Renesas RA Family

Quick Start Guide: EK-RA8D1 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

EK-RA8D1

Contents

1. Overview

This document is for the Modbus protocol stack that operates on the EK-RA8D1 evaluation board, and describes the function overview, application programming interface (API), and application samples for developing and implementing applications using the protocol stack.

This package supports the Ethernet-based Modbus TCP protocol.

This Quick Start Guide provides:

- Instructions for running the Quick Start example project.
- Instructions for importing, modifying, and building the Quick Start example project using Flexible Software Package (FSP) and e^2 studio Integrated Development Environment (IDE).
- Instructions for connecting with a master and operating 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	TCP	Transmission Control Protocol
9	Wireshark	Free packet capture tool to check packets flowing on LAN

1.2 Reference

Technical information about Modbus is available through Modbus organization site, and information about EK-RA8D1 is available through Renesas.

Table 1.2 Technical Inputs

Index	Technical Inputs
1	r01ds0416xx0110-ra8d1.pdf
2	r01uh0995xx0110-ra8d1.pdf
3	r20ut5205eg0100_ek-ra8d1_user_manual.pdf
4	Modicon Modbus Protocol Reference Guide Rev.J
5	Modbus Application Protocol Specification V1.1b3

2. Features

Modbus protocol stack for EK-RA8D1 allows for quick and easy development of the Modbus TCP applications.

Modbus function code supported by the initialization API is 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. Structure of the Sample Application

This sample application consists of three blocks:

- FSP driver including FreeRTOS+TCP.
- Modbus protocol stack sample program using RTOS and TCP/IP stack.
- Application sample program using Modbus protocol stack.

3.1 FSP Drivers

- `e2studio/ra`
  This directory includes the code required for the following Modbus protocol stack:
  - BSP (Board support package) for EK-RA8D1
  - HAL (Hardware abstraction layer) drivers
  - FreeRTOS and FreeRTOS+TCP.

  FreeRTOS is an open-source software for real-time operating system (RTOS) for microcontrollers.
  Refer to the following link for details.
  https://www.freertos.org/index.html
  https://aws.amazon.com/freertos/

- `e2studio/ra_gen`
  This directory included the code required for the following Modbus protocol stack:
  - HAL (Hardware abstraction layer) drivers

- `e2studio/ra_cfg`
  This directory included the code required for the following Modbus protocol stack.
  - BSP (Board support package) for EK-RA8D1
  - FreeRTOS and FreeRTOS+TCP.

3.2 Modbus Protocol Stack

- `e2studio/Modbus`
  - Modbus protocol stack and TCP/IP communication are implemented.
  - Codes in this directory will create and delete tasks. User does not need to modify codes.

- `e2studio/Modbus_user`
  - Users can register their own implementations of Modbus function codes into Modbus protocol stack.
  - Codes in this directory are examples to initialize Modbus protocol stack and register the user's implementation of Modbus function codes by Modbus protocol stack APIs.

3.3 ModbusDemoApplication.exe

This executable file is the TCP demo server for TCP/IP communication. It can be used to run the Modbus protocol stack demonstration.

4. Operating Environment

The sample program covered in this manual run in the following environment.

Table 4.1 Operating Environment

Item	Description
Board	EK-RA8D1 v1.0
CPU	Cortex®-M85
Operating frequency	CPU clock (CPUCLK): 480 MHz
Operating voltage	3.3 V
Device requirements	R7FA8D1AHECBD • Flash memory Capacity: 2 MB • SDRAM Capacity: 1 MB
Integrated development environment	e² studio 2023-10 or later
MCU software package	FSP (Flexible Software Package) v5.1.0
Emulator	J-LINK OB
Communications protocol	Modbus TCP
Master tool	ModbusDemoApplication.exe: Modbus evaluation test program

5. Board Setting and Connection

Connect the PC to the EK-RA8D1 board as shown below.
Power is supplied by connecting a USB micro-B cable to the board.
For Modbus TCP communication, use RJ45 connector and connect to PC with LAN cable.

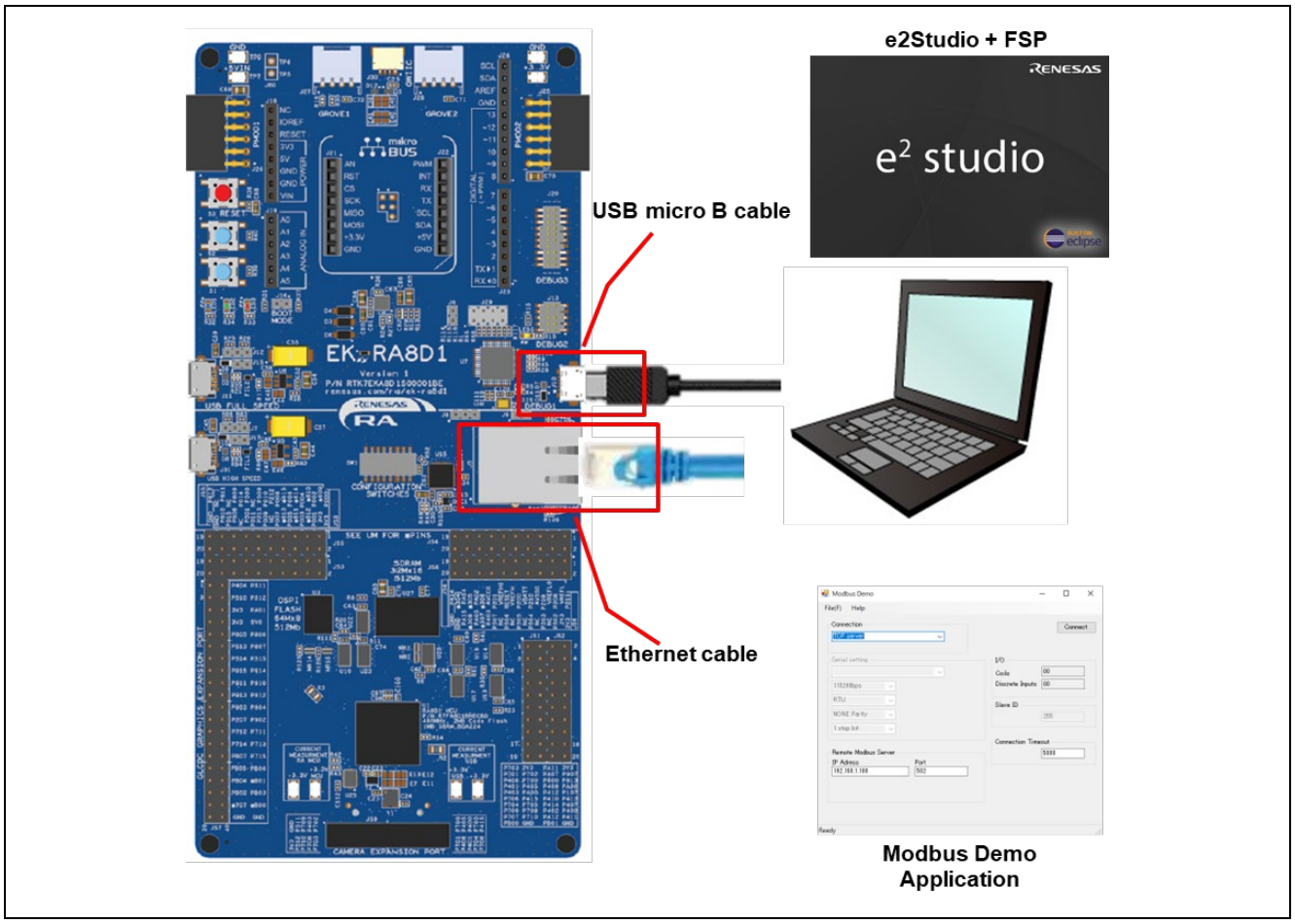
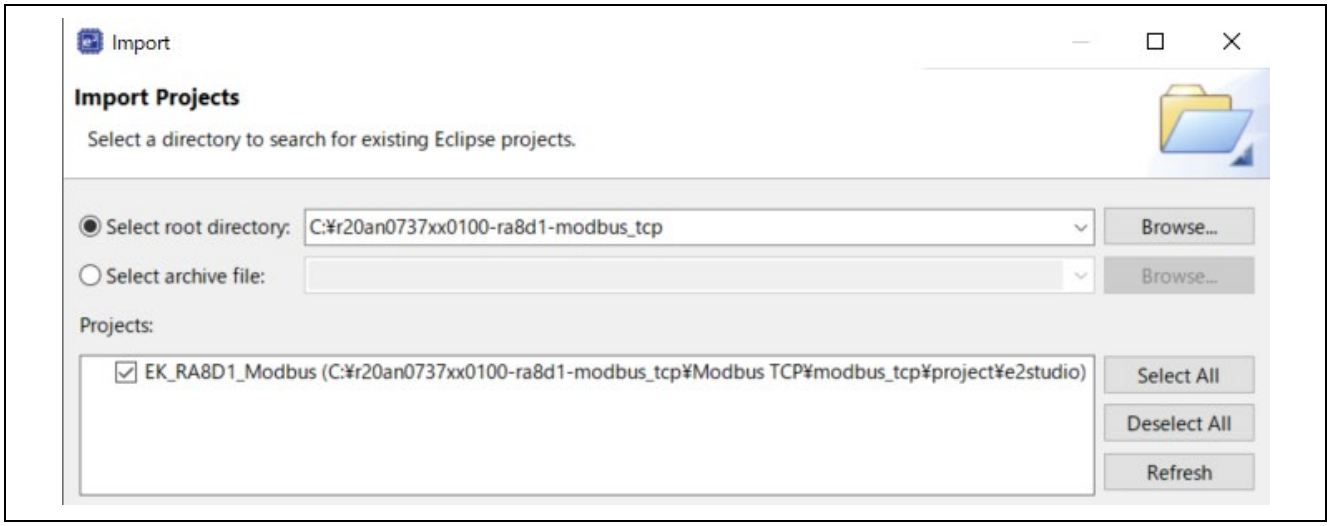


Figure 5. EK-RA8D1 Board Connection Configuration

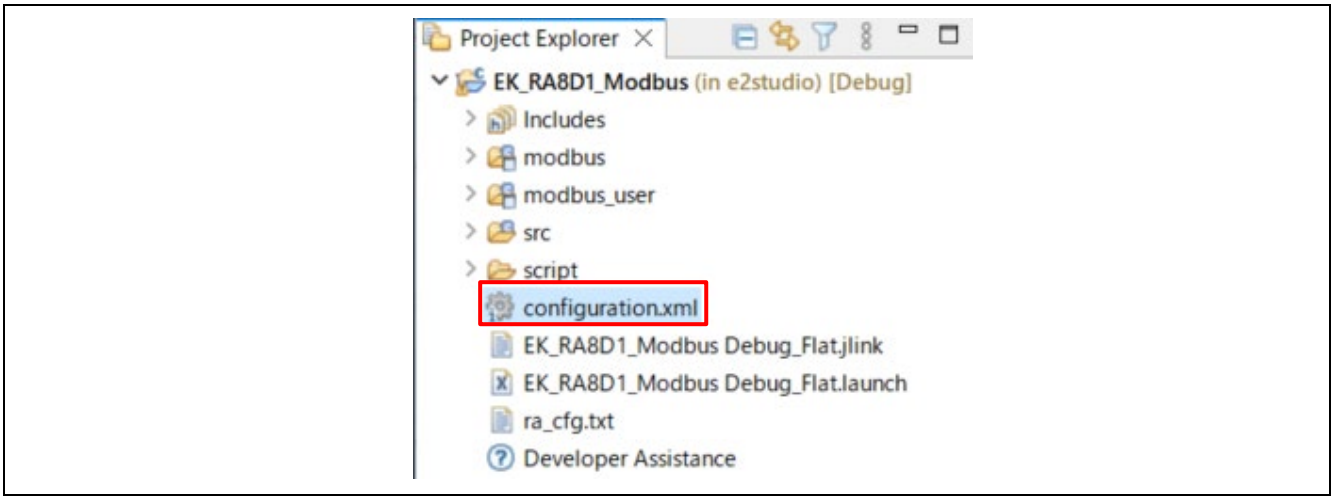
6. Execution of Modbus Sample Program

This section describes the instructions for communicating with the Modbus sample application.
Refer to section, 4 Operating Environment and section 5, Board Setting and Connection in advance to complete tool installation and hardware connection.

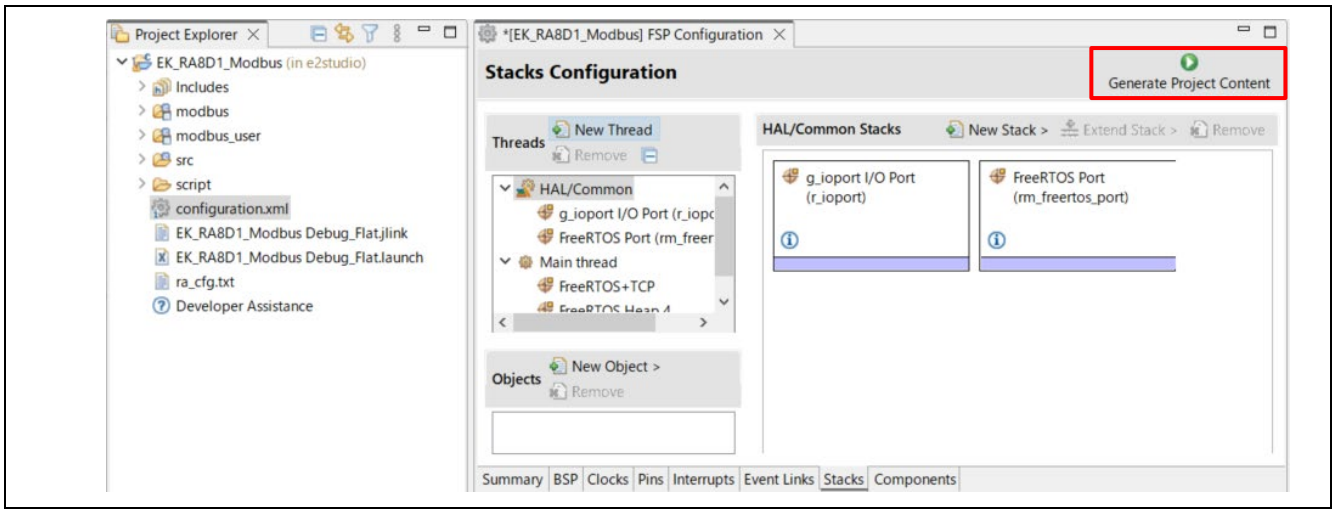
1. Import the sample project after the e^2 studio is started by selecting **File** > **Import** > **Existing Projects into Workspace**.
   Check the **select root directory** and select **r20an0737xx0100-ra8d1-modbus_tcp** folder > **Finish**.



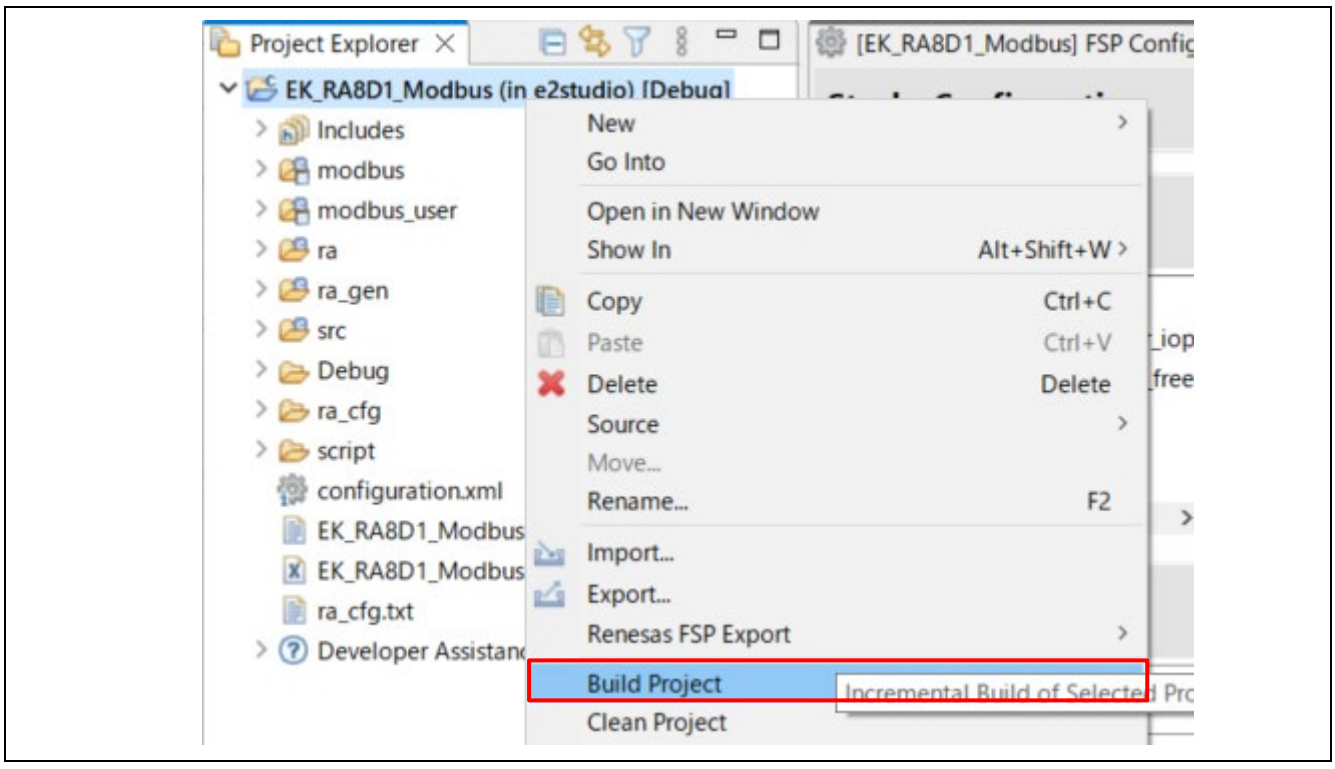
2. Open "cofiguration.xml" in the " EK_RA8D1_Modbus" project



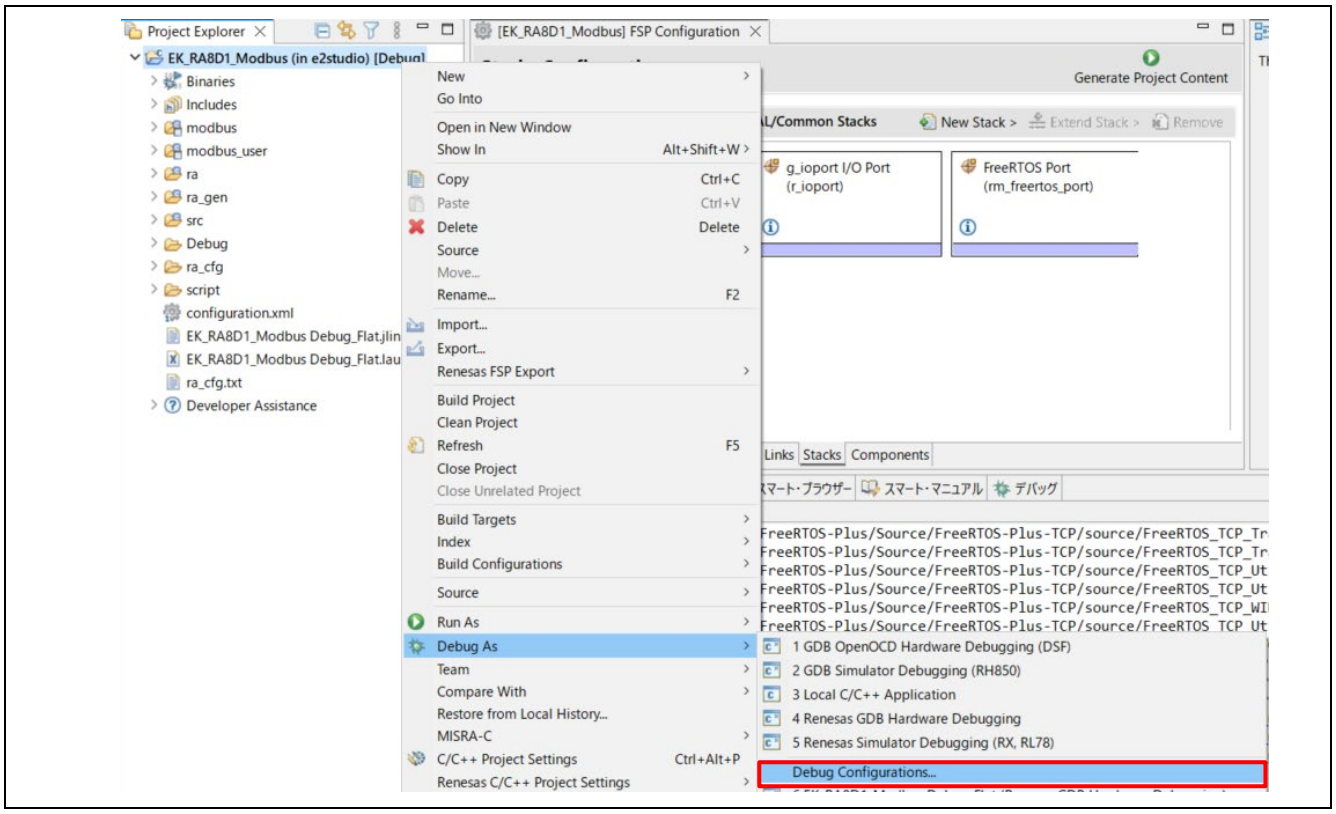
3. Generate the code with "Generate Project Content".



4. Execute the build.
   At this time, confirm that there are no build errors.

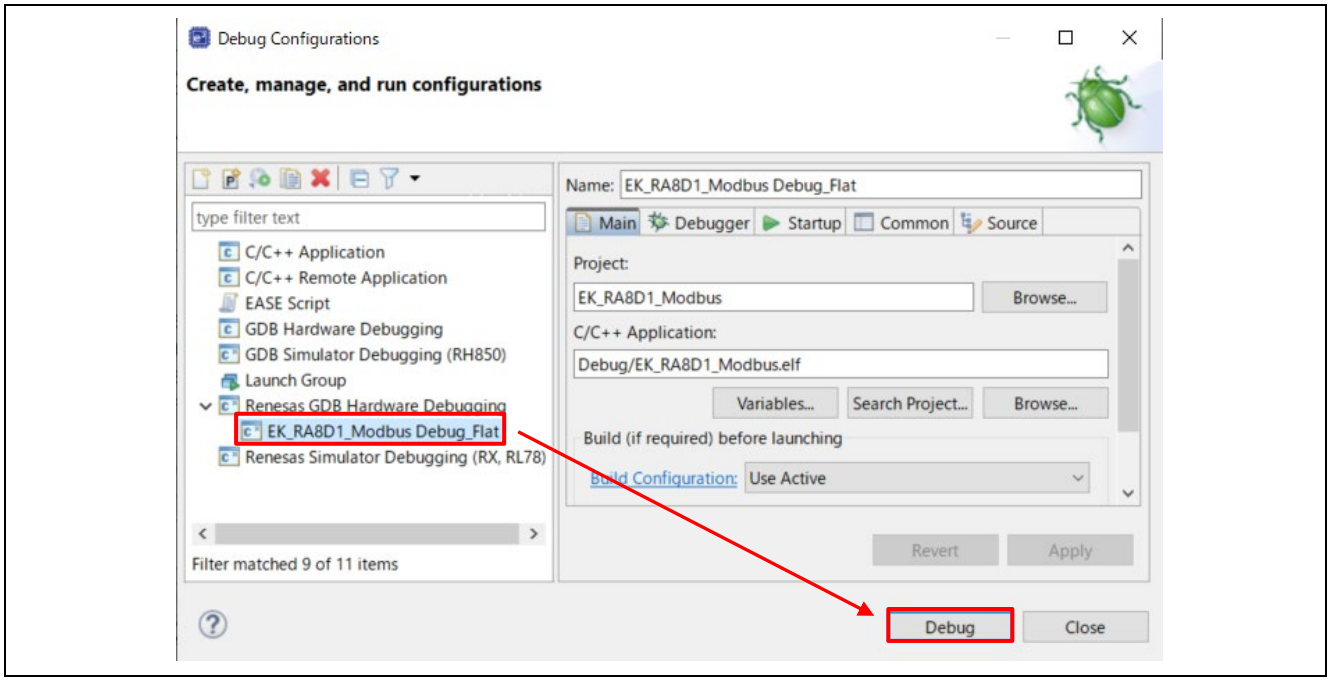


5. Download the application and run the debugger.
   After connecting the board and J-Link OB, start debugging using the following procedure. In **Project Explorer** view, right-click the node of project to be debugged and select **Debug As** > **Debug Configurations**.

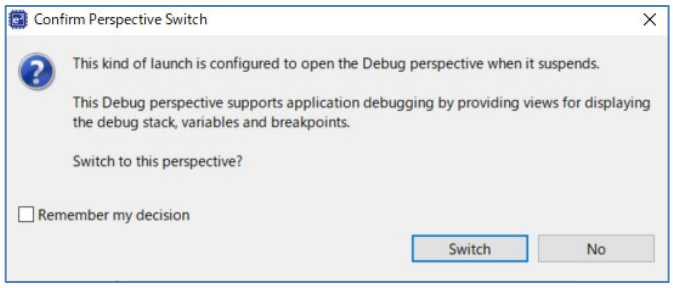


6. Program download.
   Select **Renesas GDB Hardware Debugging** > **EK_RA8D1_Modbus Debug_Flat**, then press **Debug**.

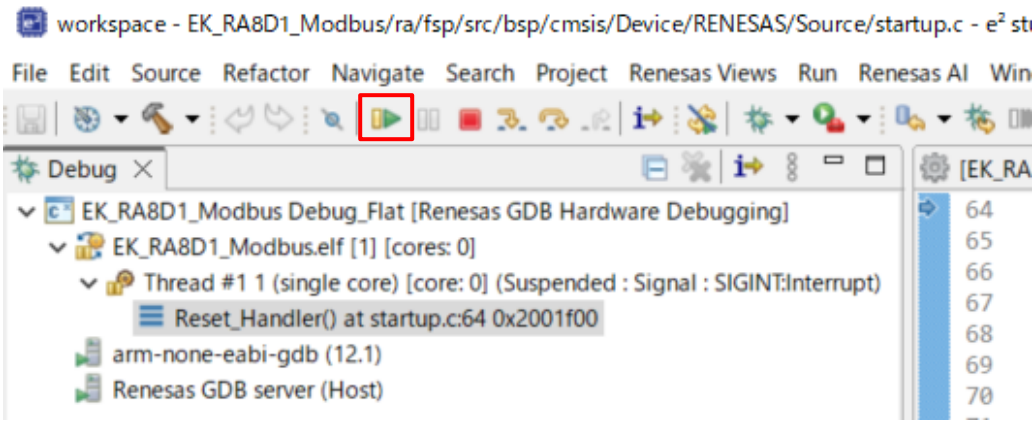
   Note: Debugger configuration is described in Appendix C.



The following dialog will appear, so switch to the debug screen.



7. Program start.
   Click the **Resume** button.
   When debugging is started, the program is interrupted at `main.c;`
   Click the **Resume** button again to run the program.



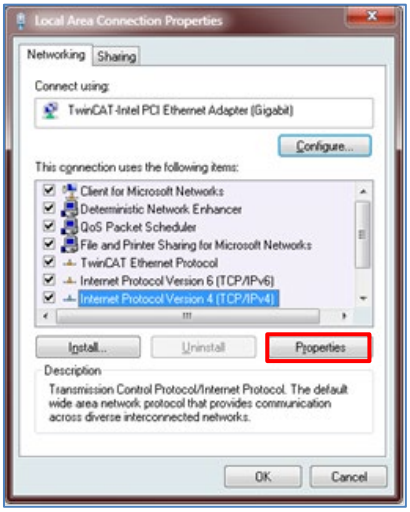
7. Modbus Communication Demo with Evaluation Tool

This section uses the evaluation tool (`ModbusDemoApplication.exe`) to demonstrate the procedure for checking the demo operation of the sample program.

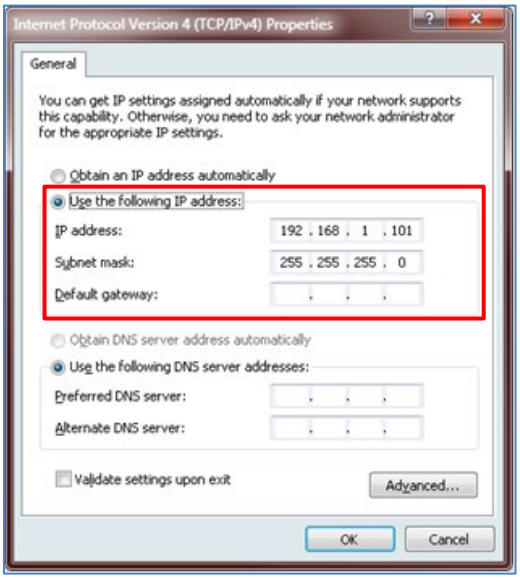
7.1 IP Address Setting

To run the Modbus sample program, it is necessary to set the IP address of the PC 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.

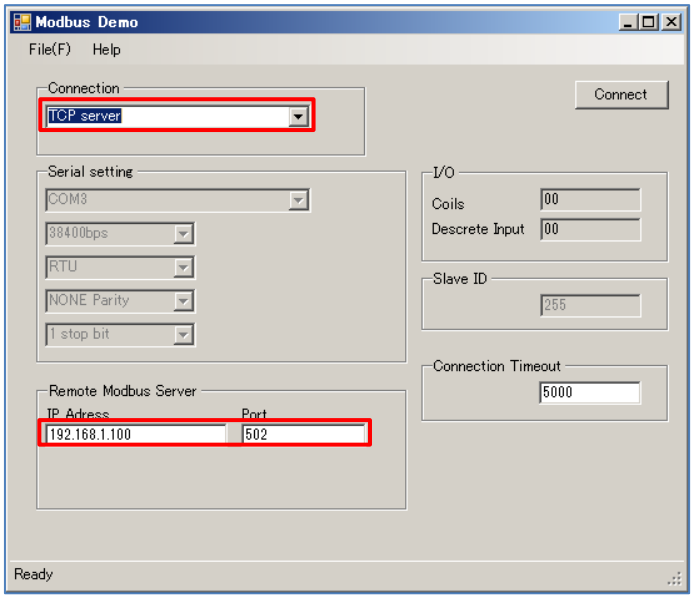


2. Set IP-address to 192.168.1.101, and subnet mask to 255.255.255.0.



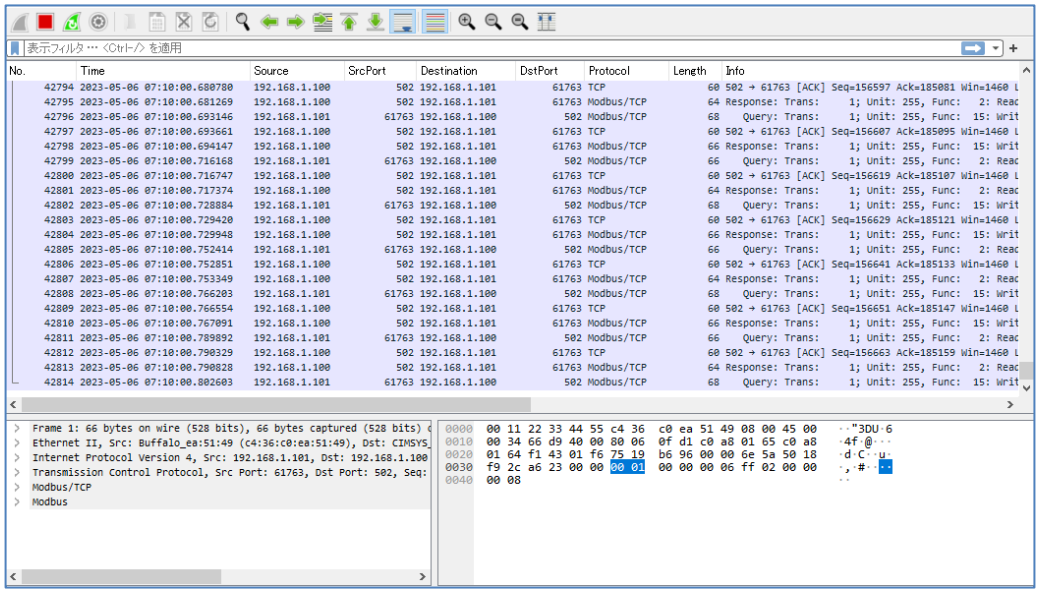
7.2 Setting of Modbus Demo Application

1. Open `ModbusDemoApplication.exe` which is included in this example project package. “Connection” is selected to TCP server and set server IP address (for example, “**192.168.1.100**”) and Port No (for example, “**502**”).



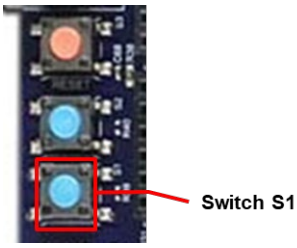
2. When **Connect** button is clicked, LED blinking is started with Modbus communication.

3. By using a packet analysis tool like Wireshark, you can check the Modbus communication status as follows.

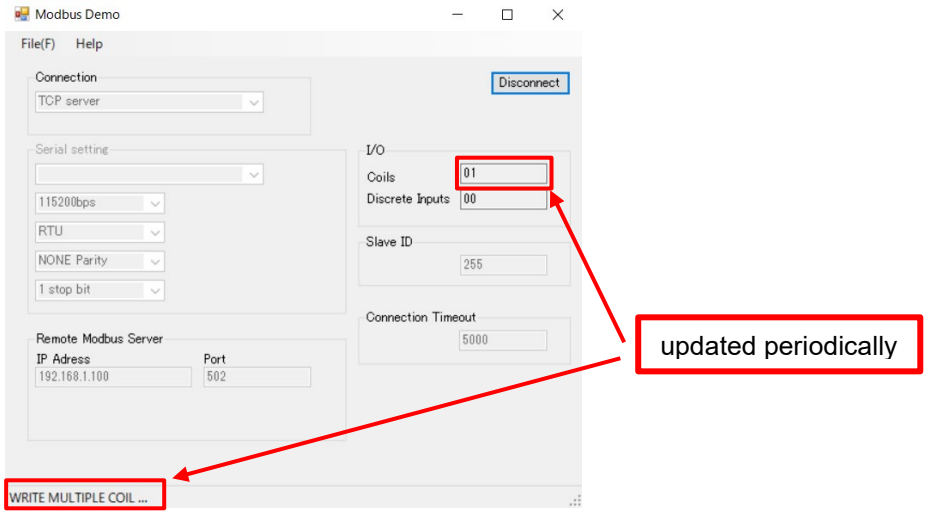


7.2.1 Specification of Demonstration

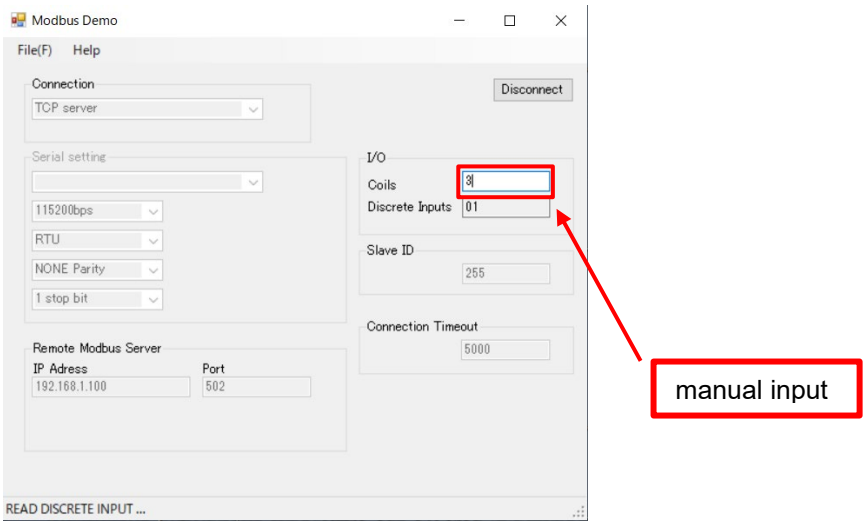
By communicating with PC through the Modbus TCP protocol, LED blinking is controlled dynamically.
For this control, Read Coil and Write Coil commands are used.
PC application checks the state of the switch (SW1), by using Modbus "Read_Discrete_Inputs" function code.
According to the states of the switch, the states of the output ports, which are connected to LED, are updated periodically.



1. When SW1 is OFF, LED1-3 flash periodically.



2. When SW1 is ON, LED1-3 light up depending on the input value of the coil value of the demo application's I/O.

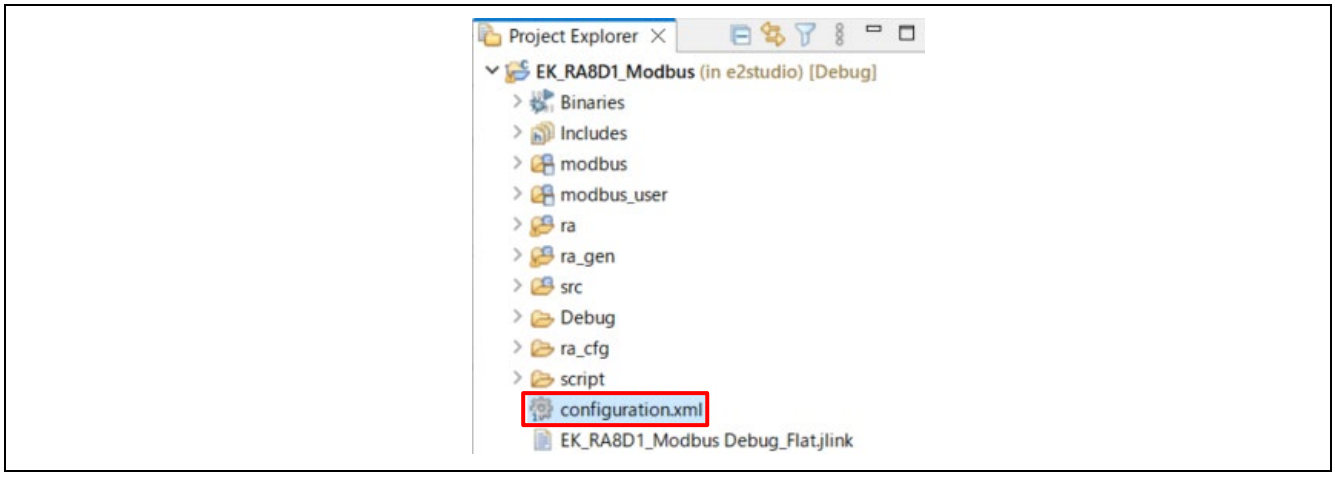


8. Appendix

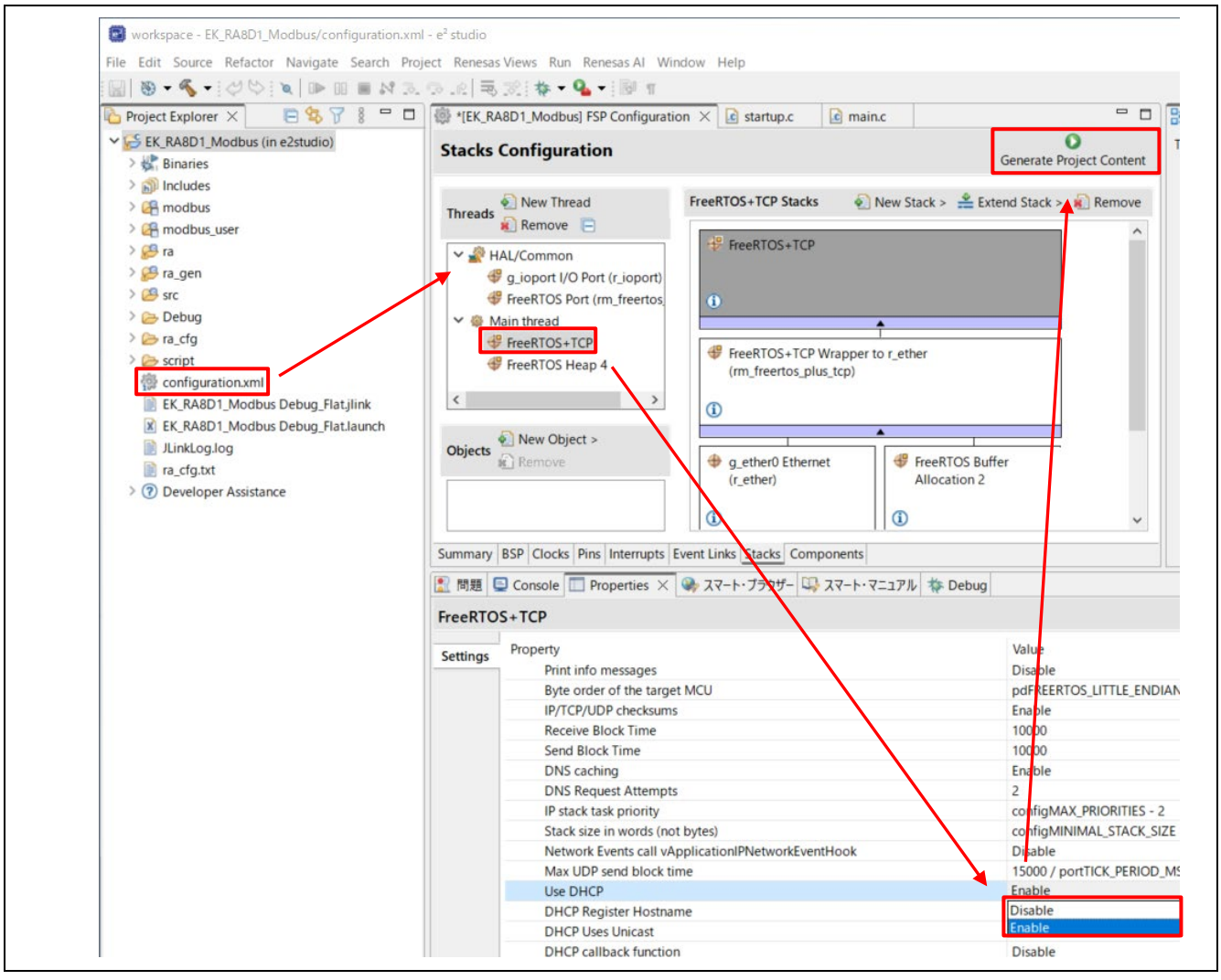
8.1 Appendix A: DHCP Mode

Set DHCP mode using FSP.

1. Open `configuration.xml` from Modbus project.



2. Click **Stacks** tab to open the Stacks Configuration window and select the **FreeRTOS + TCP** in the left threads window. Open the properties, change **Use DHCP** to **Enable** and click **Generate Project Content** button.



8.2 Appendix B: User-defined Function

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

8.2.1 Register Callback Function

Define a user-written function. This sample program uses an LED light as example.
Definition file: `/Modbus_user/modbus_init.c`

- Callback function corresponding to function code1 (Read coil)
  - Read from the coil corresponding to the switches.

- Callback function corresponding to function code5 (Write single coil)
  - Write to the coil corresponding to the LED.

8.2.2 Register Function Code

Definition file: `/Modbus_user/modbus_func.c`
Define the function to be registered in call back function.

8.2.3 User-Defined Functions

User-defined functions are defined in the `Modbus_user/modbus_user.c`
Use the user-defined Read/Write function to process each function.
The corresponding Read/Write function and its table of each address of Coil / Discrete Input / Holding register / Input register are prepared.

【Read Coils】	
address	**access**
0001	LED1, g_coils_area
0002	LED2, g_coils_area
0003	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	LED1, g_coils_area
0002	LED2, g_coils_area
0003	LED3, g_coils_area
0004	g_coils_area
0005	g_coils_area
0006	g_coils_area
0007	g_coils_area
0008	g_coils_area

【Read_Discrete_Inputs】

address	access
1001	S1,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	g_discrete_input_area
1007	g_discrete_input_area
1008	g_discrete_input_area
1009	g_discrete_input_area
10010	ILLEGAL DATA ADDRESS
10011	g_discrete_input_area
10012	g_discrete_input_area

【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

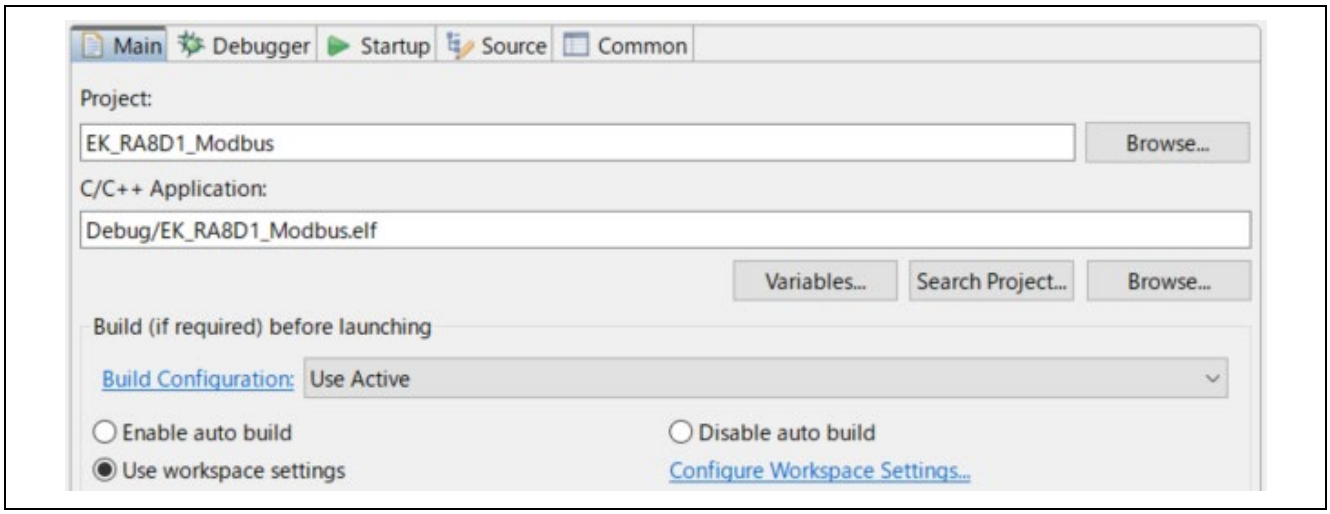
【READ_HOLDING_REGISTERS】

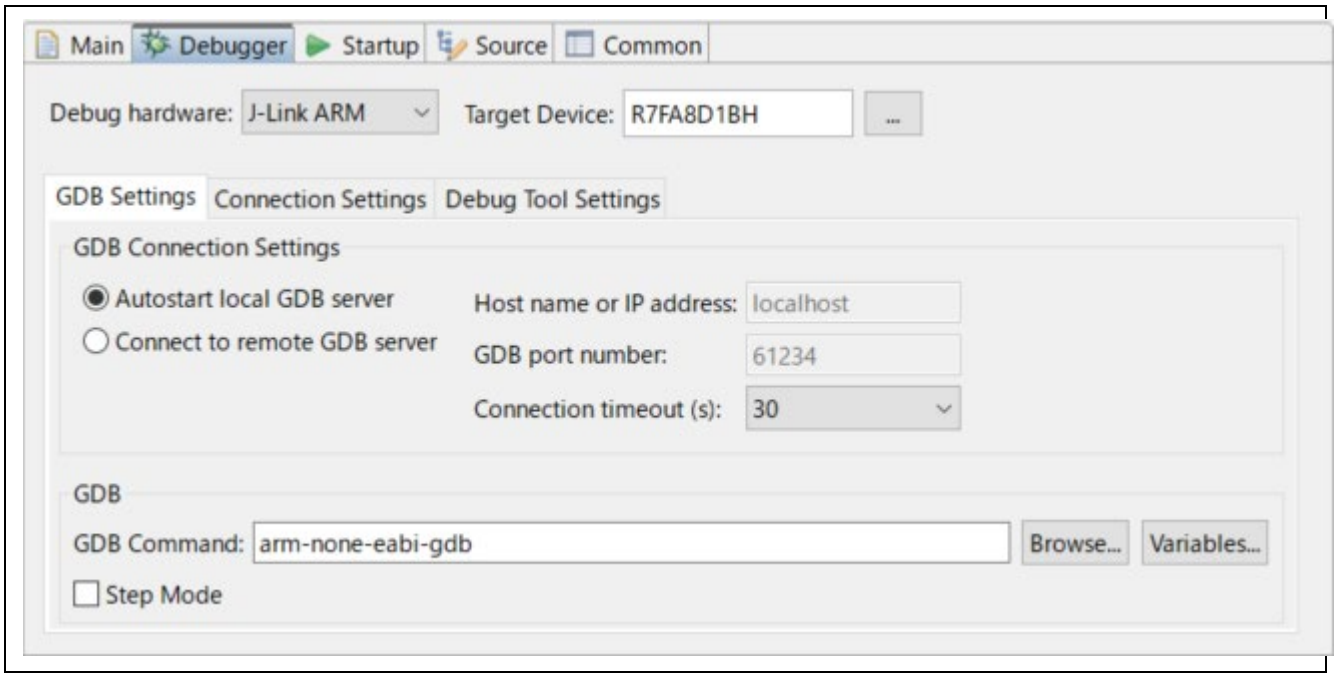
address	access
4001	g_holding_reg_area
4002	g_holding_reg_area
4003	g_holding_reg_area
4004	ILLEGAL DATA ADDRESS
4005	ILLEGAL DATA ADDRESS
4006	ILLEGAL DATA ADDRESS
4007	g_holding_reg_area

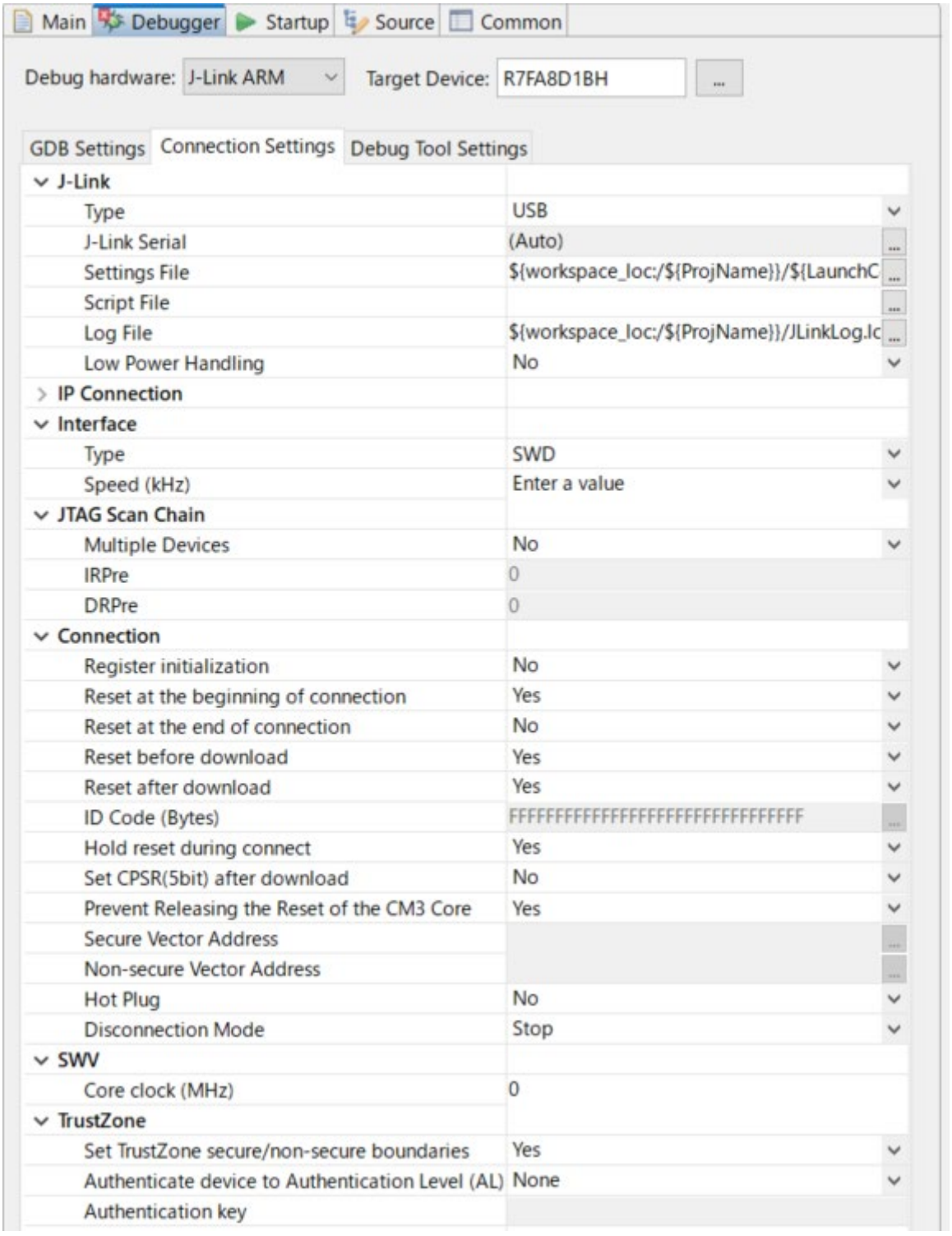
【WRITE_SINGLE_REGISTER】

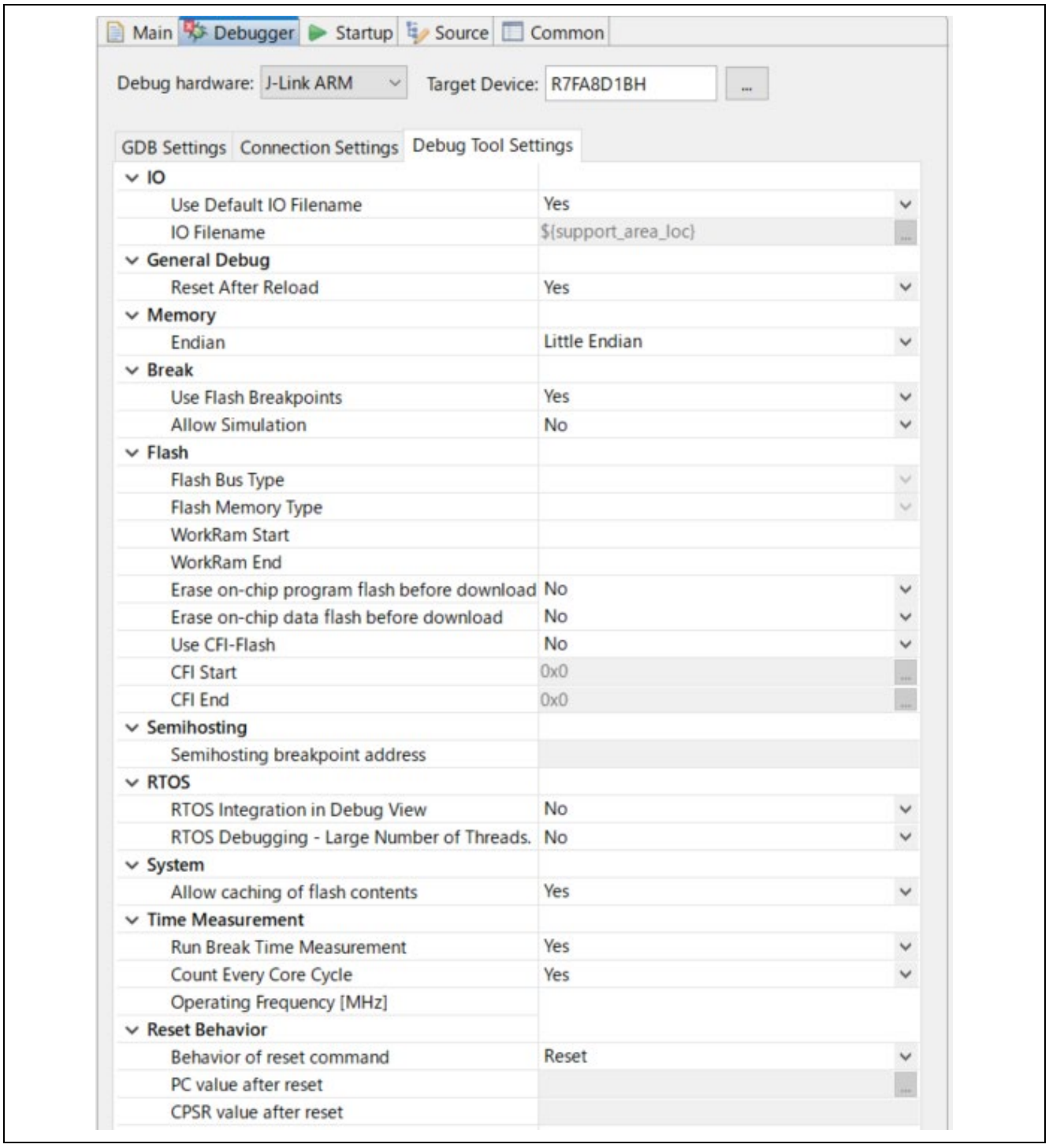
address	access
4001	g_holding_reg_area
4002	g_holding_reg_area
4003	g_holding_reg_area
4004	ILLEGAL DATA ADDRESS
4005	ILLEGAL DATA ADDRESS
4006	ILLEGAL DATA ADDRESS
4007	g_holding_reg_area

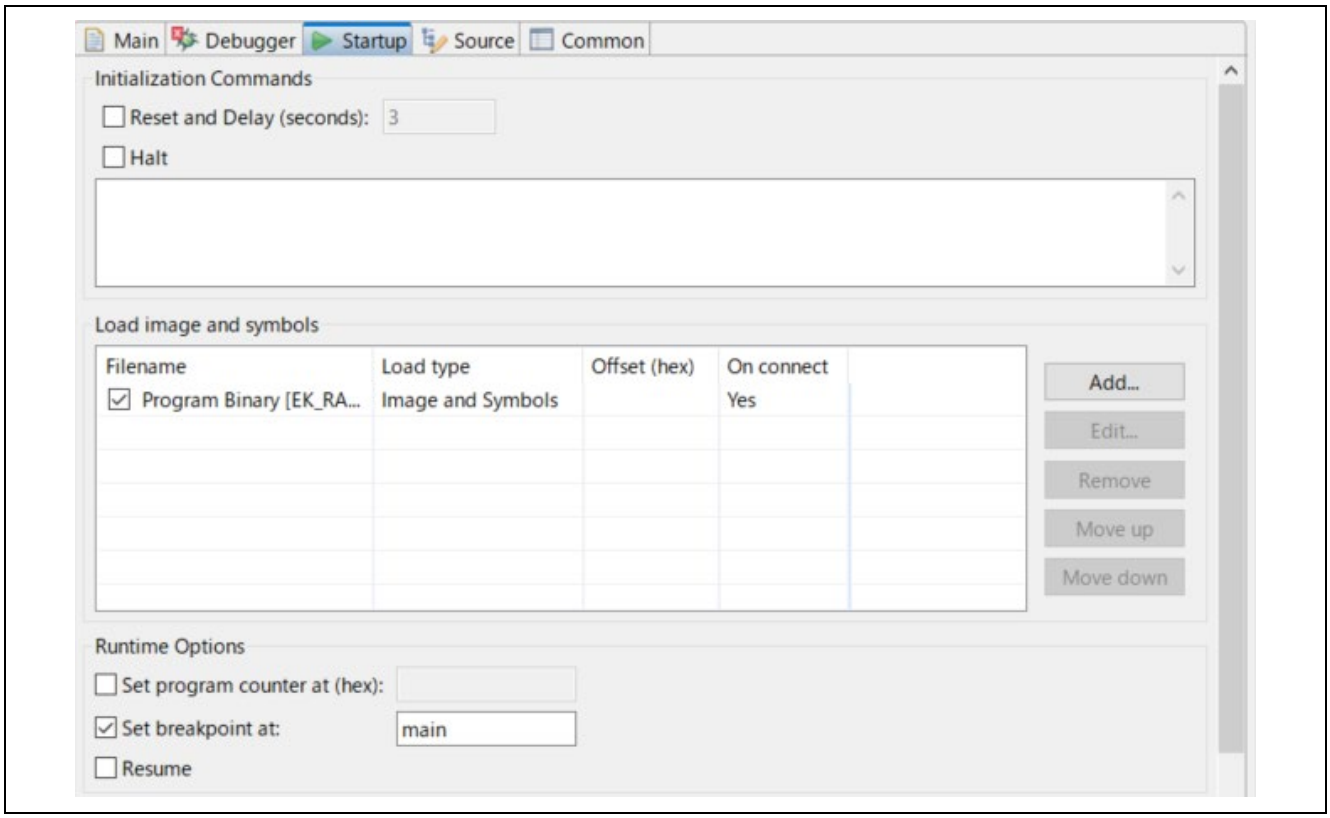
8.3 Appendix C: Debugger configuration

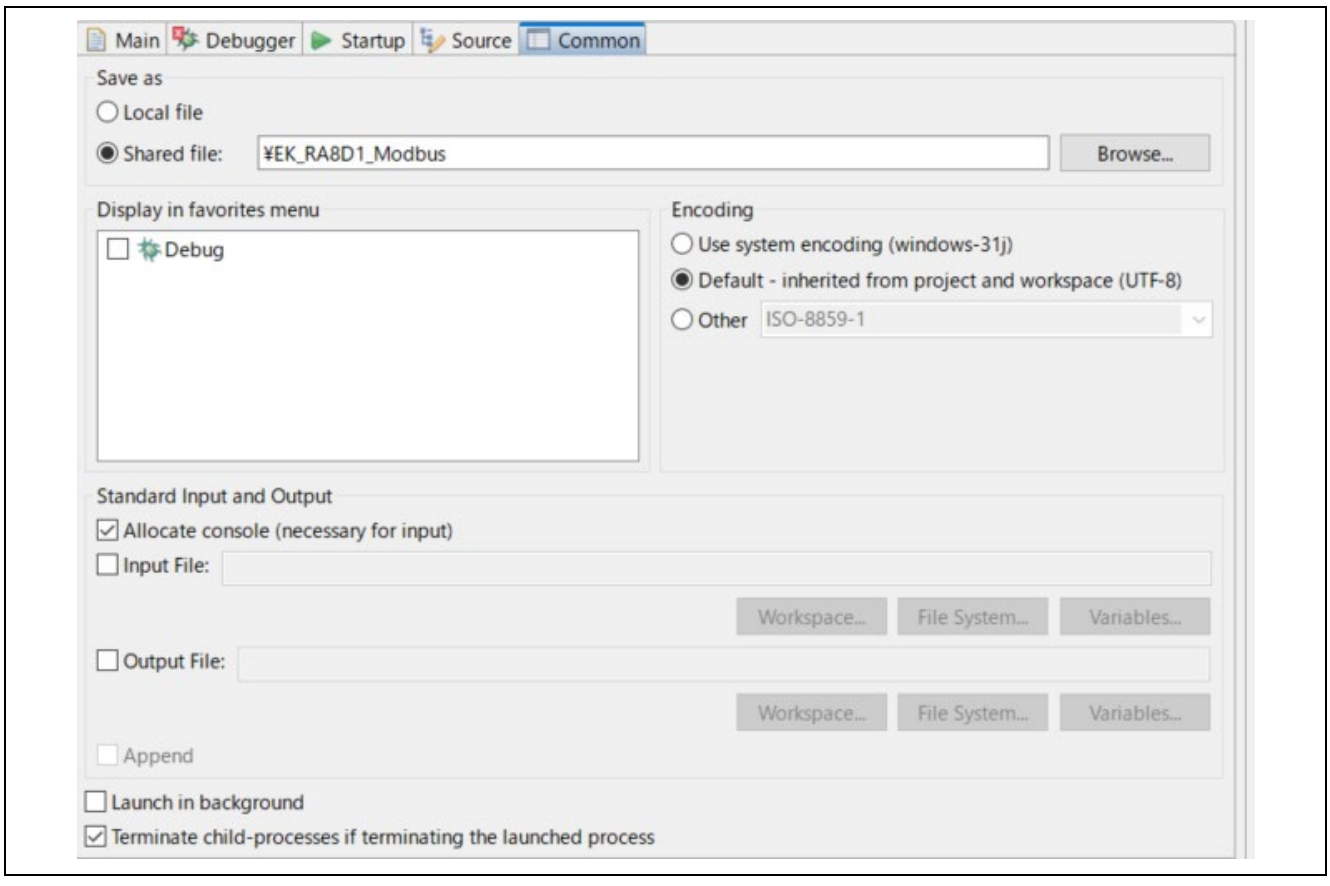





Main
Debugger
Startup
Source
Common
Debug hardware: J-Link ARM
Target Device: R7FA8D1BH
GDB Settings
Connection Settings
Debug Tool Settings
J-Link
Type
USB
J-Link Serial
(Auto)
Settings File
${workspace_loc:/${ProjName}}/${LaunchC
Script File
Log File
${workspace_loc:/${ProjName}}/JLinkLog.lc
Low Power Handling
No
IP Connection
Interface
Type
SWD
Speed (kHz)
Enter a value
JTAG Scan Chain
Multiple Devices
No
IRPre
0
DRPre
0
Connection
Register initialization
No
Reset at the beginning of connection
Yes
Reset at the end of connection
No
Reset before download
Yes
Reset after download
Yes
ID Code (Bytes)
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
Hold reset during connect
Yes
Set CPSR(5bit) after download
No
Prevent Releasing the Reset of the CM3 Core
Yes
Secure Vector Address
Non-secure Vector Address
Hot Plug
No
Disconnection Mode
Stop
SWV
Core clock (MHz)
0
TrustZone
Set TrustZone secure/non-secure boundaries
Yes
Authenticate device to Authentication Level (AL)
None
Authentication key


Main
Debugger
Startup
Source
Common
Debug hardware: J-Link ARM
Target Device: R7FA8D1BH
GDB Settings
Connection Settings
Debug Tool Settings
IO
Use Default IO Filename
Yes
IO Filename
${support_area_loc}
General Debug
Reset After Reload
Yes
Memory
Endian
Little Endian
Break
Use Flash Breakpoints
Yes
Allow Simulation
No
Flash
Flash Bus Type
Flash Memory Type
WorkRam Start
WorkRam End
Erase on-chip program flash before download
No
Erase on-chip data flash before download
No
Use CFI-Flash
No
CFI Start
0x0
CFI End
0x0
Semihosting
Semihosting breakpoint address
RTOS
RTOS Integration in Debug View
No
RTOS Debugging - Large Number of Threads.
No
System
Allow caching of flash contents
Yes
Time Measurement
Run Break Time Measurement
Yes
Count Every Core Cycle
Yes
Operating Frequency [MHz]
Reset Behavior
Behavior of reset command
Reset
PC value after reset
CPSR value after reset


Main
Debugger
Startup
Source
Common
Initialization Commands
Reset and Delay (seconds): 3
Halt
Load image and symbols
Filename
Load type
Offset (hex)
On connect
Program Binary [EK_RA...
Image and Symbols
Yes
Add...
Edit...
Remove
Move up
Move down
Runtime Options
Set program counter at (hex):
Set breakpoint at: main
Resume


Main
Debugger
Startup
Source
Common
Save as
Local file
Shared file: ¥EK_RA8D1_Modbus
Browse...
Display in favorites menu
Debug
Encoding
Use system encoding (windows-31j)
Default - inherited from project and workspace (UTF-8)
Other ISO-8859-1
Standard Input and Output
Allocate console (necessary for input)
Input File:
Workspace...
File System...
Variables...
Output File:
Workspace...
File System...
Variables...
Append
Launch in background
Terminate child-processes if terminating the launched process

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Dec.11.23	-	First version

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

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

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