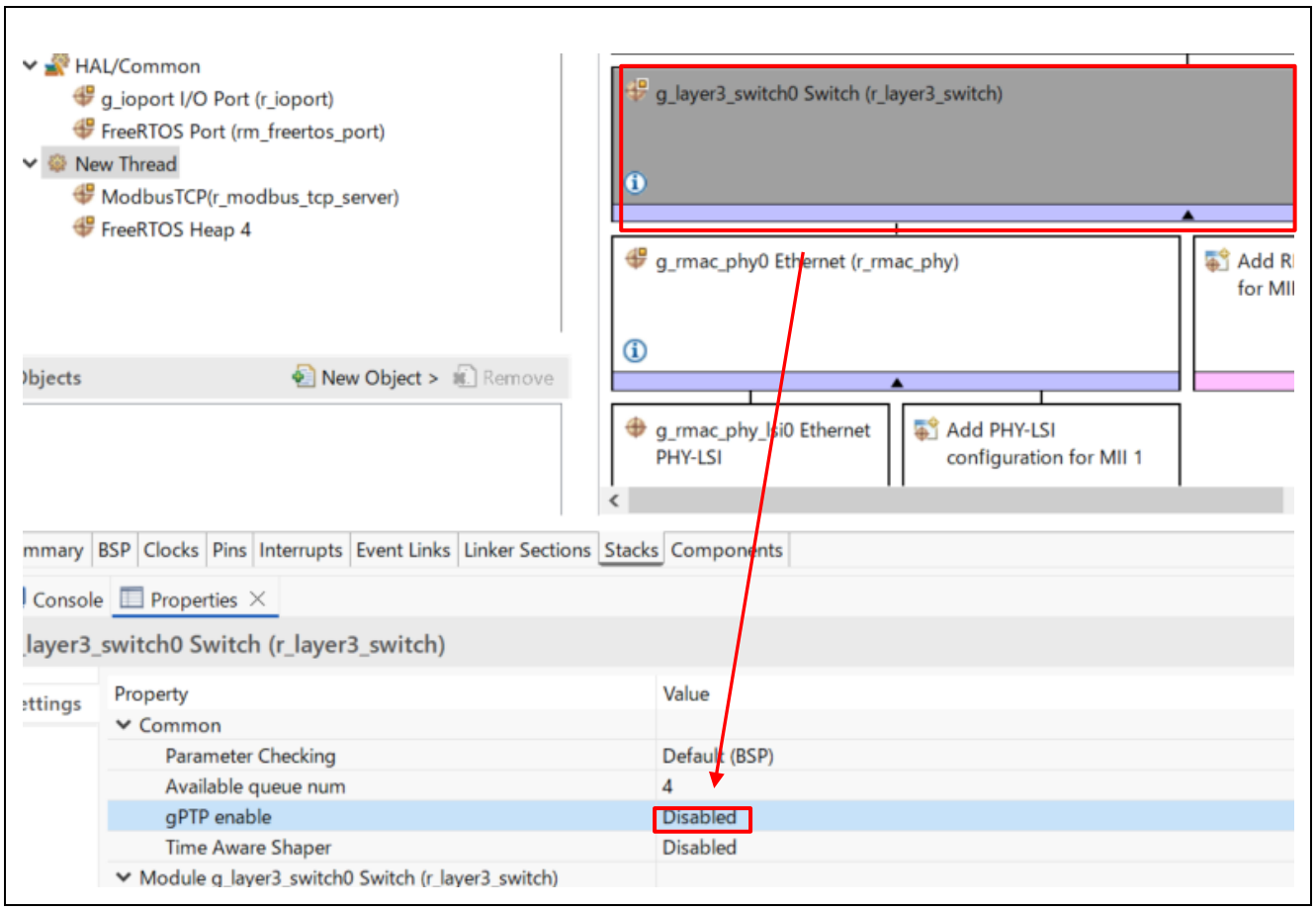


2. Set r_rmac
Change the “Stacks” → ”g_ether0 Ethernet MAC (r_rmac)” → ”Module g_ether0 Ethernet MAC (r_rmac)” → “Promiscuous Mode” in “Filters” to “Enable”.



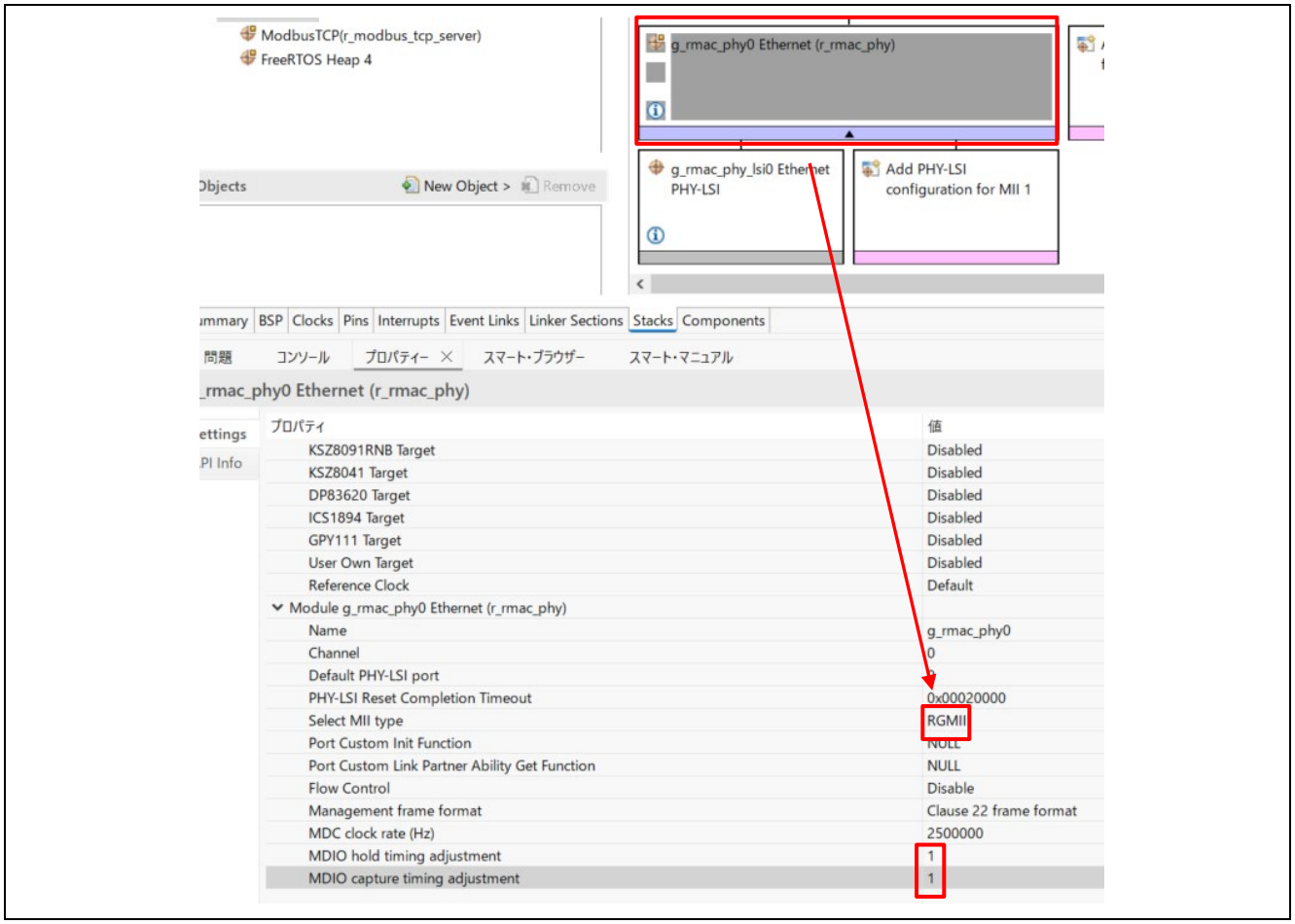
3. Set r_layer3_switch
   Open “Properties” of “g_layer3_switch0 Switch (r_layer3_switch)” in “Stacks” and change “gPTP enable” to the following values.

   gPTP enable：**Disabled**

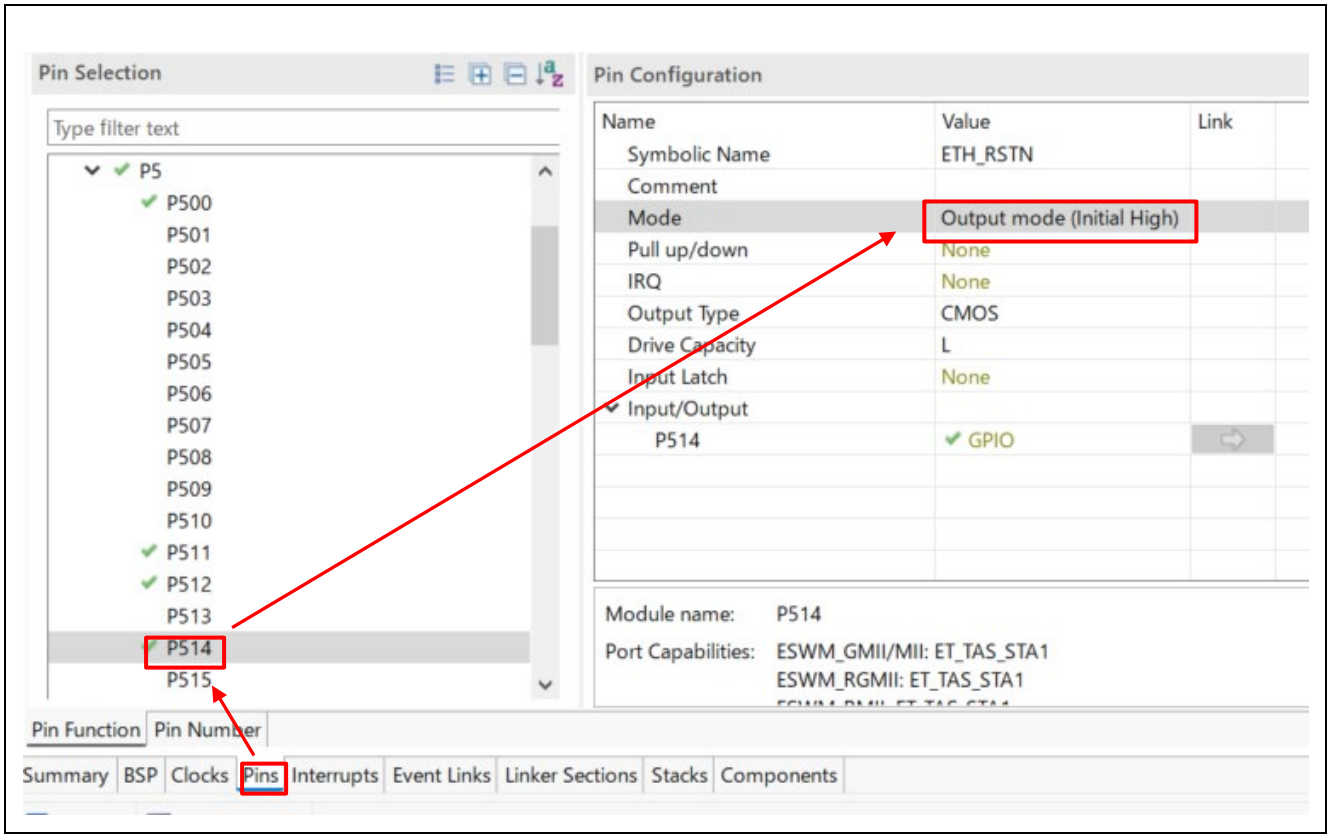


4. Set r_rmac_phy
   Open “Properties” of “g_mac_phy0 Ethernet (r_rmac_phy)” in “Stacks” and change “Select MII type”, ” MDIO hold timing adjustment”, and “MDIO capture timing adjustment” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

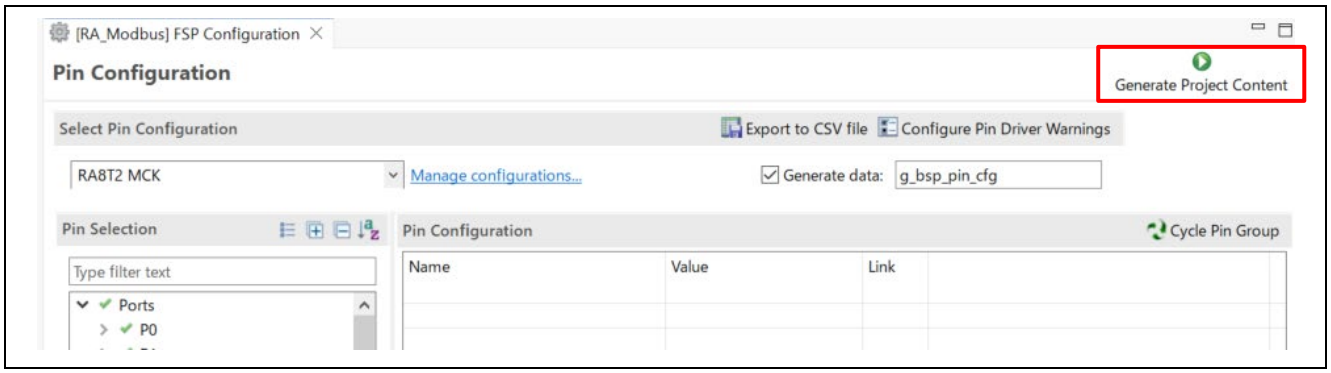
   Select MII type：**RGMII**
   MDIO holds timing adjustment：**1**
   MDIO capture timing adjustment：**1**



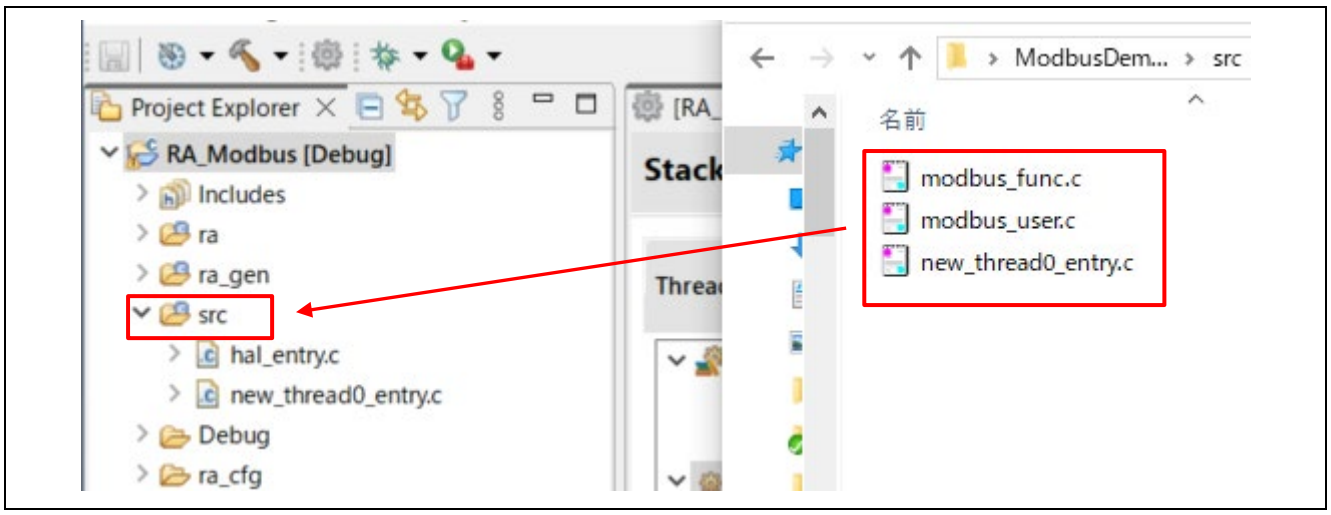
5. Set PHY Reset Terminals
   Change the "Mode" of “Pins” → ”Ports” → ”P5” → "P514" to "Output mode (Initial High)".

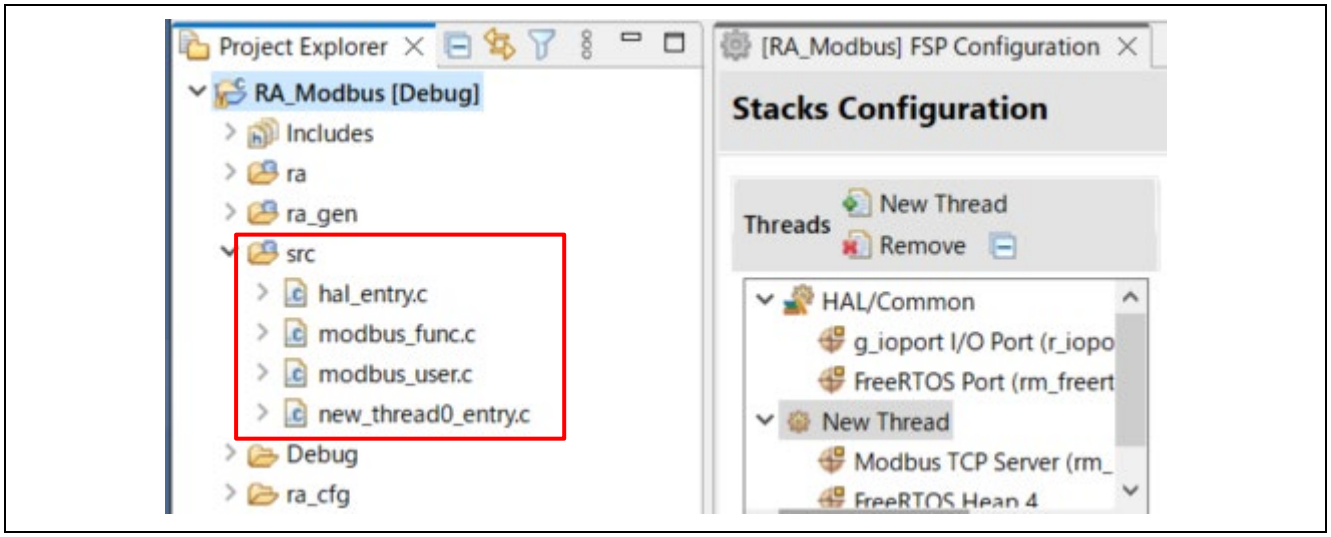


6. Generate the code
   Generate the code with "Generate Project Content".



7. Add Modbus Sample Application
   Copy modbus_func.c, modbus_user.c, and new_thread0_entry.c from the src folder of the sample program package to the src folder of the project and overwrite them.

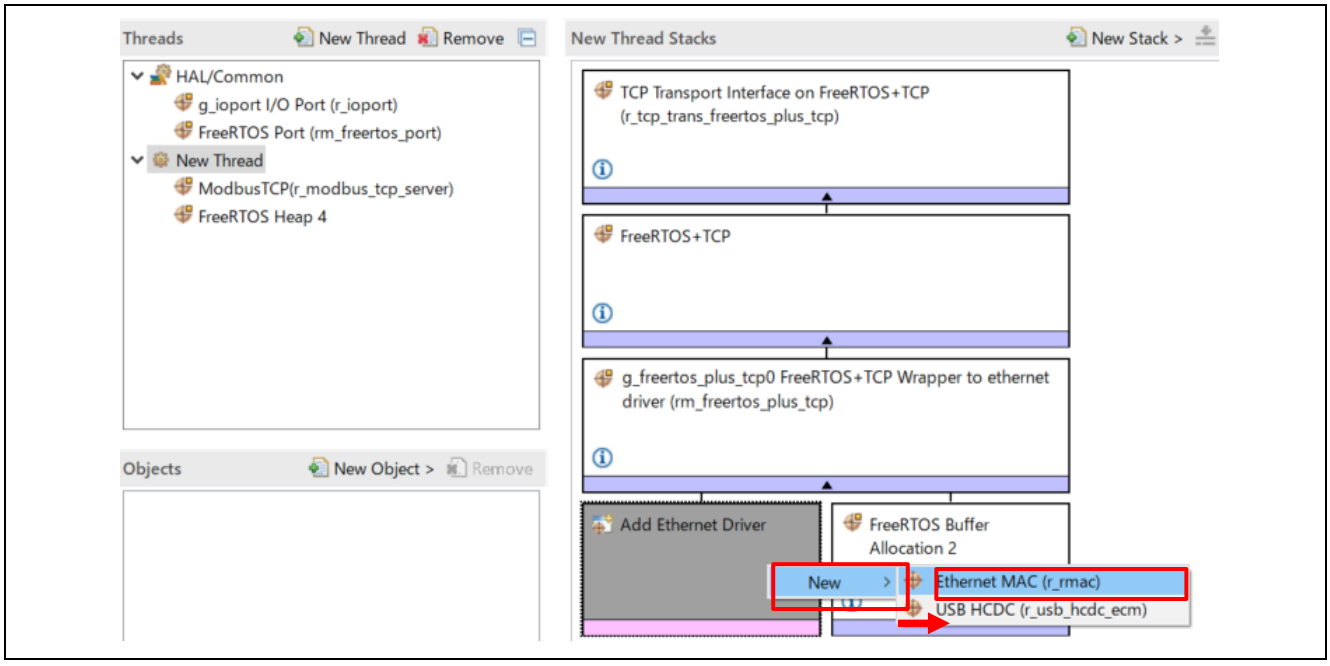




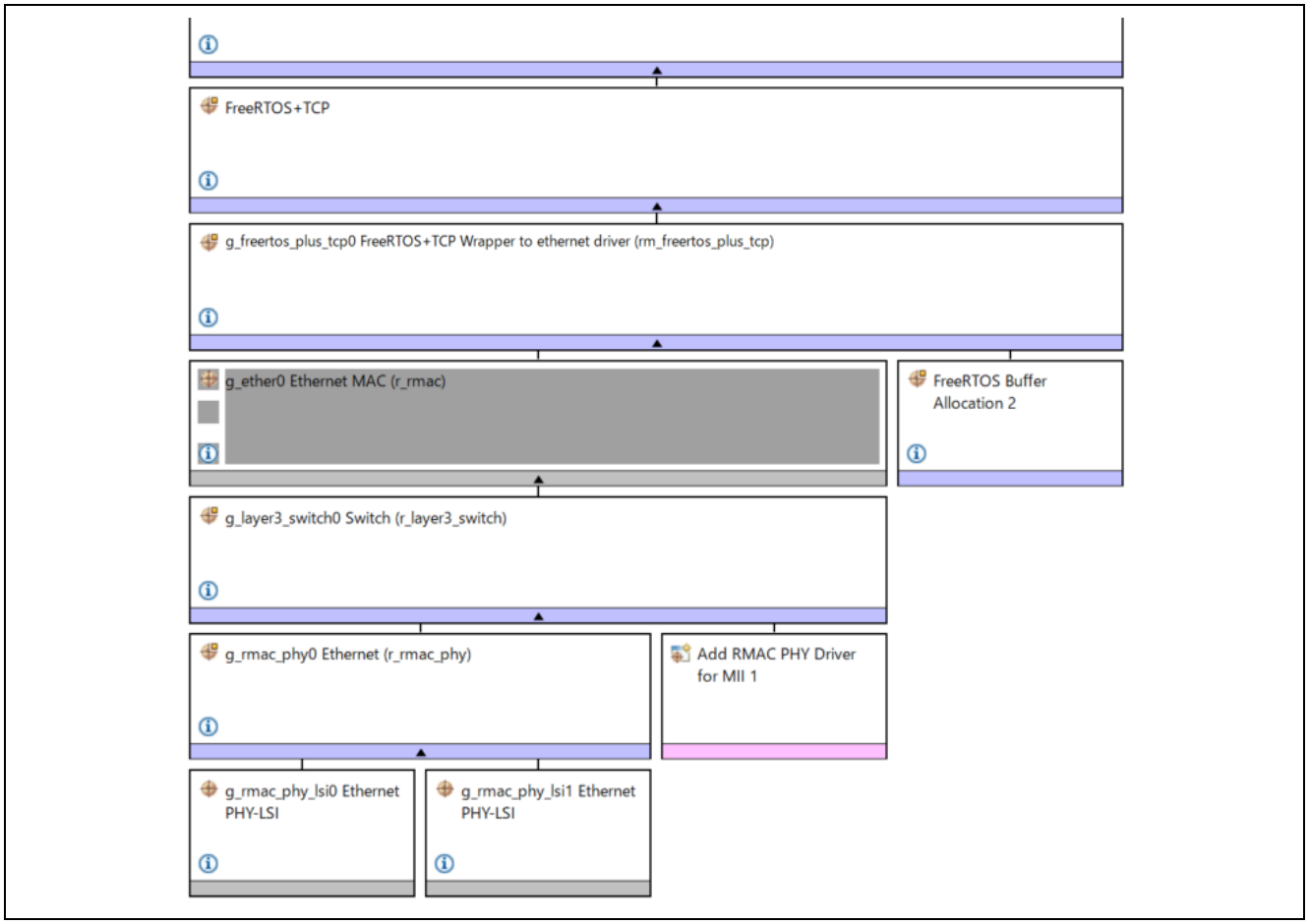
6.2.7 EK-RA8T2 Creating Procedures

This section describes the procedures for creating EK-RA8T2.

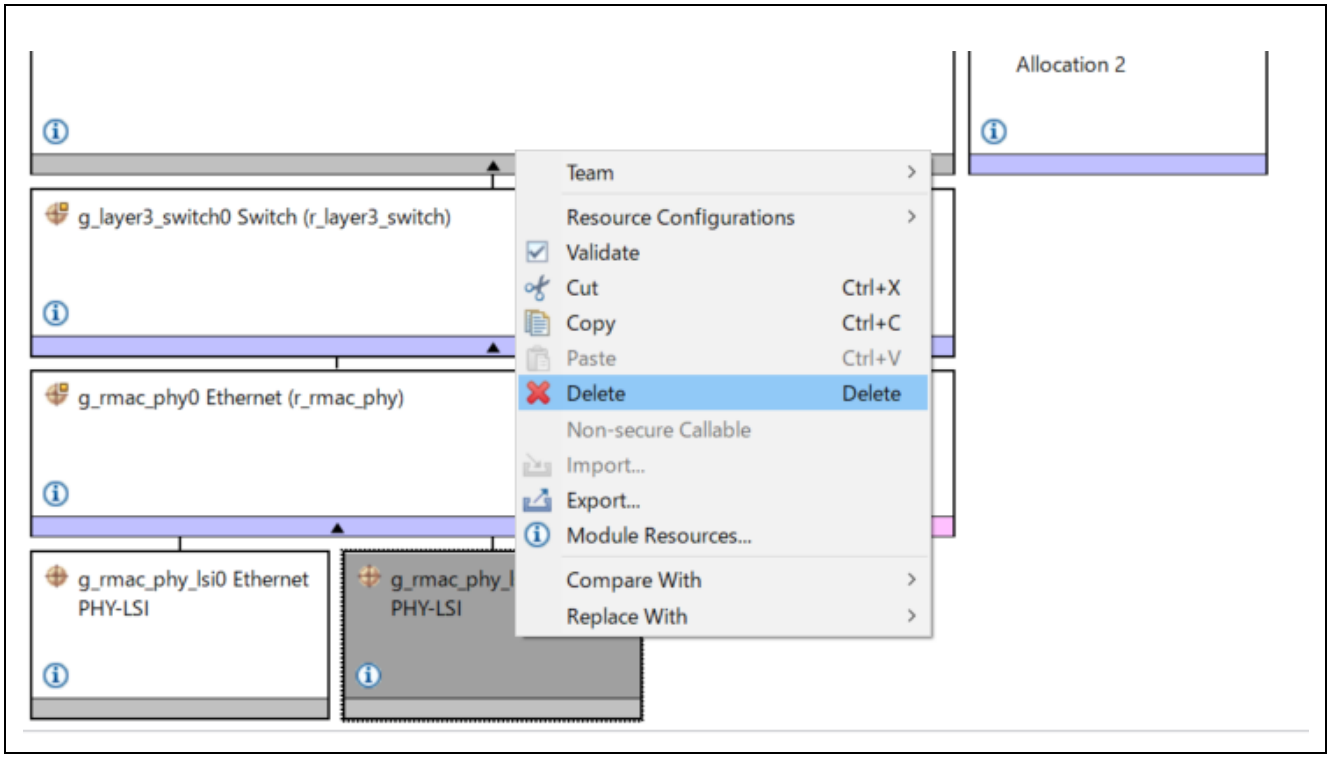
1. Add Ethernet Driver
   Click “New” → “Ethernet (r_rmac)” to “Add Ethernet Driver”.



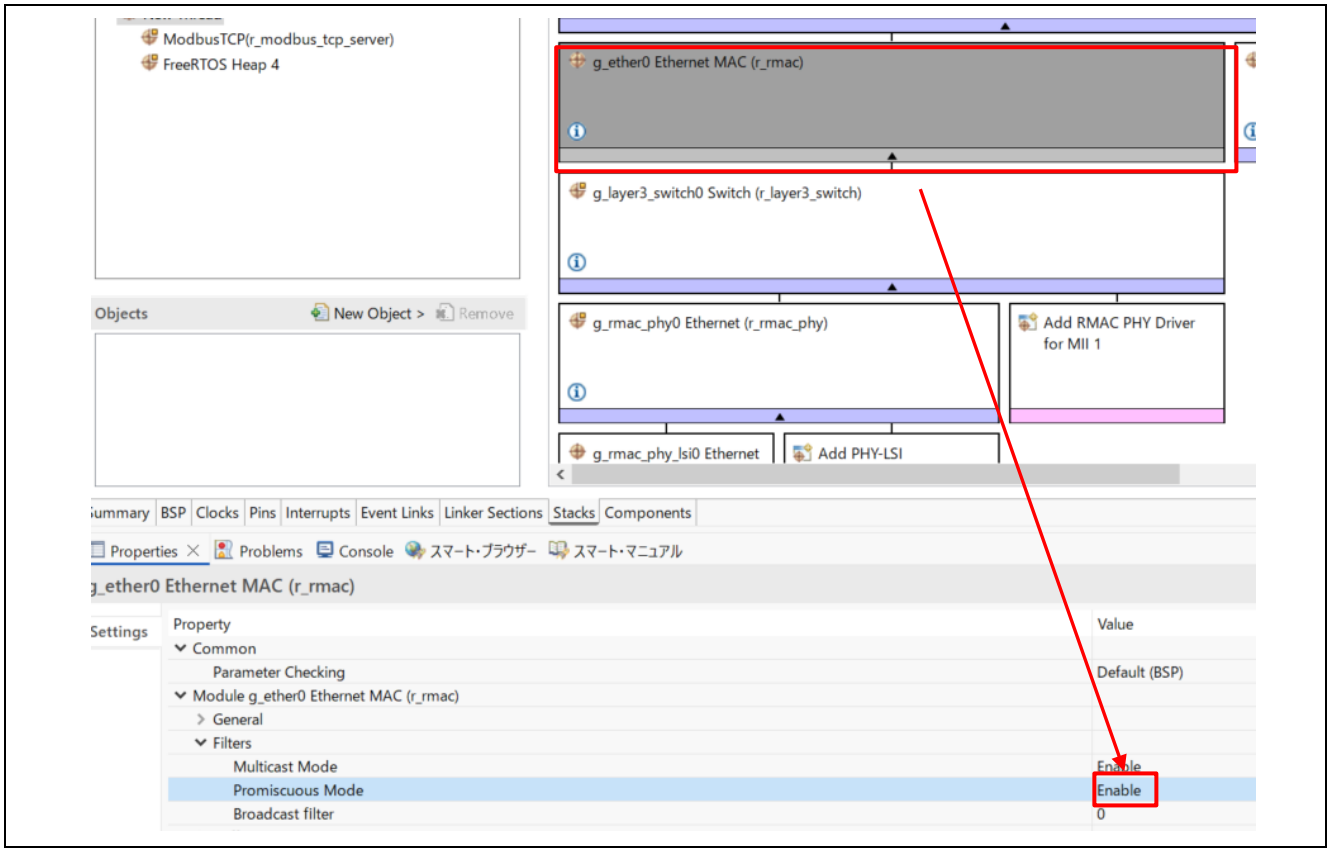
The stack is configured as follows:



Right-click on “g_rmac_phy_lsi1 Ethernet PHY-LSI”, select Delete, and then click “OK” on the “Remove Stack Elements” pop-up.

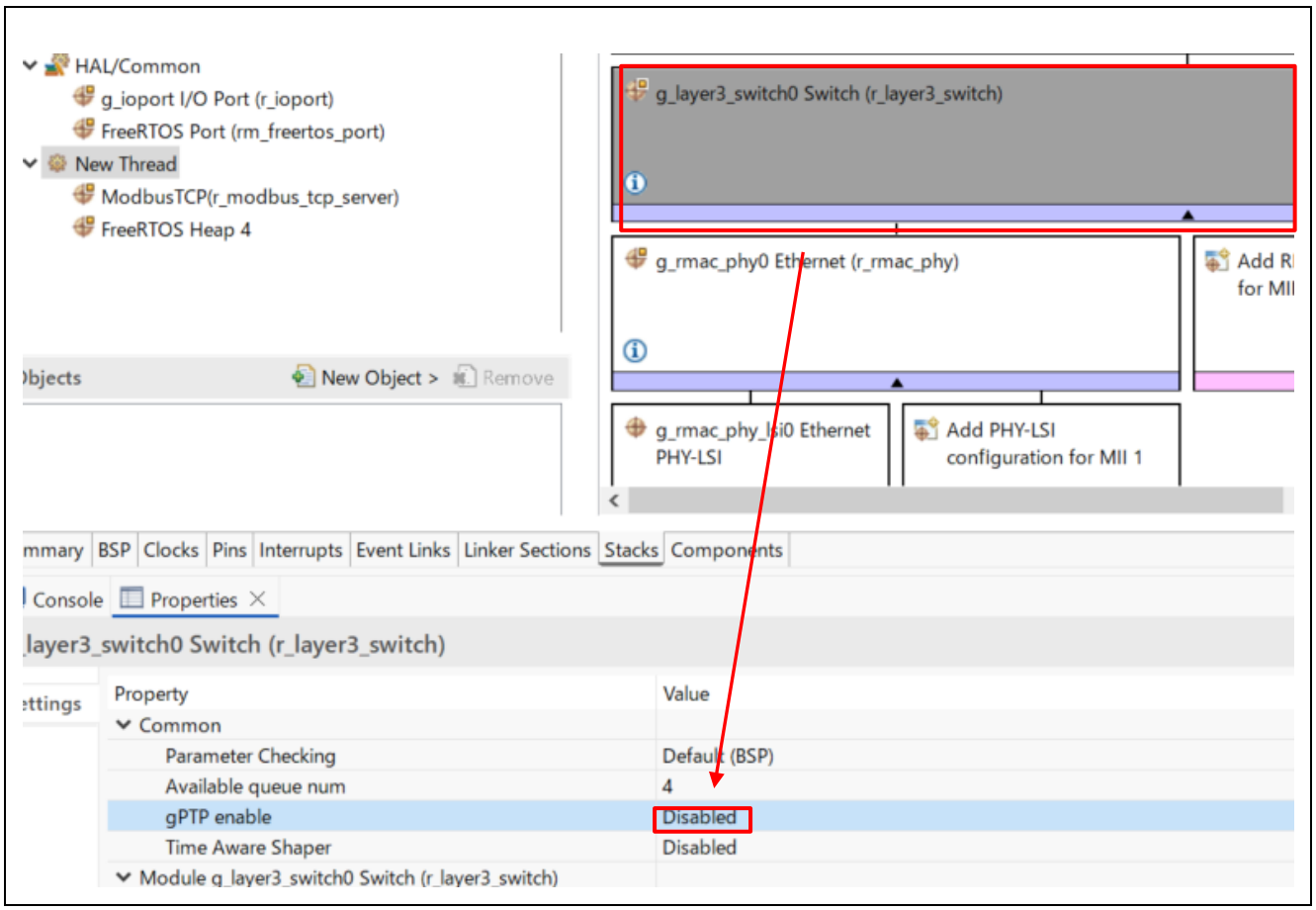


2. Set r_rmac
Change the “Stacks” → ”g_ether0 Ethernet MAC (r_rmac)” → ”Module g_ether0 Ethernet MAC (r_rmac)” → “Promiscuous Mode” in “Filters” to “Enable”.



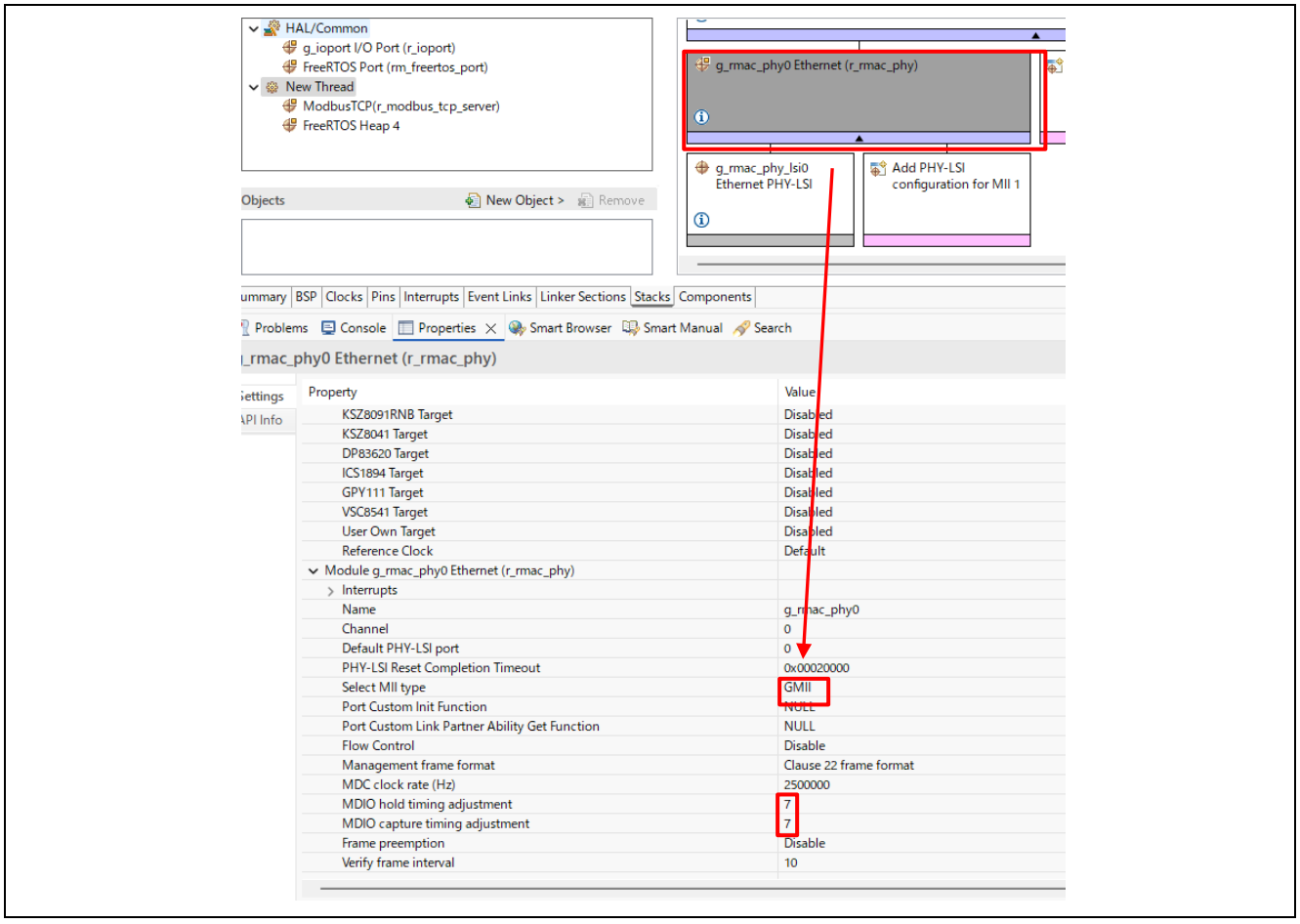
3. Set r_layer3_switch
   Open “Properties” of “g_layer3_switch0 Switch (r_layer3_switch)” in “Stacks” and change “gPTP enable” to the following values.

   gPTP enable：**Disabled**

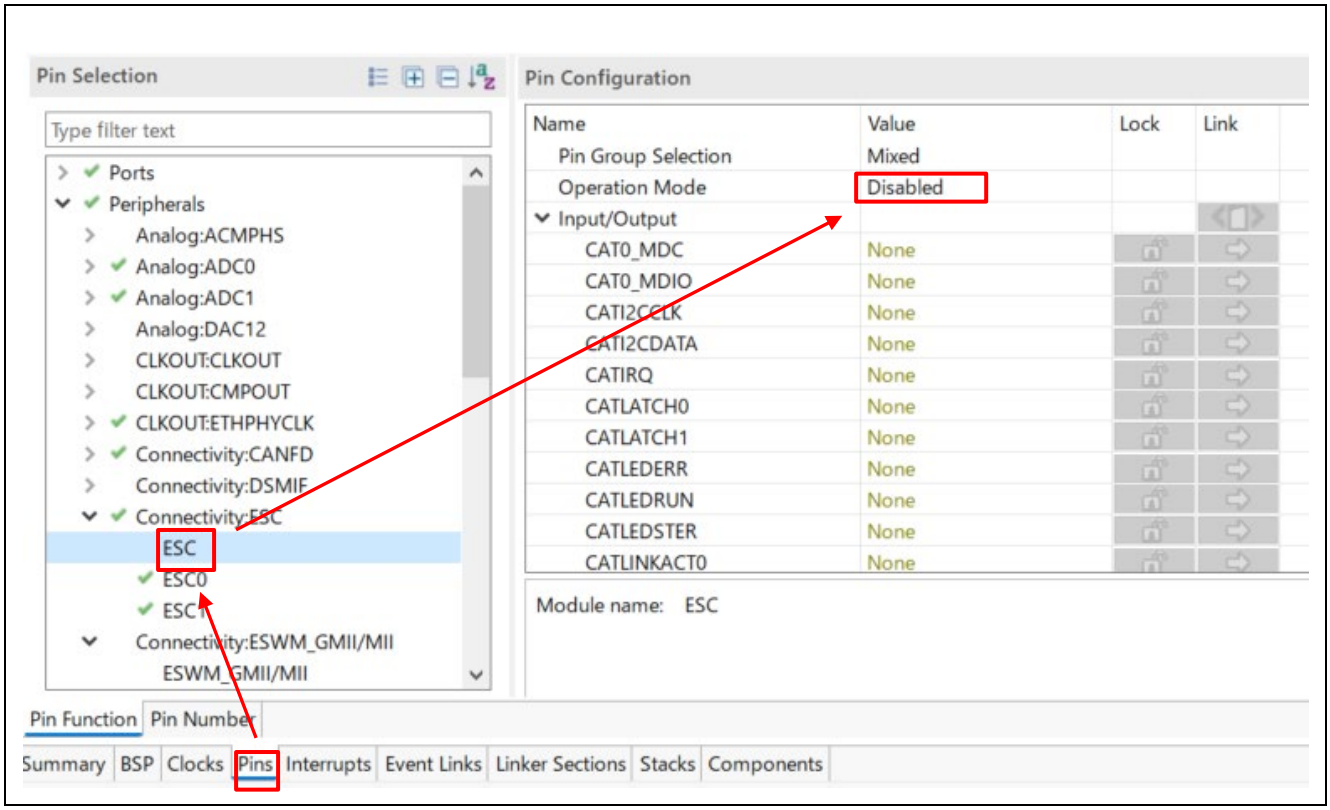


4. Set r_rmac_phy
   Open “Properties” of “g_mac_phy0 Ethernet (r_rmac_phy)” in “Stacks” and change “Select MII type”, ” MDIO hold timing adjustment”, and “MDIO capture timing adjustment” in “Module g_mac_phy0 Ethernet (r_rmac_phy)” to the following values.

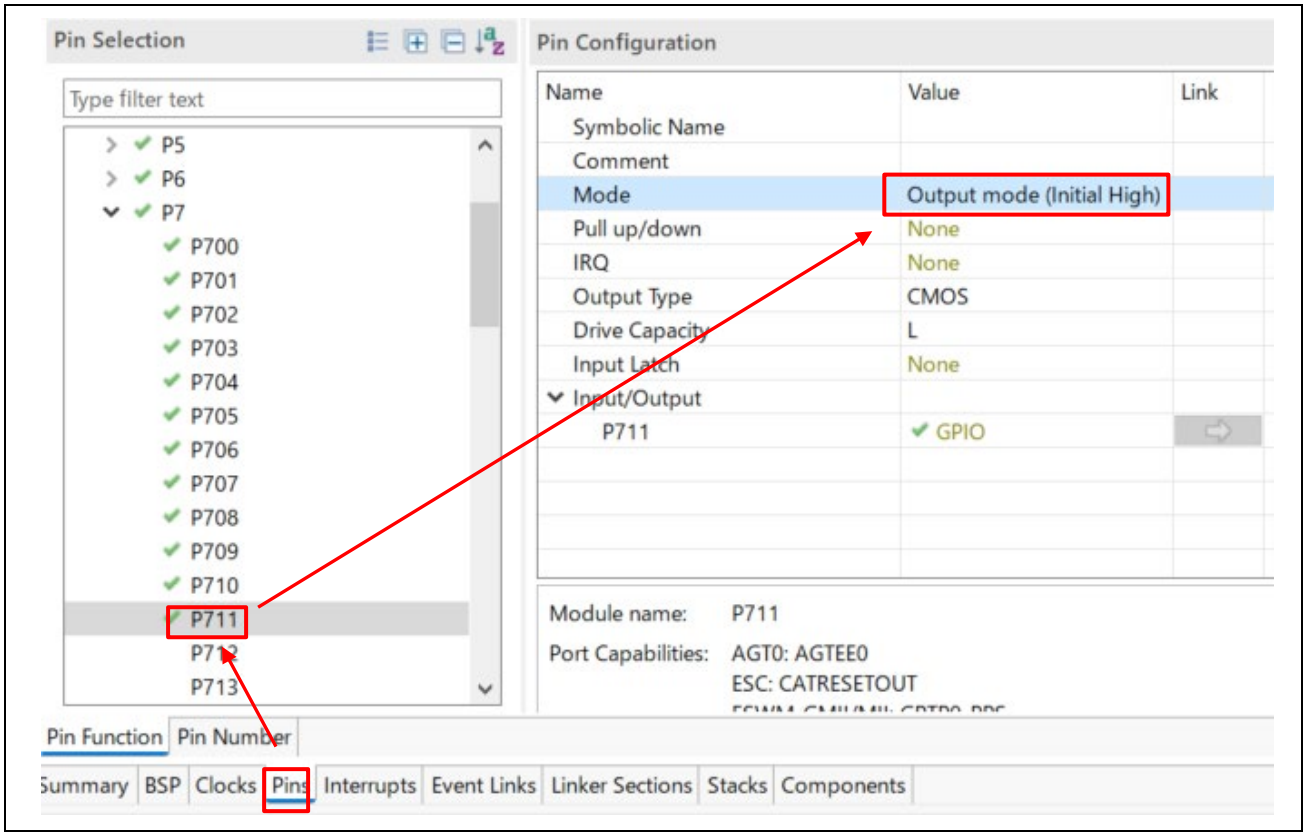
   Select MII type：**GMII**
   MDIO holds timing adjustment：**7**
   MDIO capture timing adjustment：**7**



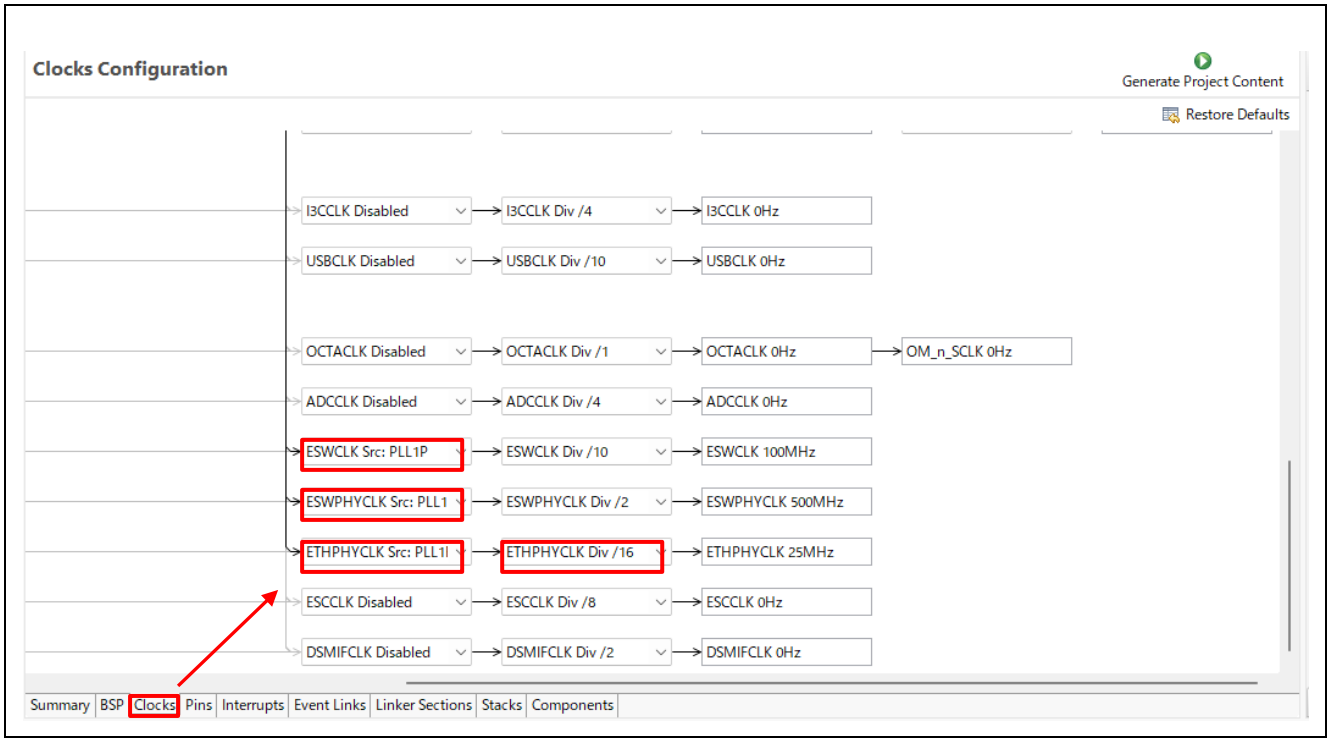
5. Set ESWM Terminals
   Change the "Operation Mode" of “Pins” → ”Peripherals” → ”Connectivity: ESC” → "ESC" to "Disabled".



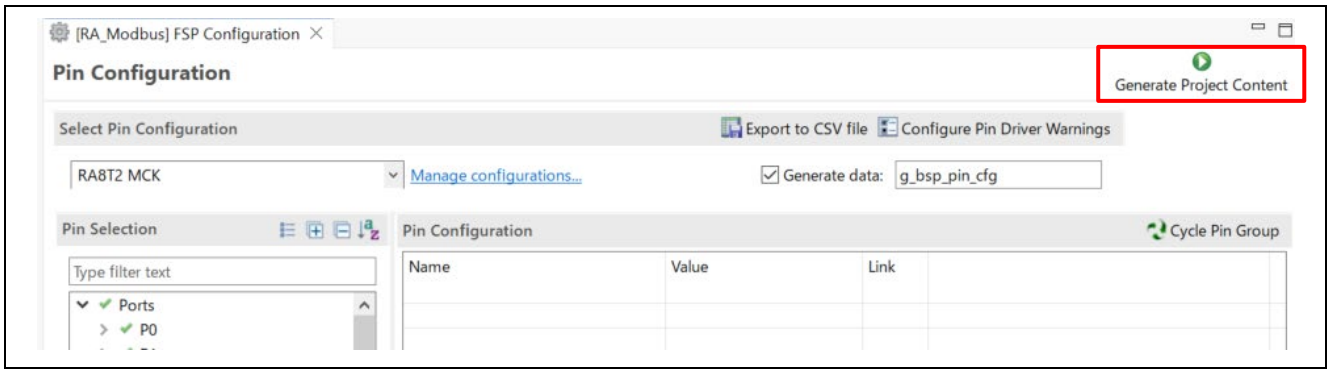
6. Set PHY Reset Terminals
   Change the "Mode" of “Pins” → ”Ports” → ”P7” → "P711" to "Output mode (Initial High)".



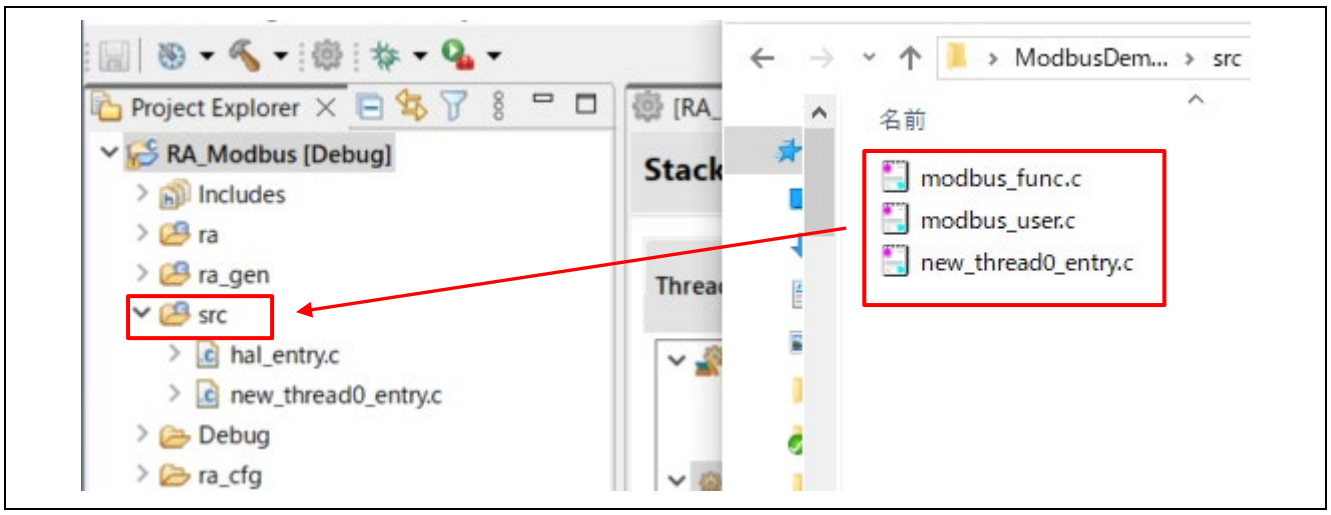
7. Set Clocks
   Change " ESWCLK Src", " ESWPHYCLK Src", “ETHPHYCLK Src”, and " ETHPHYCLK Div" in "Clocks" to the following values.
   ESWCLK Src：**PLL1P**
   ESWPHYCLK Src：**PLL1P**
   ETHPHYCLK Src：**PLL1R**
   ETHPHYCLK Div：／ **16**

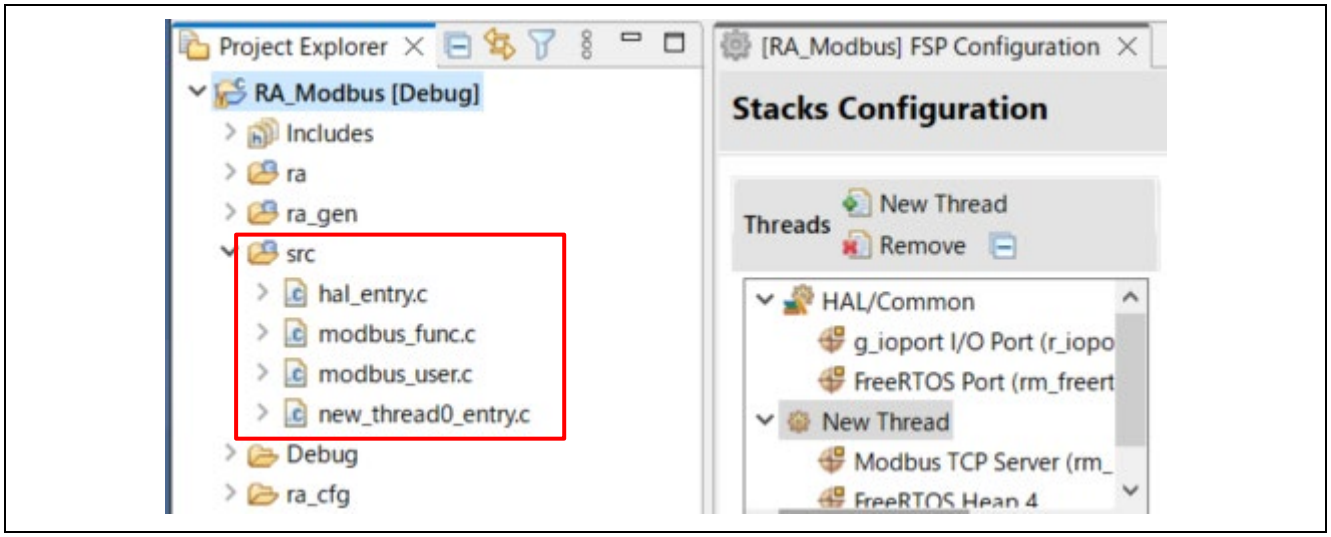


8. Generate the code
   Generate the code with "Generate Project Content".



9. Add Modbus Sample Application
   Copy modbus_func.c, modbus_user.c, and new_thread0_entry.c from the src folder of the sample program package to the src folder of the project and overwrite them.

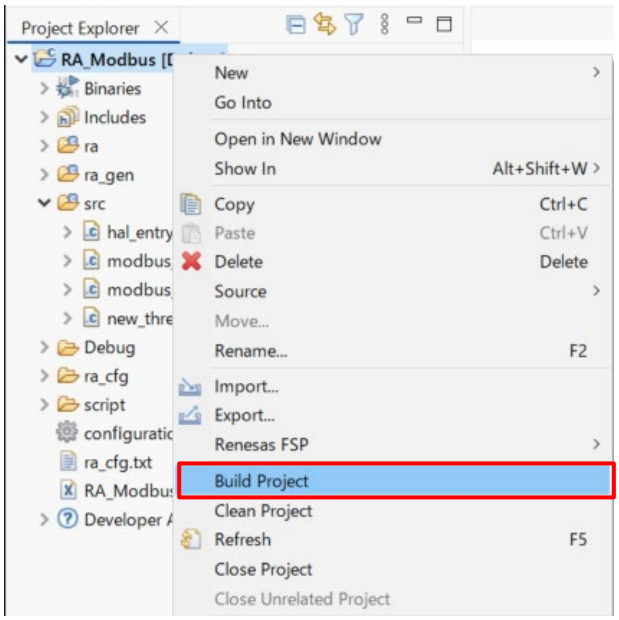




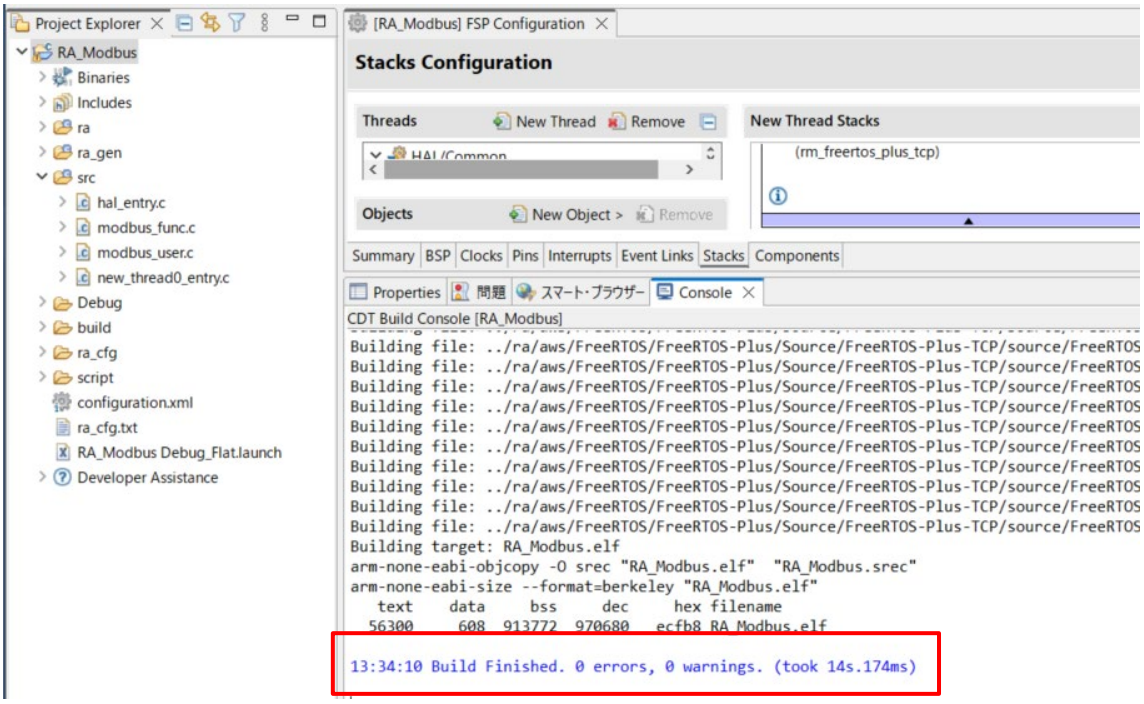
7. Execution of Modbus Sample Project

Before you begin, read "**5. Evaluation Board Connection Setup**" to complete the hardware connections. Also, read "**6. Setting Up the Modbus Sample Project**" to complete the preparation of the Modbus sample project.

1. Build the project
   Right-click on the project from the “Project Explorer”, then select “Build Project”.

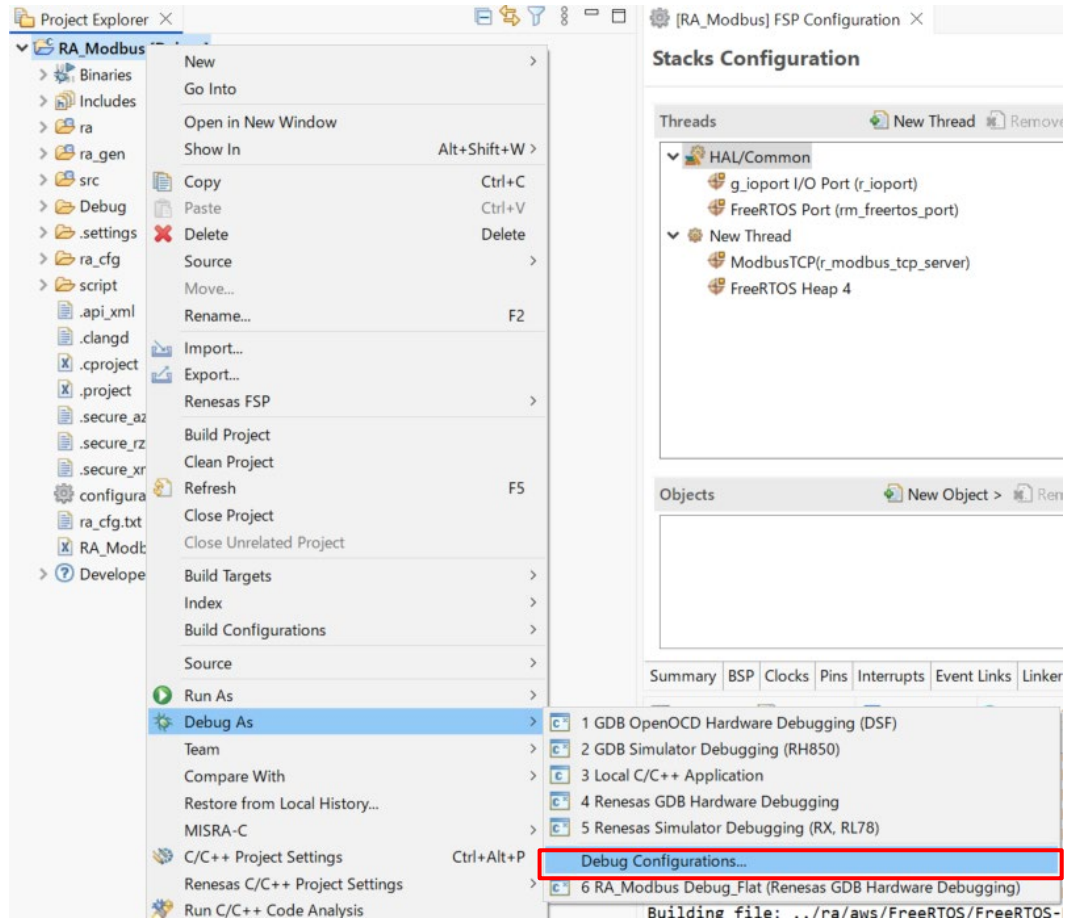


At this time, make sure there are no build errors.



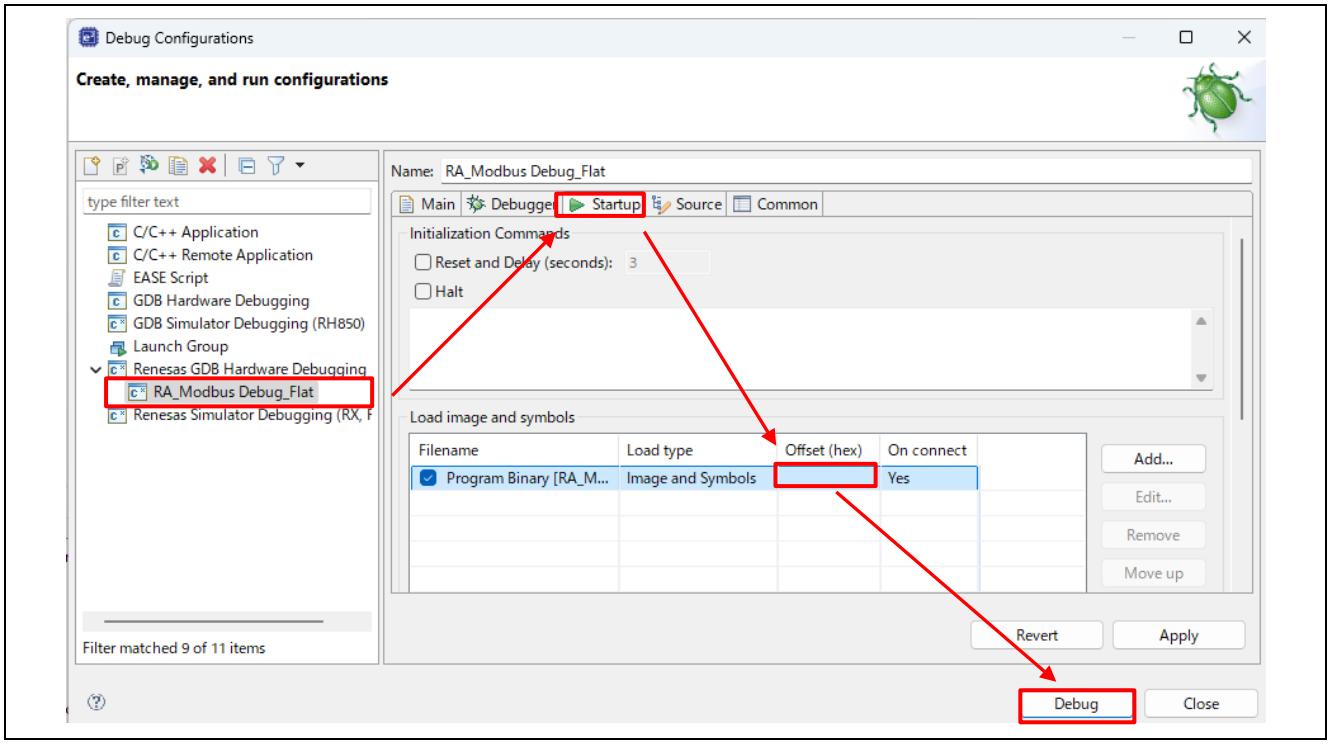
2. Download the application and run the debugger.
   To start debugging, follow the steps below:

   In “Project Explorer” view, right-click on the project to be debugged and select “Debug As” → “Debug Configurations”.



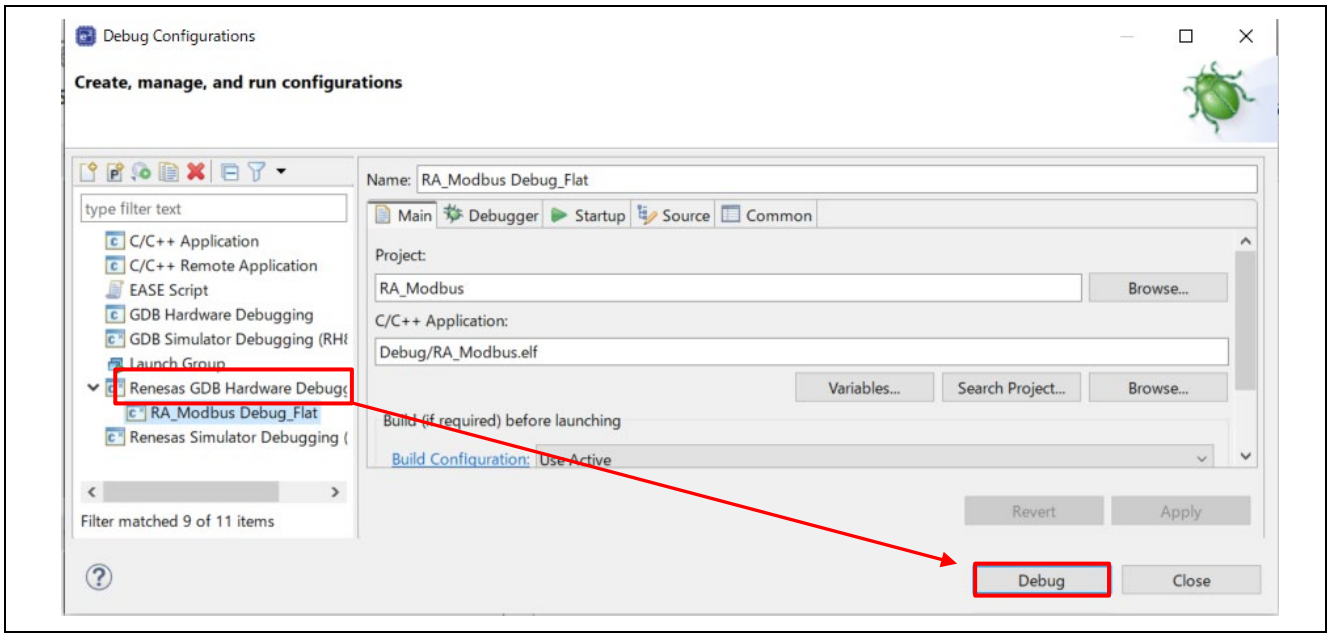
3. Program download.
When the toolchain is the Arm Compiler:

Select “Renesas GDB Hardware Debugging” → “RA_Modbus Debug_Flat”, then select the “Startup” tab.
Remove the “Offset (hex)” value "0" for “Load image and symbols” and click “Debug”.

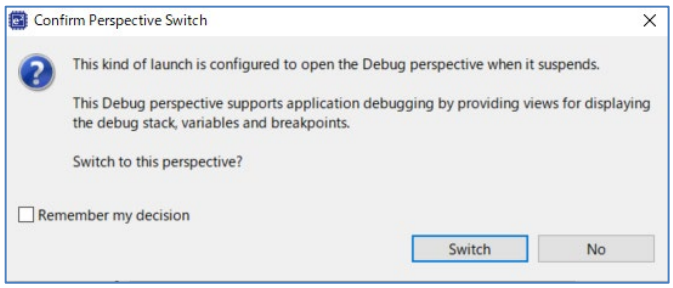


When the toolchain is not the Arm Compiler:

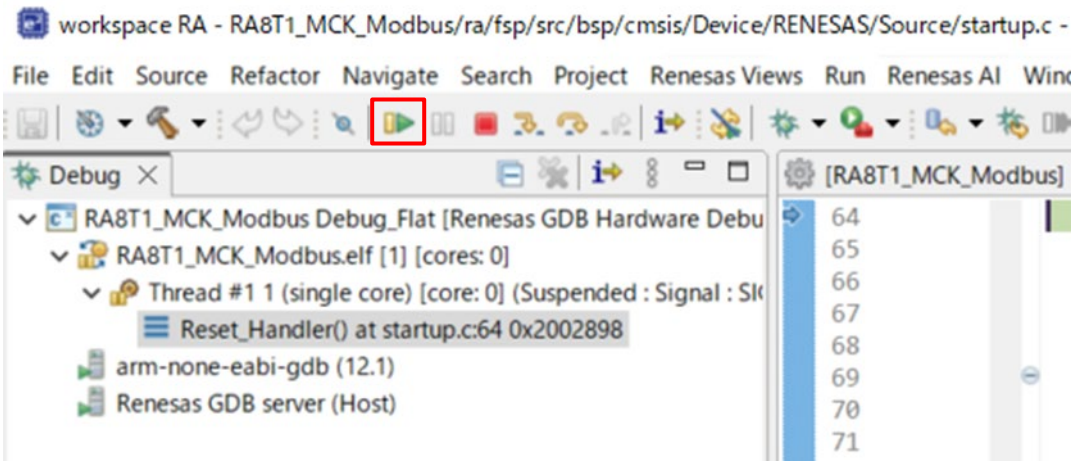
Select “Renesas GDB Hardware Debugging” → “RA_Modbus Debug_Flat”, then click “Debug”.



The following dialog appears. Switch to the debug screen.



4. Program starts.
   Click the **Resume** button.
   When debugging starts, the program is suspended at main.c.
   Click the **Resume** button again to run the program.



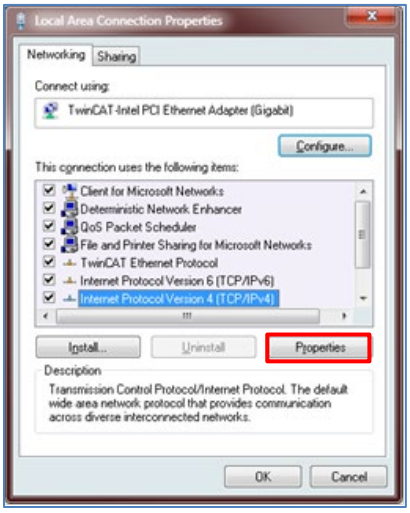
8. Modbus Communication Using Modbus Demo Application

This section demonstrates the procedure for checking the demo operation of the Modbus sample application using the Modbus demo application. For information on configuring the Modbus protocol stack, see "**9.1. Appendix A: Modbus Protocol Stack Configuration**".

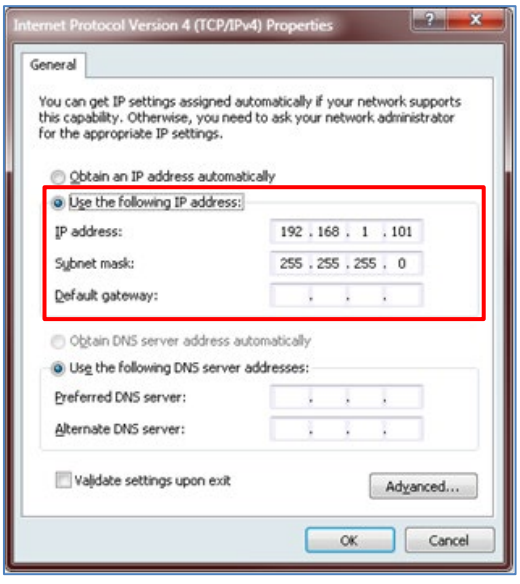
8.1 IP Address Setting

To run the Modbus sample application, it is necessary to set the IP address of the PC running the evaluation tool, which is the client, to the same domain as the evaluation board.

1. Open the network connections list.
   Control panel → **Network and Sharing Center** → **Change adapter settings.**
   Double-click (or right-click) on the Local Area Connection, then select **Properties**.
   Select TCP/IPv4 and click the **Properties** button.



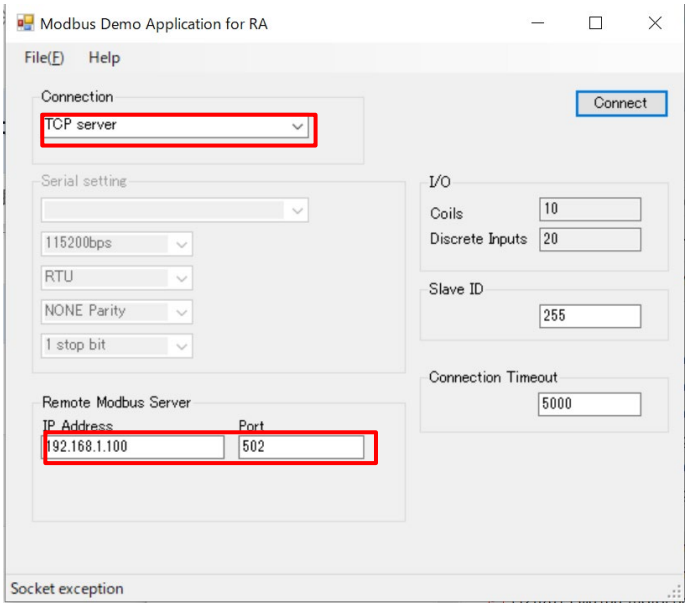
2. Set IP address and subnet mask
   IP Address : 192.168.1.101, subnet mask : 255.255.255.0.



8.2 Setting up the Modbus Demo Application

Launch "ModbusDemoApplication.exe" included in this package and configure the following settings.

Connection：**TCP server**
IP Address：Modbus TCP server IP address (example: "192.168.1.100")
Port：Port number (example: "502")



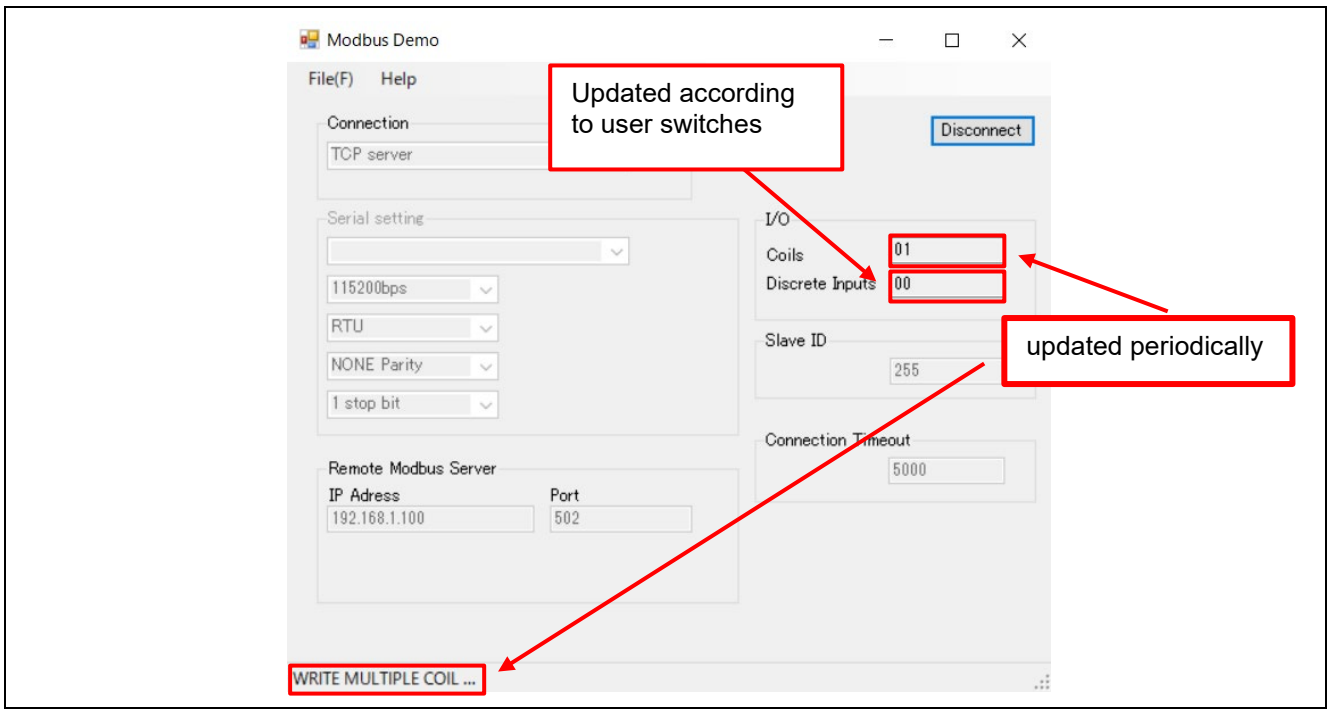
8.3 Modbus Demo Application Specification

The LED blinking can be controlled dynamically by communicating with a PC through the Modbus TCP protocol.

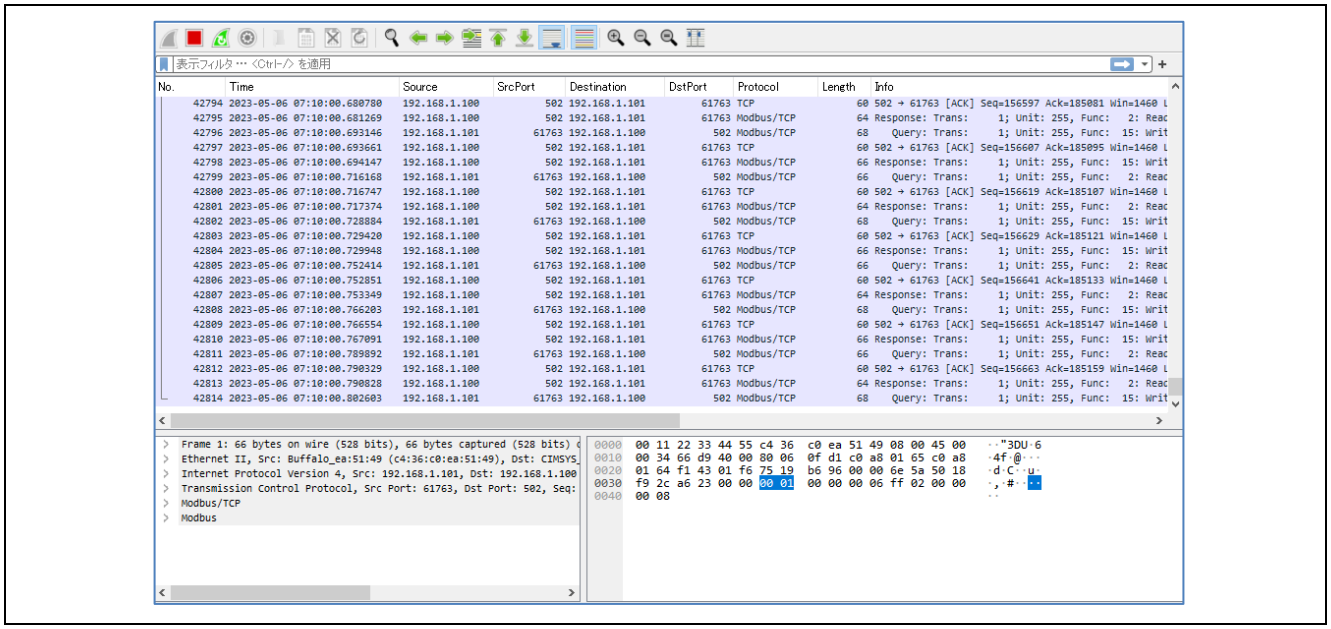
For this control, Read Coil and Write Coil function codes are used.

After clicking the "Connect" button, LEDs 1 to 3 will blink periodically.

"Discrete Inputs" are updated depending on whether the user switches listed in "**9.4.2 User-defined Functions**" is ON or OFF.



Check the Modbus communication status by using a packet analysis tool like Wireshark.



9 Appendix

9.1 Appendix A: Modbus Protocol Stack Configuration

The Modbus protocol stack configuration is described below.

Configuration	Options	Default	Description
Common			
Parameter Checking	・Default (BSP) ・Enable ・Disable	Default (BSP)	If selected code for parameter checking is included in the build.
Accept Task Stack Size	Legal values are 0x400 or higher	0x400	Accept task stack size. Legal values are 0x400 or higher.
Accept Task Priority	Legal values range from 0 through (Max Priorities - 1)	2	Accept task priority. Legal values range from 0 through (Max Priorities - 1). Also, set Accept Task, Receive Task, and Service Task with the same priority.
Receive Task Stack Size	Legal values are 0x400 or higher	0x400	Receive task stack size. Legal values are 0x400 or higher.
Receive Task Priority	Legal values range from 0 through (Max Priorities - 1)	2	Receive task priority. Legal values range from 0 through (Max Priorities - 1). Also, set Accept Task, Receive Task, and Service Task with the same priority.
Service Task Stack Size	Legal values are 0x400 or higher.	0x400	Service task stack size. Legal values are 0x400 or higher.
Service Task Priority	Legal values range from 0 through (Max Priorities - 1)	2	Service task priority. Legal values range from 0 through (Max Priorities - 1). Also, set Accept Task, Receive Task, and Service Task with the same priority.
Maximum Number of Clients	Legal values are from 1 to 3	3	Maximum number of connection sockets for clients. Valid values are 1 to 3.
Receive Queue Length	Legal values are 8 or higher	8	The length of the queue that passes data between tasks. Legal values are 8 or higher.
Server ID	Legal values are from 1 to 255	255	Modbus server ID. Legal values are from 1 to 255.

Configuration	Options	Default	Description
Module Modbus TCP(r_modbus_tcp_server)			
Name	Name Must Be a Valid C Symbol	g_modbus_tcp_server0	Module name
Callback for Function Code	Name Must Be a Valid C Symbol	function_code_callback	Enter the user callback function name for “Function Code”
Additional Port Number	Legal values range from 0 to 65535. Also, do not specify the Modbus TCP Server default port number “502” with this property.	0	Modbus TCP Server listens on both the default port “502” and the port number specified in this property. Enter 0 if you do not want to use a port other than the default. Also, do not specify the Modbus TCP Server default port number “502” with this property.
IP List Status	・Disable ・Enable	Enable	IP list enabled/disabled. If you want to use the IP list, select Enable. ***1**
IP List Mode	・BlackList ・WhiteList	WhiteList	The selected option takes effect if the “IP List Status” is “Enable”. ***1**
IP Addresses	Enter Valid IP addresses between 0.0.0.0 ~ 255.255.255.255 and each IP addresses should be separated with commas.	192.168.1.101	Enter one or more IP addresses to register in the IP List. ***1**

***1: For details, see " 9.2. Appendix B: IP List Related Parameters" section.**

9.2 Appendix B: IP List Related Parameters

IP List Status, IP List Mode, and IP Addresses are IP list-related parameters.
The settings for the "When not using an IP list", "When using an IP list as a WhiteList", and "When using an IP list as a BlackList" configurations are described below.

- When not using an IP list
  IP List Status: Disable
  IP List Mode: Any value (this configuration is invalid because IP List Status is “Disable”)
  IP Addresses: Any value (this configuration is invalid because IP List Status is “Disable”)

- When using an IP list as a WhiteList
  IP List Status: Enable
  IP List Mode: WhiteList
  IP Addresses: Any IP address to register as a WhiteList
  If you are following the procedure explained in section "8. Modbus Communication Using Modbus Demo Application" to confirm the operation, set the IP address to "192.168.1.101".

- When using an IP list as a BlackList
  IP List Status: Enable
  IP List Mode: BlackList
  IP Addresses: Any IP address to register as a BlackList
  If you are following the procedure explained in section "8. Modbus Communication Using Modbus Demo Application" to confirm the operation, set an IP address other than "192.168.1.101".

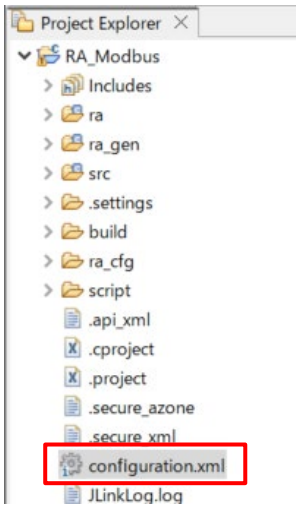
If multiple IP addresses must be registered in the IP Addresses parameter, separate the IP addresses with a comma (”,”) as shown below.

Example: 192.168.1.101,192.168.1.102,192.168.1.103

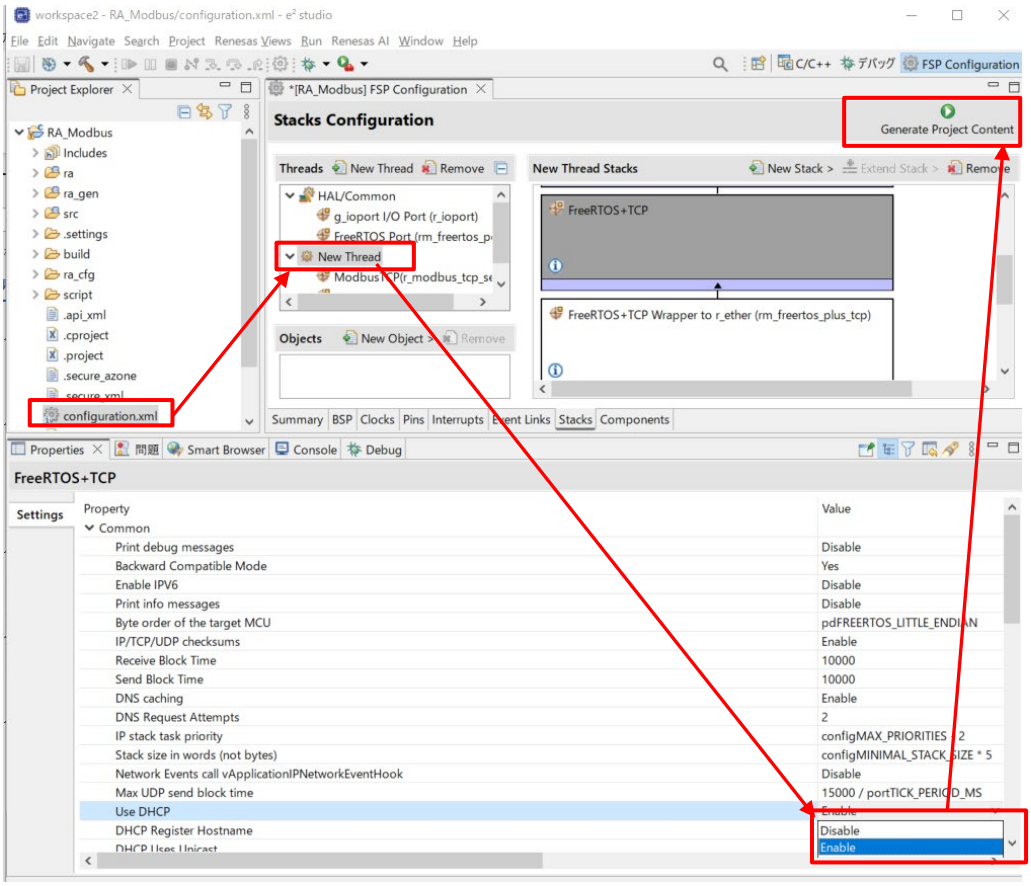
9.3 Appendix C: DHCP Mode

When the operation must be confirmed using DHCP mode, execute the procedure below:

1. Open configuration.xml from your Modbus project.



2. Click the "Stacks" tab to open the stack configuration screen and select "FreeRTOS + TCP" in the thread window on the left.
3. Open the properties, change "Use DHCP" to "Enable", and click the "Generate Project Content" button.



9.4 Appendix D: User-defined Function

This section describes the Modbus sample application. Users can register their own implementation of the Modbus function code with the Modbus protocol stack.

9.4.1 Register Function Code

Definition file: src/modbus_func.c
Define the function to be registered in the callback function of the Modbus protocol stack.

9.4.2 User-defined Functions

User-defined functions are defined in the src/modbus_user.c
User-defined read/write functions are used to process each function.

Some functions access the following components of the evaluation board.

Evaluation Boards	User LED			User-Switch	
	①	②	③	①	②
EK-RA6M3 EK-RA6M4 EK-RA6M5 EK-RA8D1 EK-RA8M1 EK-RA8D2 EK-RA8P1 EK-RA8M2 EK-RA8T2	User LED1	User LED2	User LED3	User-Switch SW1	User-Switch SW2
MCK-RA8T1 MCK-RA8T2	LED1	LED2	LED3	-	-

Read/Write functions and tables are provided that correspond to each address of the coil/discrete input/holding register/input register.
The evaluation board parts and global variables accessed by the functions in each table are as follows.

【Read Coils】	
address	**Access**
0001	Above table User - LED①, g_coils_area
0002	Above table User - LED②, g_coils_area
0003	Above table User - LED③, g_coils_area
0004	g_coils_area
0005	g_coils_area
0006	g_coils_area
0007	g_coils_area
0008	g_coils_area

【Write_Single_Coils】	
address	**access**
0001	Above table User - LED①, g_coils_area *1
0002	Above table User - LED②, g_coils_area *1
0003	Above table User - LED③, g_coils_area *1
0004	g_coils_area
0005	g_coils_area
0006	g_coils_area
0007	g_coils_area
0008	g_coils_area

*1：Each LED on the evaluation board will turn on/off depending on the value written by this function.

【Read_Discrete_Inputs】	
address	**access**
1001	g_discrete_input_area
1002	g_discrete_input_area
1003	g_discrete_input_area
1004	g_discrete_input_area
1005	g_discrete_input_area
1006	Above table User-Switch①, g_discrete_input_area *2
1007	Above table User-Switch②, g_discrete_input_area *2
1008	g_discrete_input_area
1009	g_discrete_input_area
10010	ILLEGAL DATA ADDRESS
10011	g_discrete_input_area
10012	g_discrete_input_area

*2：The value read by this function is displayed in “Discrete Inputs” of the Modbus demo application.

【Read_Discrete_Inputs】	
address	**access**
3001	g_input_reg_area
3002	g_input_reg_area
3003	g_input_reg_area
3004	ILLEGAL DATA ADDRESS
3005	ILLEGAL DATA ADDRESS
3006	ILLEGAL DATA ADDRESS
3007	ILLEGAL DATA ADDRESS
3008	g_input_reg_area

【READ_HOLDING_REGISTERS】	
address	**access**
4001	g_holding_reg_area
4002	g_holding_reg_area
4003	g_holding_reg_area
4004	ILLEGAL DATA ADDRESS
4005	ILLEGAL DATA ADDRESS
4006	ILLEGAL DATA ADDRESS
4007	g_holding_reg_area

【WRITE_SINGLE_REGISTER】	
address	**access**
4001	g_holding_reg_area
4002	g_holding_reg_area
4003	g_holding_reg_area
4004	ILLEGAL DATA ADDRESS
4005	ILLEGAL DATA ADDRESS
4006	ILLEGAL DATA ADDRESS
4007	g_holding_reg_area

9.5 Appendix E: Multiple Client Communication

The Modbus protocol stack can connect up to three clients using Modbus communication.
If you create a project using the steps in "**6. Setting Up the Modbus Sample Project**", you can communicate continuously with the client under the following conditions.

- Number of clients: 1 - 3
- Communication interval: 1000 ms
- Communication Timeout Time : 3000 ms
- No devices that are not related to Modbus communication are connected to the same network.

If you want the communication interval or timeout time to be shorter than the above time, or if you need to connect other devices within the same network, change the following:

- Go to “Total number of available network buffers” property of “Stacks” → “FreeRTOS+TCP” → “Common “and increase its value.
  Note that the total number of available network buffers uses 56 bytes of RAM, and the amount of RAM used will increase proportionally to this value.
  (If the total number of available network buffers is 30, the amount of RAM used will be 56 x 30 = 1680 bytes)
- **Below is the settings for EK-RA6M3 / EK-RA6M4 / EK-RA6M5 / EK-RA8D1 / EK-RA8M1 / MCK-RA8T1.**
  Go to "Stacks" → "g_ether0 Ethernet" → "Module g_ether0 Ethernet (r_ether)" → "Buffers" → “Number of RX buffer" and change its value greater than or equal to 1 (default value). The recommended value is [Number of clients].
  (The RAM size used by the number of RX buffers is 1536 bytes.)
  (If you change the Number of RX buffers to 3, the total is 1536 x 3 = 4608 bytes)

Note: If you want to use the Modbus sample project in your system, evaluate it thoroughly.

When performing Modbus communication with multiple connected clients, users must change the IP list-related parameters described in " **9.2. Appendix B: IP List Related Parameters**".
If the IP address of each client is other than "192.168.1.101", set the IP List Status, IP List Mode, and IP Addresses parameters as follows:

- When using an IP list as a WhiteList (Recommendation)
  IP List Status: Enable
  IP List Mode: WhiteList
  IP Addresses: [Each client's IP address] (Example: 192.168.1.101, 192.168.1.102, 192.168.1.103)

- When not using an IP list
  IP List Status: Disable
  IP List Mode: Any value (this configuration is invalid because IP List Status is “Disable”)
  IP Addresses: Any value (this configuration is invalid because IP List Status is “Disable”)

- When using an IP list as a BlackList
  IP List Status: Enable
  IP List Mode: BlackList
  IP Addresses: IP addresses other than [Each client's IP address]

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jun 27, 2025	-	First version
1.10	Sep 25, 2025		Added MCK-RA8T2
		Page 4	Updated Table 1.2
		Page 6	Updated 3.1 Modbus Sample Project
		Page 9	Added Figure 5.3
		Page 18 - 43	6.2 Creation of a new Modbus Project is divided into common procedures for all evaluation boards, procedures for each evaluation board, and procedures for MCK-RA8T2 are added
			Updated Operating Environment Requirements
		Page 7	Updated Table 4.1
			Added description of multi-client communication
		Page 56	Added 9.5 Appendix E: Multiple Client Communication
1.20	Oct 31, 2025		Added EK-RA8D2, EK-RA8P1 and EK-RA8M2
		Page 4	Updated Table 1.2
		Page 6	Updated 3.1 Modbus Sample Project
		Page 9	Updated Figure 5.3
		Page 16	Changed the title of 6.1.2 to MCK-RA8T2 / EK-RA8D2 / EK-RA8P1 / EK-RA8M2 Importing Procedures
		Page 45 - 67	Added 6.2.4 EK-RA8D2 Importing Procedures, 6.2.5 EK-RA8P1 Importing Procedures and 6.2.6 EK-RA8M2 Importing Procedures
		Page 80	Changed 9.5 Appendix E: Multiple Client Communication
			Updated Operating Environment Requirements
		Page 7	Updated Table 4.1
			Additional Procedures for Upgrading FSP Version
		Page 38	Added step 3 to 6.2.3
1.30	Mar 31, 2026		Added EK-RA8T2
		Page 5	Added Table 1.3
		Page 7	Updated 3.1 Modbus Sample Project
		Page 11	Added Figure 5.4
		Page 17, 19	Added steps to execute the Modbus sample project
		Page 18	Changed the title of 6.1.2 to MCK-RA8T2 / EK-RA8D2 / EK-RA8P1 / EK-RA8M2 / EK-RA8T2 Importing Procedures
		Page 70 - 76	Added 6.2.7 EK-RA8T2 Importing Procedures
		Page 52, 61, 67	Removed ESW Clock setting
			Updated from FSP6.2.0 to FSP6.4.0
		Page 8	Updated Table 4.1
		Page 82	Changed the description of Setting up the Modbus Demo Application
		Page 83	Changed chapter number from 8.2.1 to 8.3 Added information about Discrete Inputs Moving the description of Wireshark from Chapter 8.2
		Page 88	Updated the User LED and User Switch tables
		Page 91	Changed Number of clients: 1 to Number of clients: 1-3 Added a description about setting IP list-related parameters

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1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
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