

## RZ/N2L Group

### RZ/N2L Industrial Network SOM Kit Application Note: EtherCAT CiA402 Slave Software

## Introduction

This document explains Sample Program setup procedures for EtherCAT<sup>®</sup> slave functionalities with the adapted EtherCAT Stack Code for Renesas RZ/N2L platform. This describes steps to confirm slave behavior and stack features using TwinCAT<sup>®</sup> Master Configuration tool.

## Target Device

RZ/N2L

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## 1. Overview

This document describes how to run EtherCAT on the RZ/N2L Group. Run the standalone variant using only one core.

EtherCAT(Ethernet for Control Automation Technology) is an Ethernet based fieldbus system, developed by Beckhoff Automation. Development of EtherCAT was to apply Ethernet for automation applications (e.g., for motion control, I/O, sensors) requiring short data update times with low communication jitter and reduced hardware costs.

Tool to generate EtherCAT Slave Stack Code (SSC Tool) is available to the ETG members free of charge. This can be downloaded from the ETG website. SSC tool can be used to generate customized stack, device description files (ESI) and individual source code documentation to suit the developer's own needs.

This document describes the procedure for testing the EtherCAT slave function using EtherCAT stack code compatible with the Renesas RZ/N2L platform. Scope of the documentation is limited to explaining how to use the SSC tool for EtherCAT slave stack code generation and testing its behavior against TwinCAT masters and test applications.

### 1.1 Abbreviations/Definitions

**Table 1. Abbreviations/Definitions**

| Index | Abbreviations /Definitions | Description                                         |
|-------|----------------------------|-----------------------------------------------------|
| 1     | CoE                        | CAN application protocol over EtherCAT              |
| 2     | EEPROM                     | Electrically Erasable Programmable Read-Only Memory |
| 3     | ESC                        | EtherCAT Slave Controller                           |
| 4     | ESI                        | EtherCAT Slave Information                          |
| 5     | FoE                        | File Access Over EtherCAT                           |
| 6     | I2C                        | Inter-Integrated Circuit                            |
| 7     | MB                         | Mail Box                                            |
| 8     | PDO                        | Process Data Object                                 |
| 9     | SSC                        | Slave Stack Code                                    |
| 10    | EoE                        | Ethernet Over EtherCAT                              |

### 1.2 Reference

Technical information about EtherCAT is available via ETG member site, and information about RZ/N2L is available via Renesas.

**Table 2. Technical Inputs**

| Index | Technical Inputs                                                                                   |
|-------|----------------------------------------------------------------------------------------------------|
| 1     | r01uh0955ejxxxx-rzn2l.pdf (RZ/N2L User's Manual: Hardware)                                         |
| 2     | r01an6434ejxxxx-rzt2-rzn2-fsp-getting-started.pdf (Getting started with Flexible Software Package) |
| 3     | r12ut0020edxxxx-rzn2l-som-kit-hw.pdf (RZ/N2L Industrial Network SOM Kit Use's Manual)              |
|       |                                                                                                    |
|       |                                                                                                    |

## 2. Features

EtherCAT slave stack code generated by SSC Tool provides the functionality of EtherCAT slave controller.

Includes the following features :

- ESM (EtherCAT State Machine)
- Mailbox protocols:
  - CoE (CAN application protocol over EtherCAT)
- Synchronization Modes:
  - Free Run
  - Sync Manager Synchronization
  - DC Synchronization
- CiA402 Drive Profile:
  - csp Mode
  - csv Mode



EtherCAT is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

### 3. Project Setup

#### 3.1 Requirements

Table 3. Requirements

| Item         | Vender              | Description                                                                                                                                                                                                                                                                                                                                  |
|--------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Board        | Renesas Electronics | RZ/N2L Industrial Network SOM Kit                                                                                                                                                                                                                                                                                                            |
| IDE          | IAR Systems         | <ul style="list-style-type: none"> <li>● Embedded Workbench® for ARM Version 9.30.1</li> </ul> Please apply patch (EWARM_Patch_for_RZN2L) which is available in <a href="http://www.renesas.com/rzn2l">http://www.renesas.com/rzn2l</a> . Regarding how to apply the patch, please read the readme file in patch file.                       |
|              | Renesas Electronics | <ul style="list-style-type: none"> <li>● e² studio 2023-04</li> <li>● FSP Smart Configurator 2023-04</li> <li>● RZ/N2L Flexible Software Package (FSP) v1.2.0</li> </ul> Please download from the link below.<br><a href="https://github.com/renesas/rzn-fsp/releases/tag/v1.2.0">https://github.com/renesas/rzn-fsp/releases/tag/v1.2.0</a> |
| Emulator     | IAR Systems         | I-jet                                                                                                                                                                                                                                                                                                                                        |
|              | SEGGER              | Hardware: J-Link<br>Software: J-Link Commander V7.82f *1                                                                                                                                                                                                                                                                                     |
| SSC Tool     | Beckhoff Automation | Slave Stack Code (SSC) Tool Version 5.13                                                                                                                                                                                                                                                                                                     |
| Software PLC | Beckhoff Automation | TwinCAT3                                                                                                                                                                                                                                                                                                                                     |

\*1: J-Link Commander is used for erasing flash memory.  
 J-Link Commander is included in “J-Link Software and Documentation Pack” on the following site.  
<https://www.segger.com/downloads/jlink/>

### 3.2 Hardware

This document describes the major hardware. Refer to RZ/N2L Industrial Network SOM Kit user's manual and schematic for more board details.

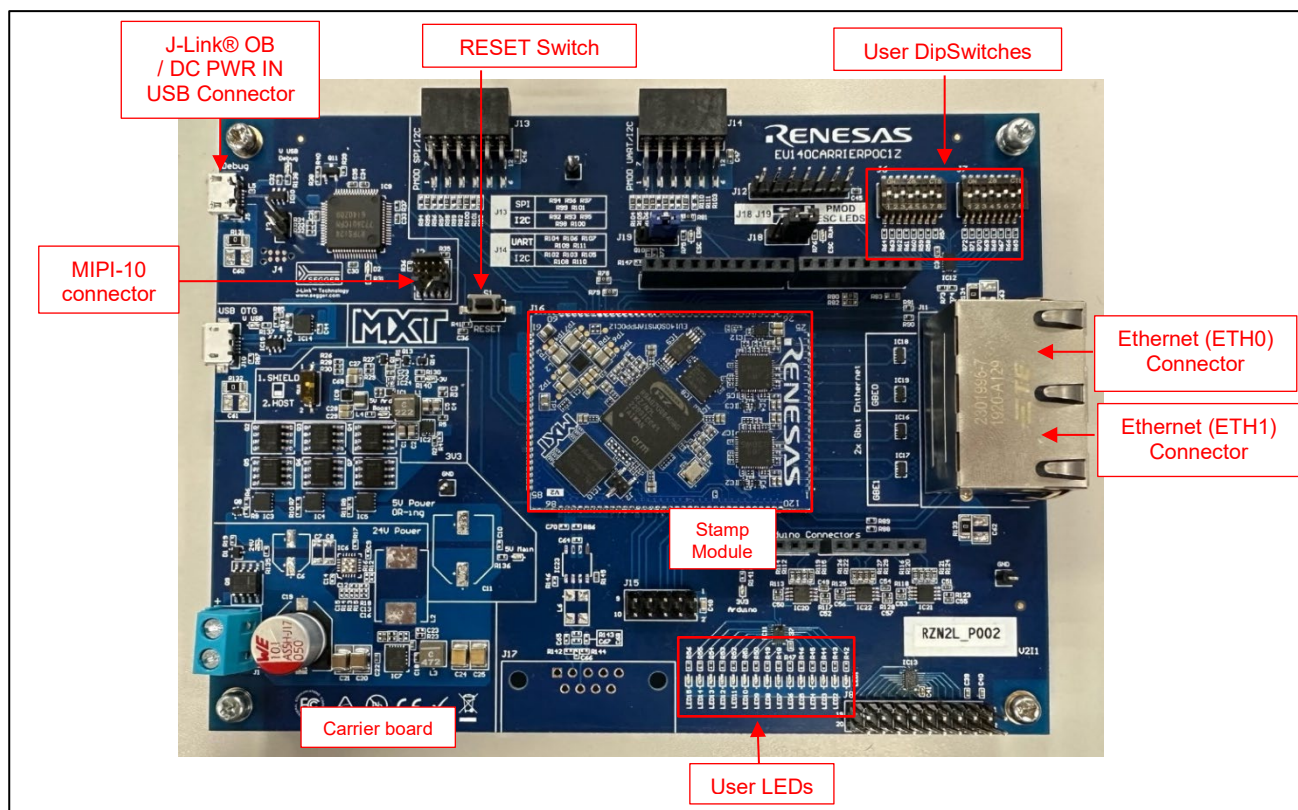


Figure 3-1 RZ/N2L Industrial Network SOM Kit

### 3.3 Note about Ethernet PHY driver using FSP

This SOM Kit has VSC8531 that is not compatible with FSP as PHY chip. Therefore, we have modified the PHY driver for VSC8531. For details, see "Appendix: FSP Configuration for VSC8531".

### 3.4 Setup the Board

Setting the board for running sample program is shown below.

1. Connect the I-jet to J2 or the USB cable to J5 for J-link OB on Carrier board.

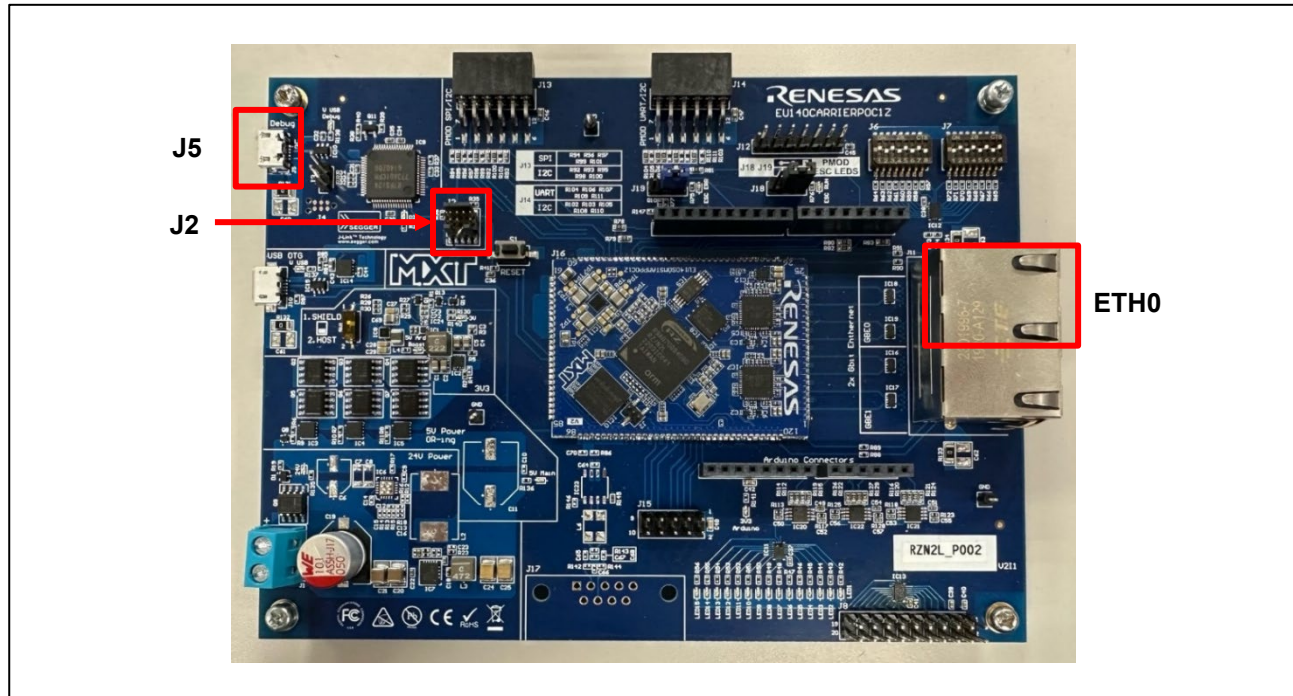


Figure 3-2 Setup the SOM Kit

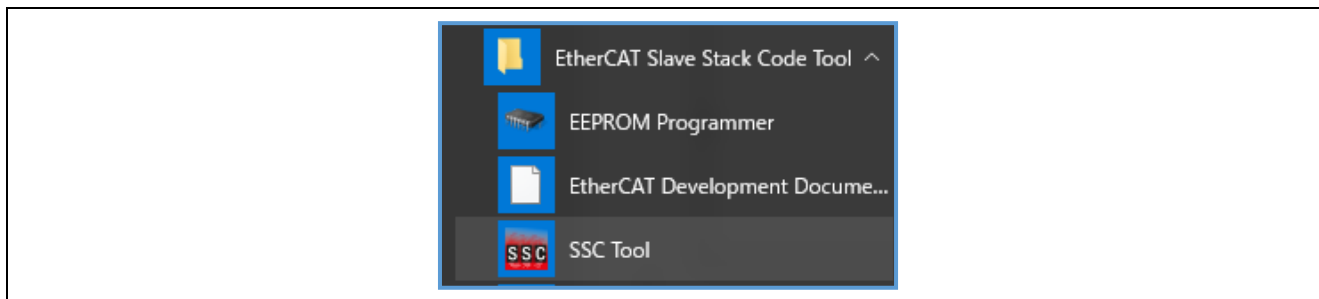
2. Power is supplied by connecting USB Micro-B cable to the USB connector “J5) of the Carrier board.
3. Connect Ethernet Cable to the Ethernet Connector “ETH0”.

### 3.5 Generating the Slave Stack Code

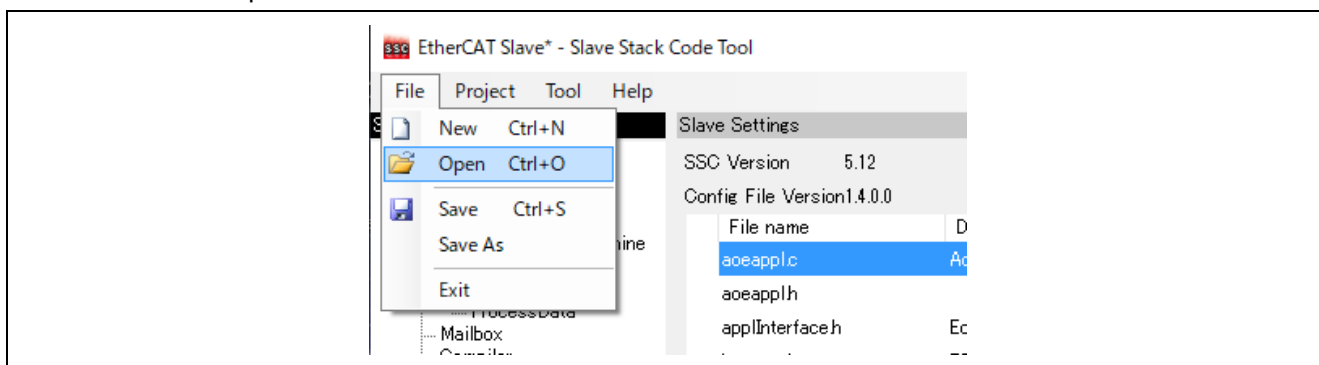
SSC Tool is used for generating the slave stack code.

Note). Replace the folder name in the following description according to the tool to be used.

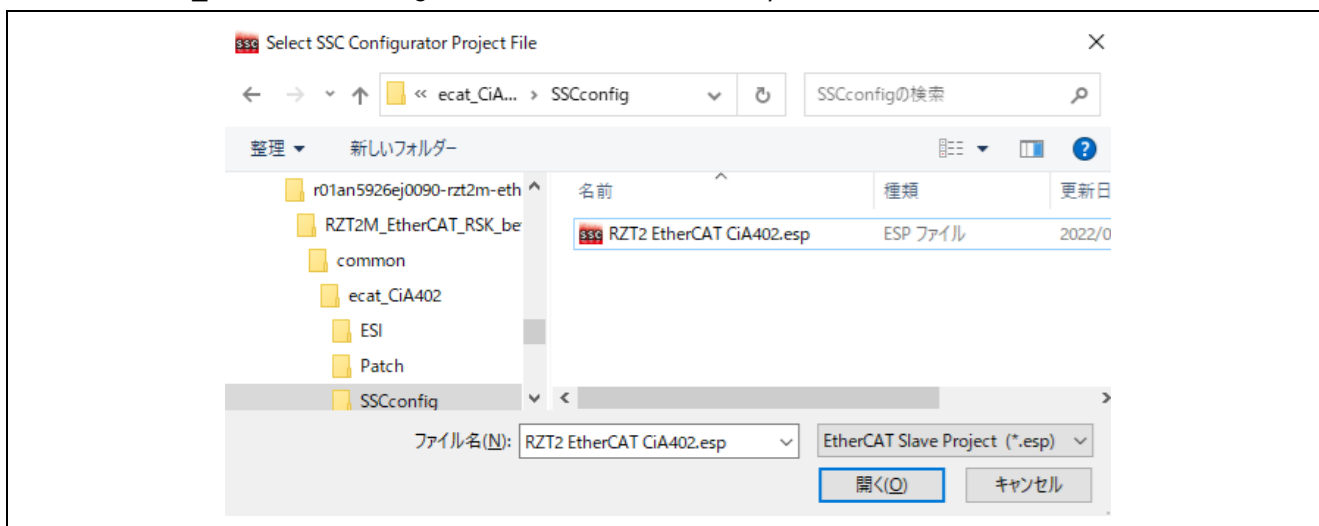
1. Start the SSC Tool from the Window Start menu.



2. Select File > Open.

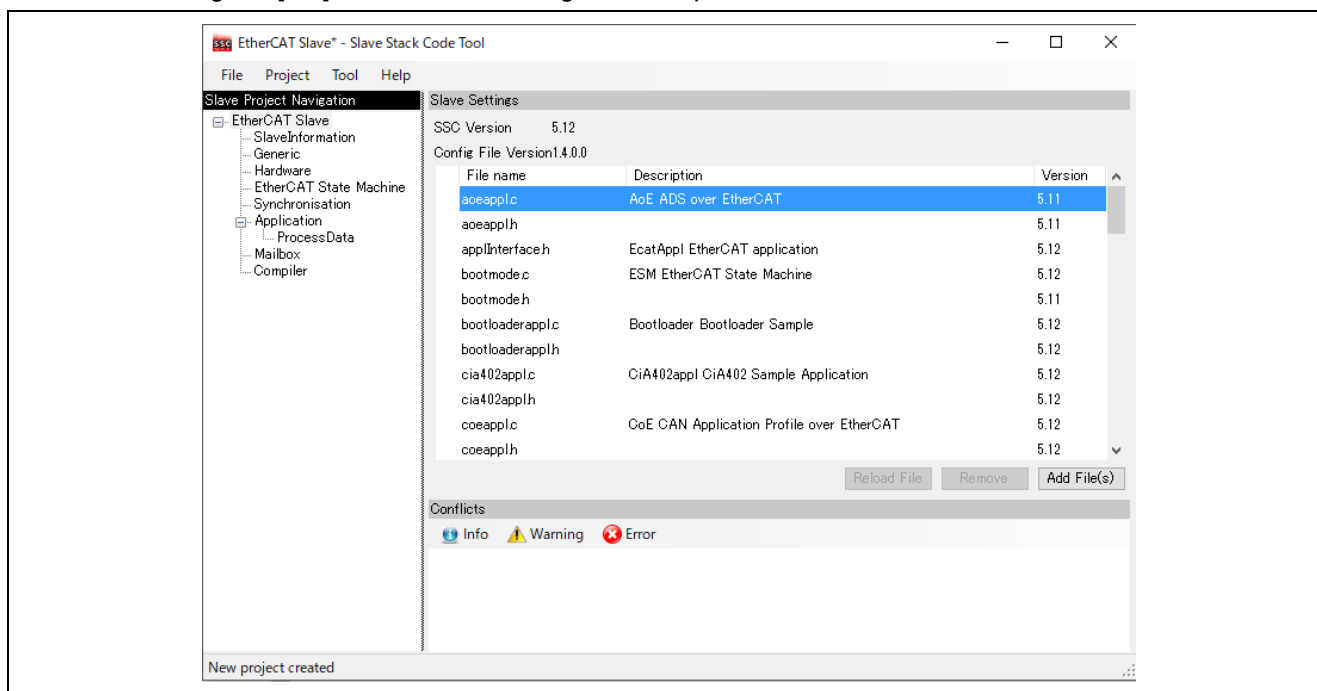


1. Select the following file,  
"common\ecat\_CiA402\SSCconfig\RZN2 EtherCAT CiA402.esp"

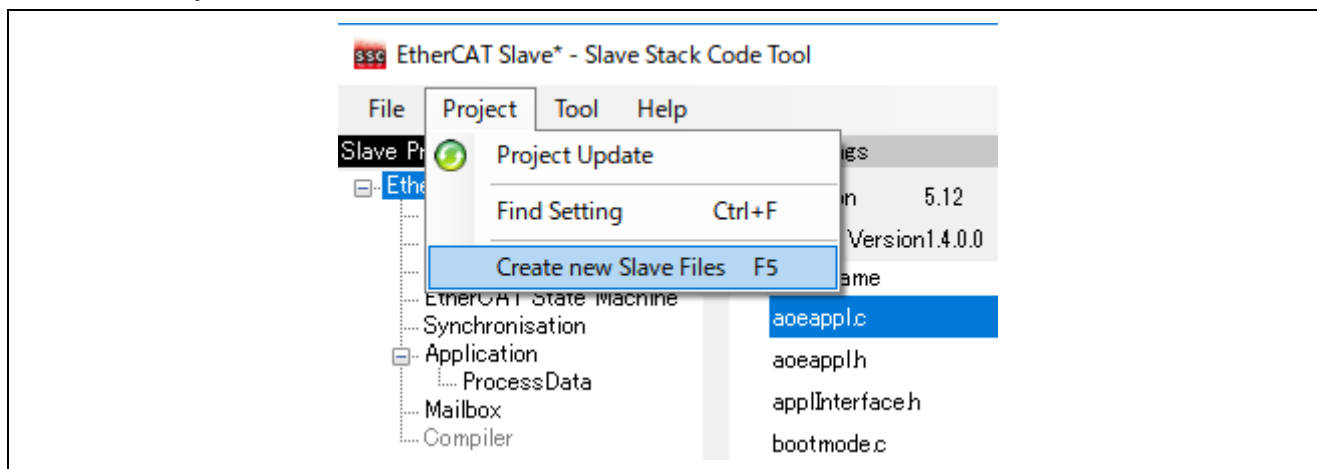




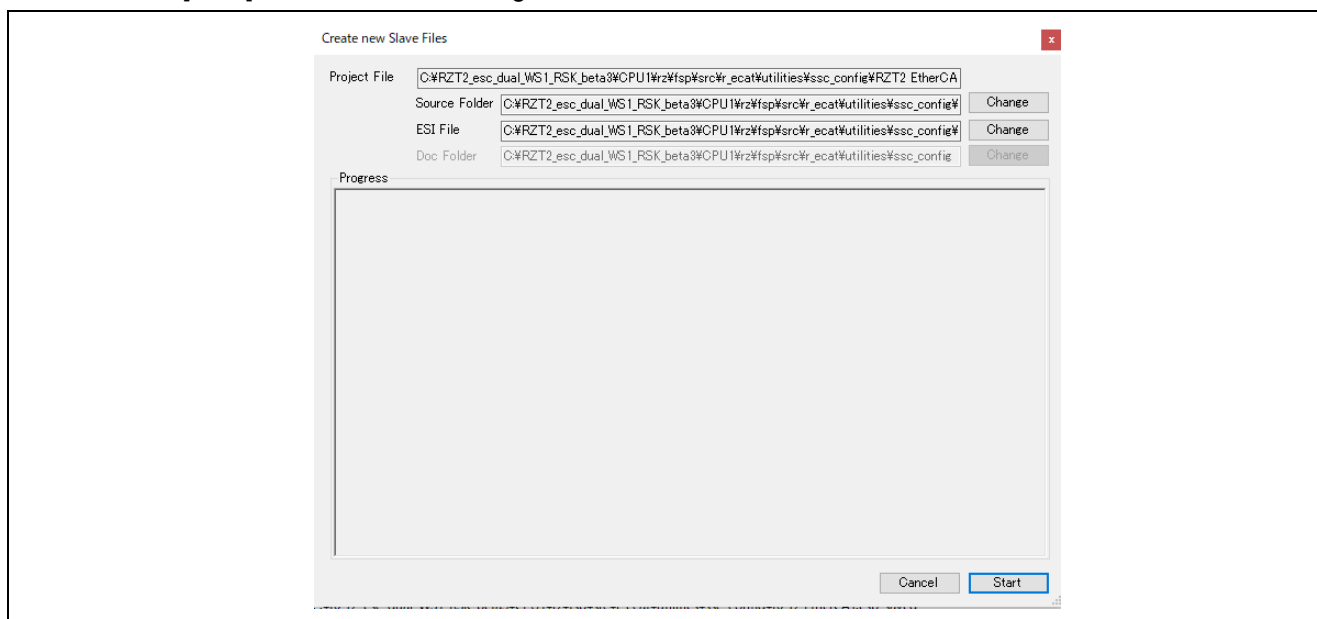
2. After clicking the [OK] button, the following window opens.



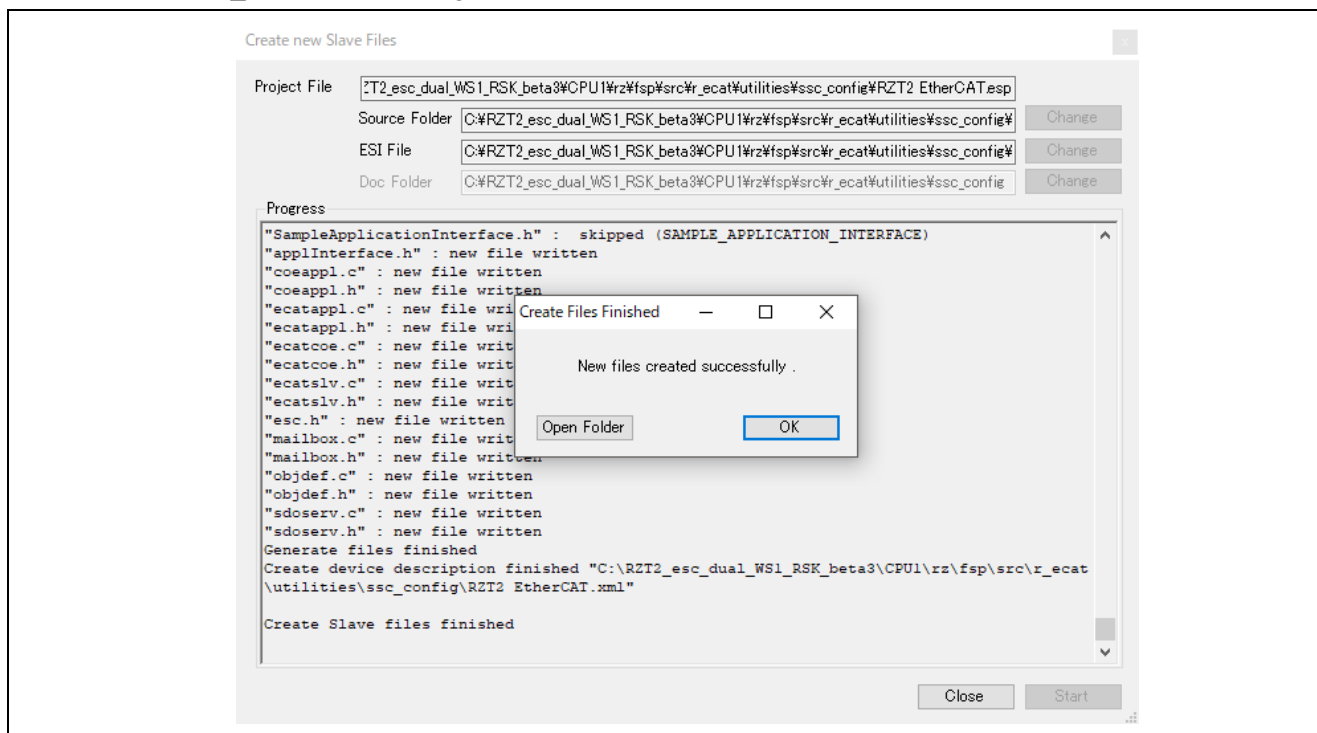
3. Select Project > Create new Slave Files.



- Click the [Start] button to start creating the EtherCAT Slave Stack Code.



- When a message “New file created successfully” appears, the creation processing is completed, and the source files are located in the following folder.  
“common\ecat\_CiA402\SSCconfig\Src”



Note), If an error occurs during generation, uncheck "Create device description" in [Tool]-> [Option]-> [Create Files] of the SSC tool.

6. Right-click on the apply\_patch.bat file and select [Run as an administrator] → [Yes]  
The patch file contains modifications to make the SSC source file suitable for the RZ/N2L.

[ewarm]  
"common\ecat\_CiA402\Patch\apply\_patch\_ewarm.bat"

[e2studio]  
"common\ecat\_CiA402\Patch\apply\_patch\_e2studio.bat"



```
--- Move SSC Src folder ---  
1 dir(s) moved.  
--- Patching process start ---  
patching file Src/cia402appl.c  
patching file Src/cia402appl.h  
patching file Src/ecatacoe.h  
patching file Src/mailbox.h  
patching file Src/sdoserv.h  
--- Patching process end ---  
--- Move patched Src folder ---  
1 dir(s) moved.  
Press any key to continue . . .
```

After execution of the patch, the modified source file is stored in the following folder.

[ewarm]  
"project\rzn2l\_som\ecat\_CiA402\ewarm\src\ethercat\  
beckhoff"

[e2studio]  
"project\rzn2l\_som\ecat\_CiA402\e2studio\src\ethercat\  
beckhoff"

Note) If the patch command is not installed on your PC, you will need to install ver. 2.5.9 or a later version of GNU patch.

If it is already installed, skip this step.

Download the patch command (currently ver. 2.5.9) from the following Web page and store "patch.exe" in a folder on a path that makes the file executable from the command prompt.

<http://gnuwin32.sourceforge.net/packages/patch.htm>

## 4. Setting up a TwinCAT3

### 4.1 Copying the ESI Files

Before starting TwinCAT, copy the ESI files that are included in the release folder to TwinCAT destination  
 “\\TwinCAT\\3.x\\Config\\IO\\EtherCAT”

ESI file for current release available at,

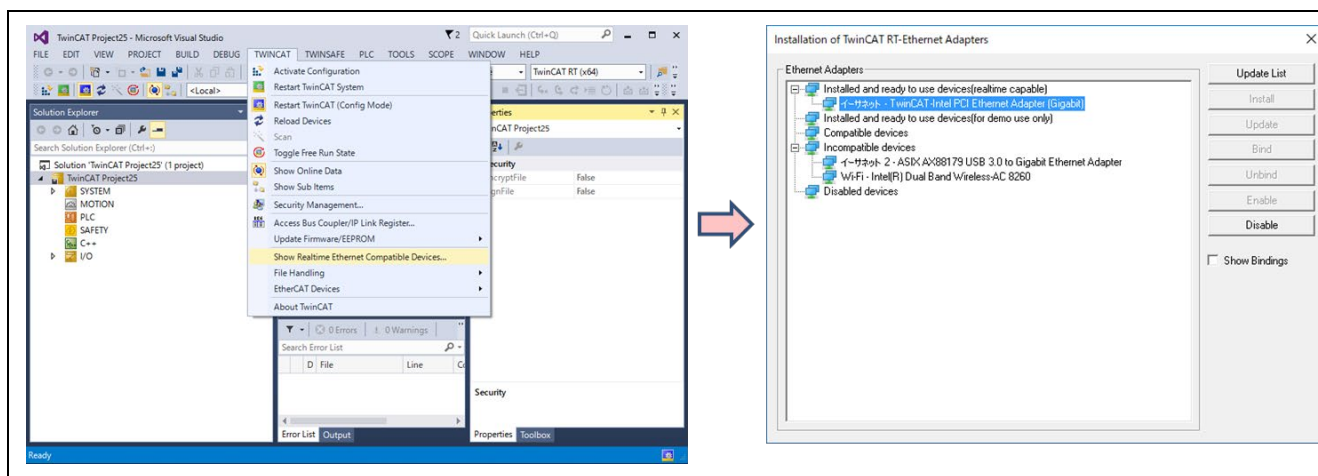
“common\\ecat\_CiA402\\ESI\\Renesas EtherCAT RZN2 CiA402.xml”

### 4.2 Add Driver

Add the Ether driver for TwinCAT. (First time only)

From the start menu, select [TwinCAT3] → [Show Realtime Ethernet Compatible Device].

Select the connected Ether port from the communication ports and install it.



## 5. Running the sample application

### 5.1 Setting sample code for EWARM

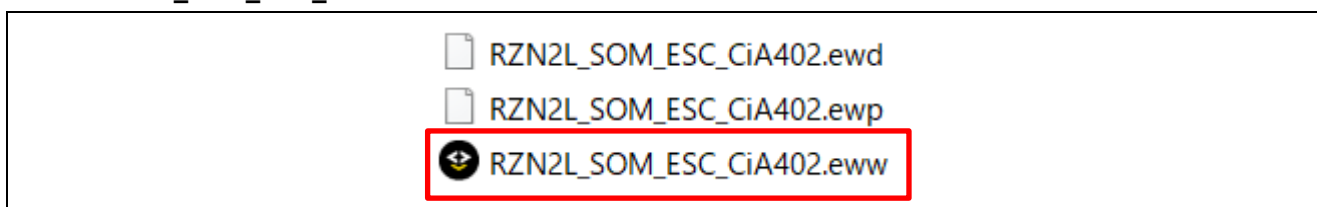
Build the sample code and load it into RAM using IAR Embedded Workbench.

Note). Please install FSP Smart Configurator in advance.

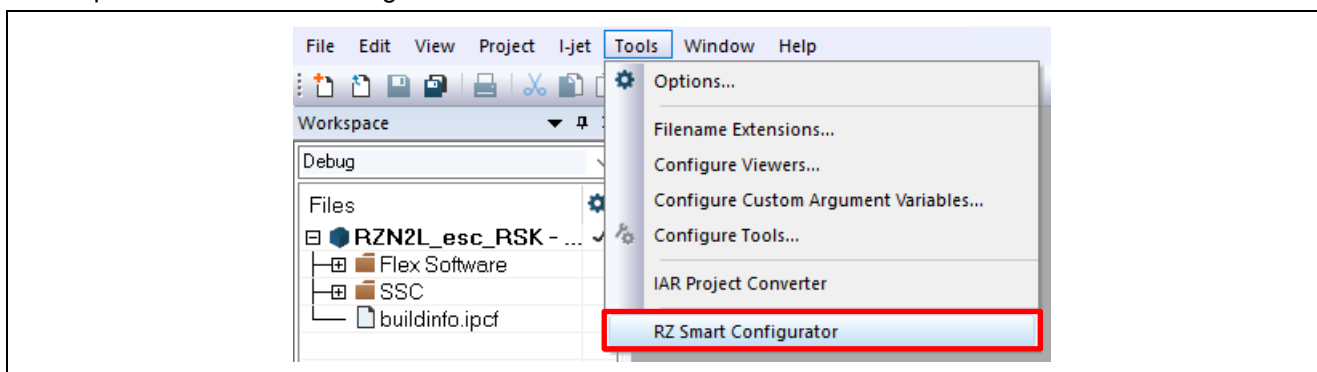
Refer to the latest getting started guide.( R01an6434ejxxx-rzt2-rzn2.pdf)

Replace the project name in the figure with the project name of this sample project.

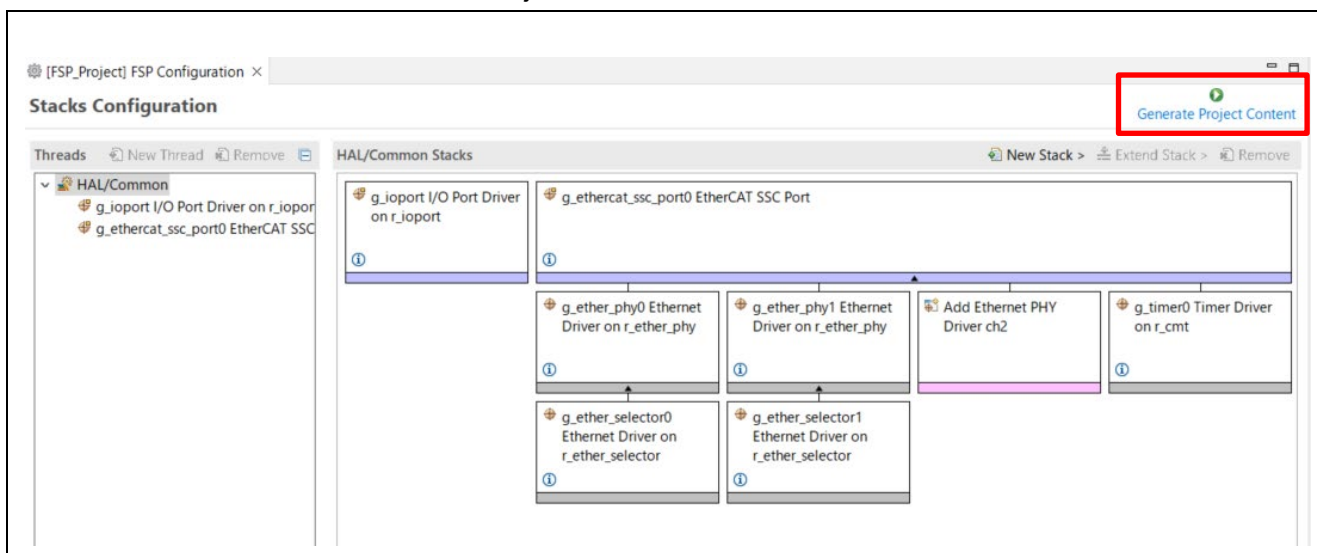
1. Open the sample project. “project\rzn2l\_som\ecat\_CiA402\ewarm\RZN2L\_SOM\_ESC\_CiA402.eww”



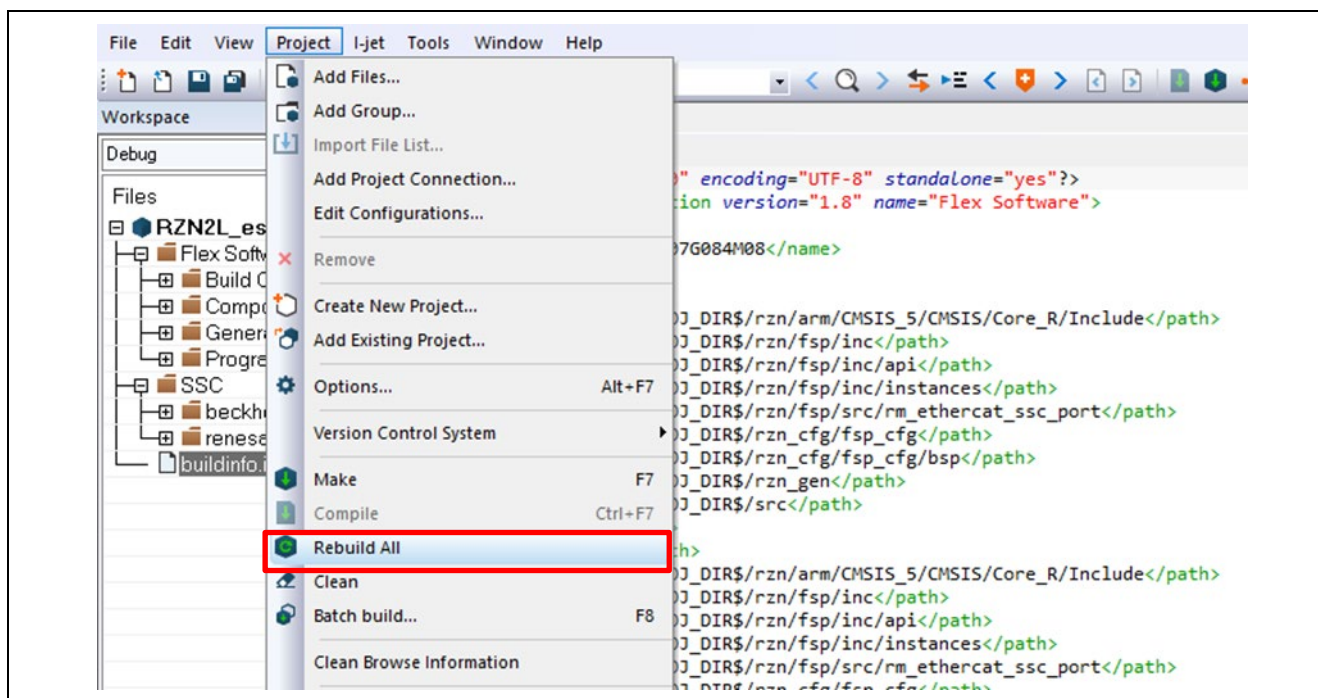
2. Open the “RZ Smart Configurator”



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

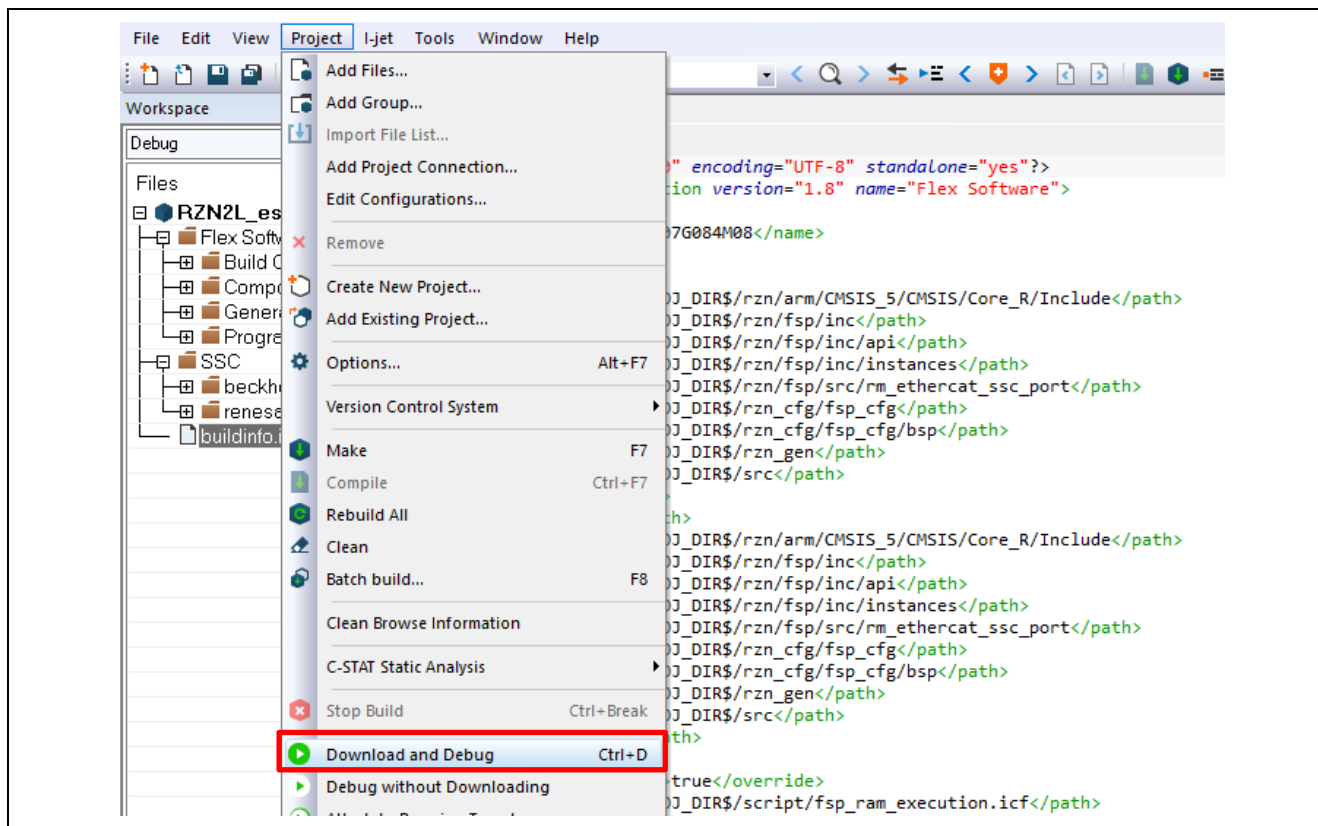


4. Select the “Rebuild All” item from the “Project” menu to rebuild the project.

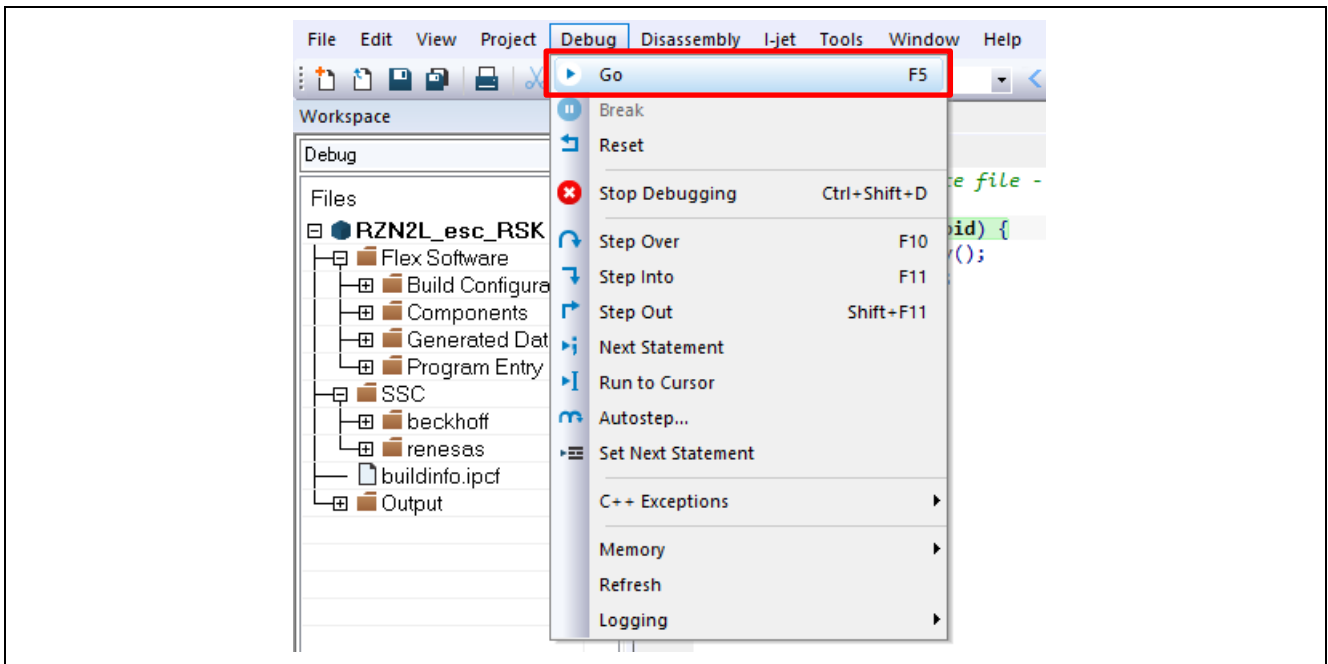


5. Press the “RESET” switch of the RZ/N2L Industrial Network SOM Kit.

6. After connecting the board and I-jet, click the Download and Debug button on the Project toolbar.



7. Press the "Resume" button for the project. Program will run.



## 5.2 Setting sample code for GCC

### 5.2.1 Erasing the flash memory

First, erase the flash memory by following the steps below. This step can be skipped after erasing the flash memory.

Open the J-Link Commander.

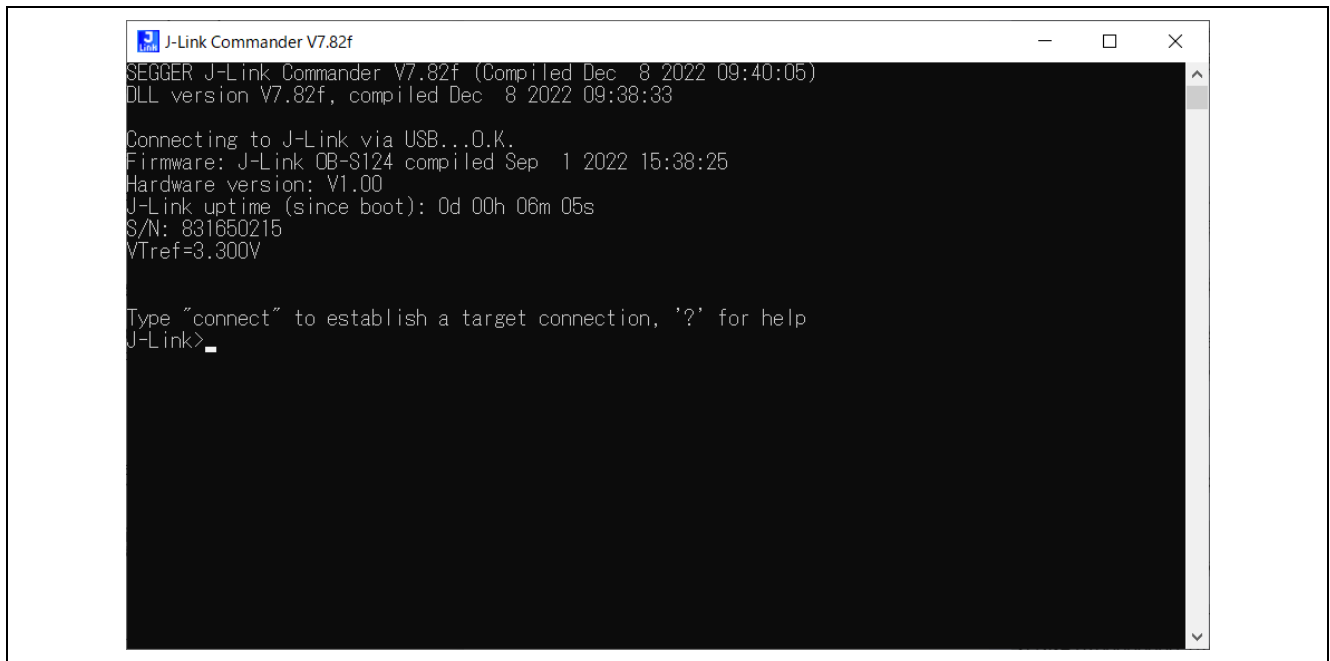


Figure 5-1 Open J-Link Commander

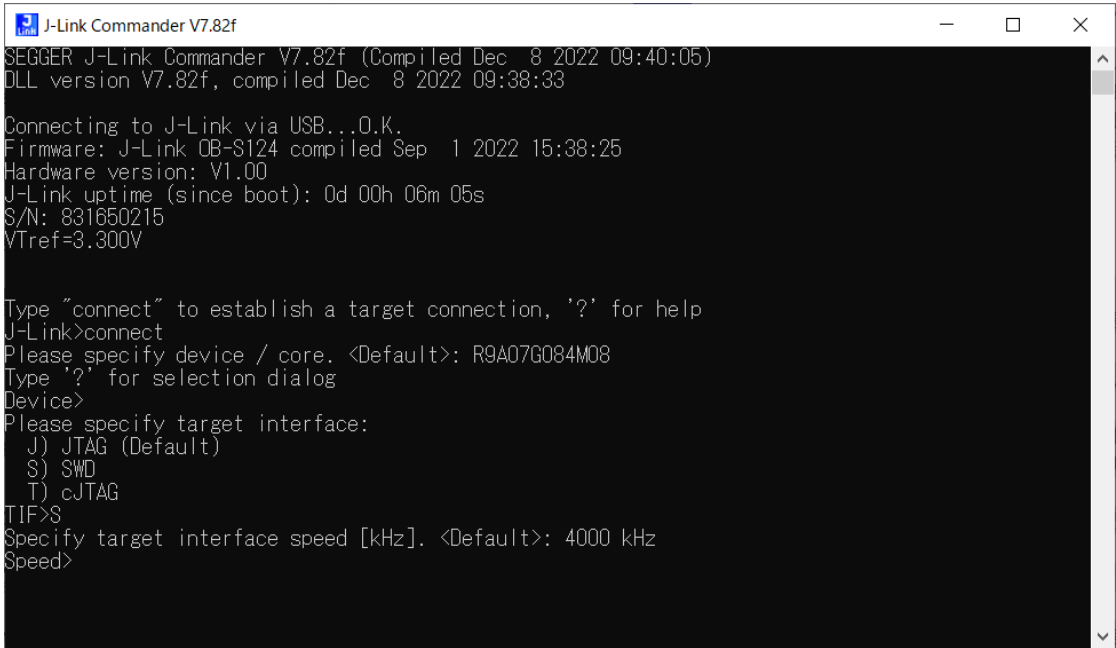


First, type “connect” to establish a target connection and press enter.

Next, specify the connection conditions as follows.

- Device> (Default = press enter)
- TIF>S
- Speed> (Default = press enter)

After that, confirm the message “Cortex-R52 identified.” Is displayed.

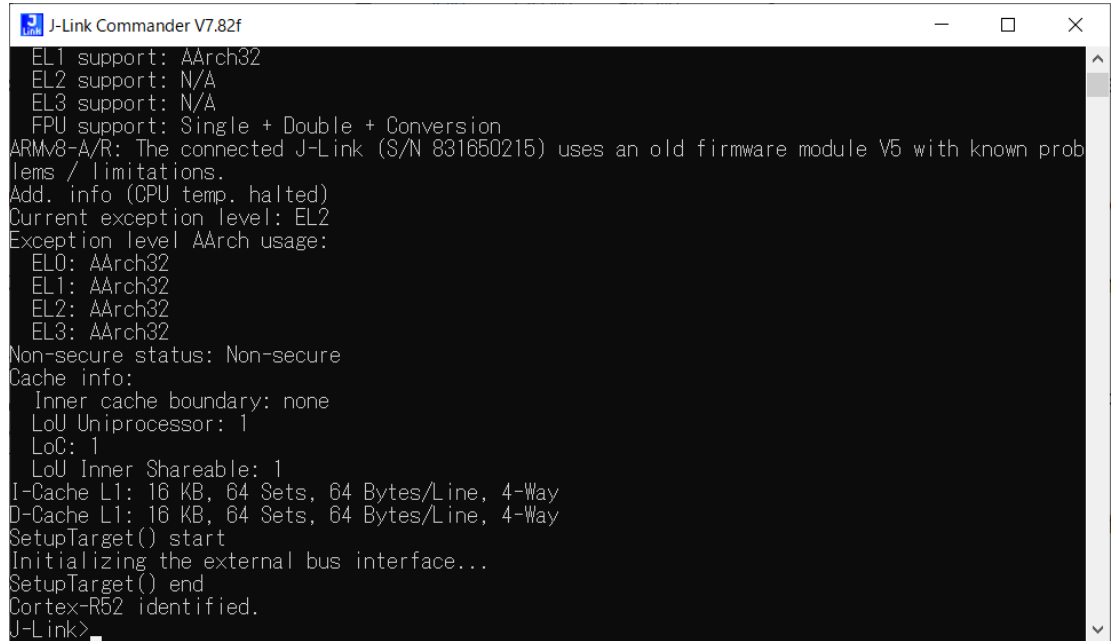


```
J-Link Commander V7.82f
SEGGER J-Link Commander V7.82f (Compiled Dec  8 2022 09:40:05)
DLL version V7.82f, compiled Dec  8 2022 09:38:33

Connecting to J-Link via USB...O.K.
Firmware: J-Link OB-S124 compiled Sep  1 2022 15:38:25
Hardware version: V1.00
J-Link uptime (since boot): 0d 00h 06m 05s
S/N: 831650215
VTref=3.300V

Type "connect" to establish a target connection, '?' for help
J-Link>connect
Please specify device / core. <Default>: R9A07G084M08
Type '?' for selection dialog
Device>
Please specify target interface:
  J) JTAG (Default)
  S) SWD
  T) cJTAG
TIF>S
Specify target interface speed [kHz]. <Default>: 4000 kHz
Speed>
```

Figure 5-2 Connection conditions (1/2)



```
J-Link Commander V7.82f
EL1 support: AArch32
EL2 support: N/A
EL3 support: N/A
FPU support: Single + Double + Conversion
ARMv8-A/R: The connected J-Link (S/N 831650215) uses an old firmware module V5 with known prob
lems / limitations.
Add. info (CPU temp. halted)
Current exception level: EL2
Exception level AArch usage:
  EL0: AArch32
  EL1: AArch32
  EL2: AArch32
  EL3: AArch32
Non-secure status: Non-secure
Cache info:
  Inner cache boundary: none
  LoU Uniprocessor: 1
  LoC: 1
  LoU Inner Shareable: 1
I-Cache L1: 16 KB, 64 Sets, 64 Bytes/Line, 4-Way
D-Cache L1: 16 KB, 64 Sets, 64 Bytes/Line, 4-Way
SetupTarget() start
Initializing the external bus interface...
SetupTarget() end
Cortex-R52 identified.
J-Link>
```

Figure 5-3 Connection conditions (2/2)

Use the commands below to enable flash erase and erase the flash memory.

- >exec EnableEraseAllFlashBanks
- >Erase 0x60000000, 0x60100000

After that, confirm the message “Erasing done.” Is displayed.

Enter “q” to exit J-Link Commander.

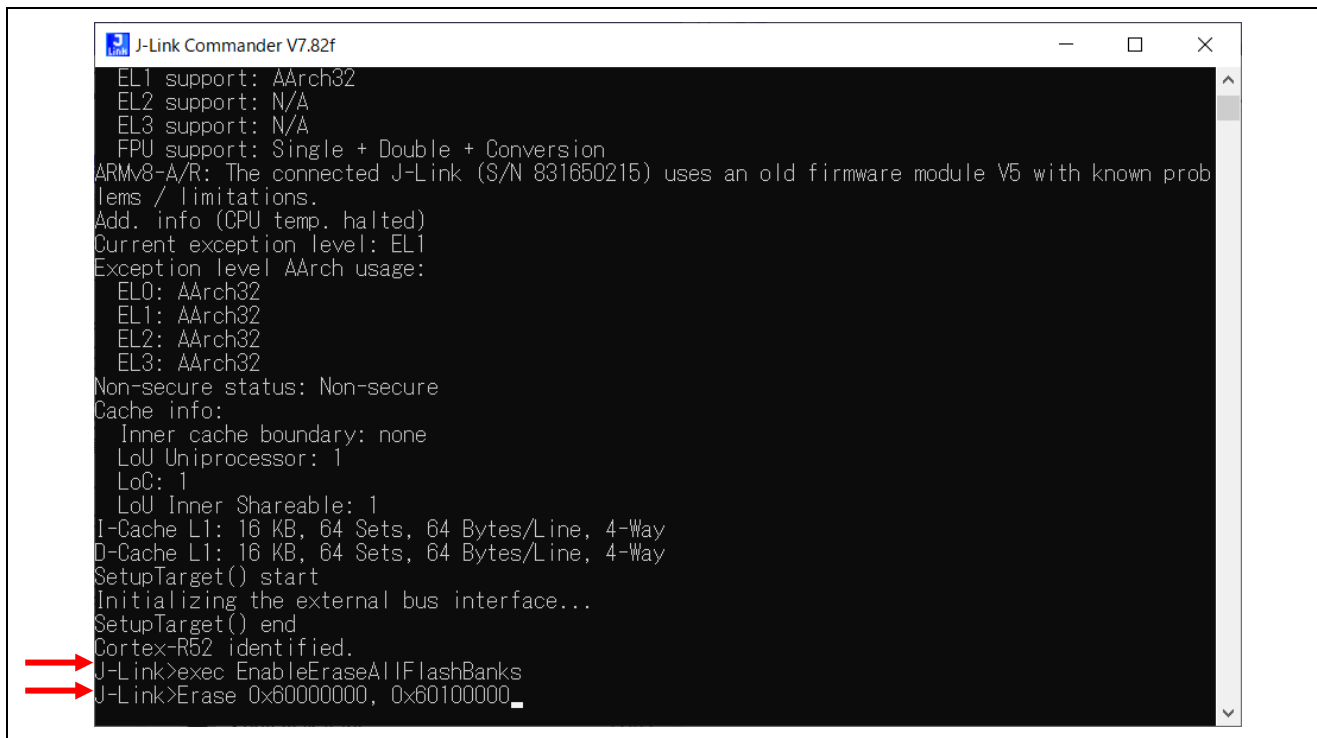


Figure 5-4 Erase flash memory (1/2)

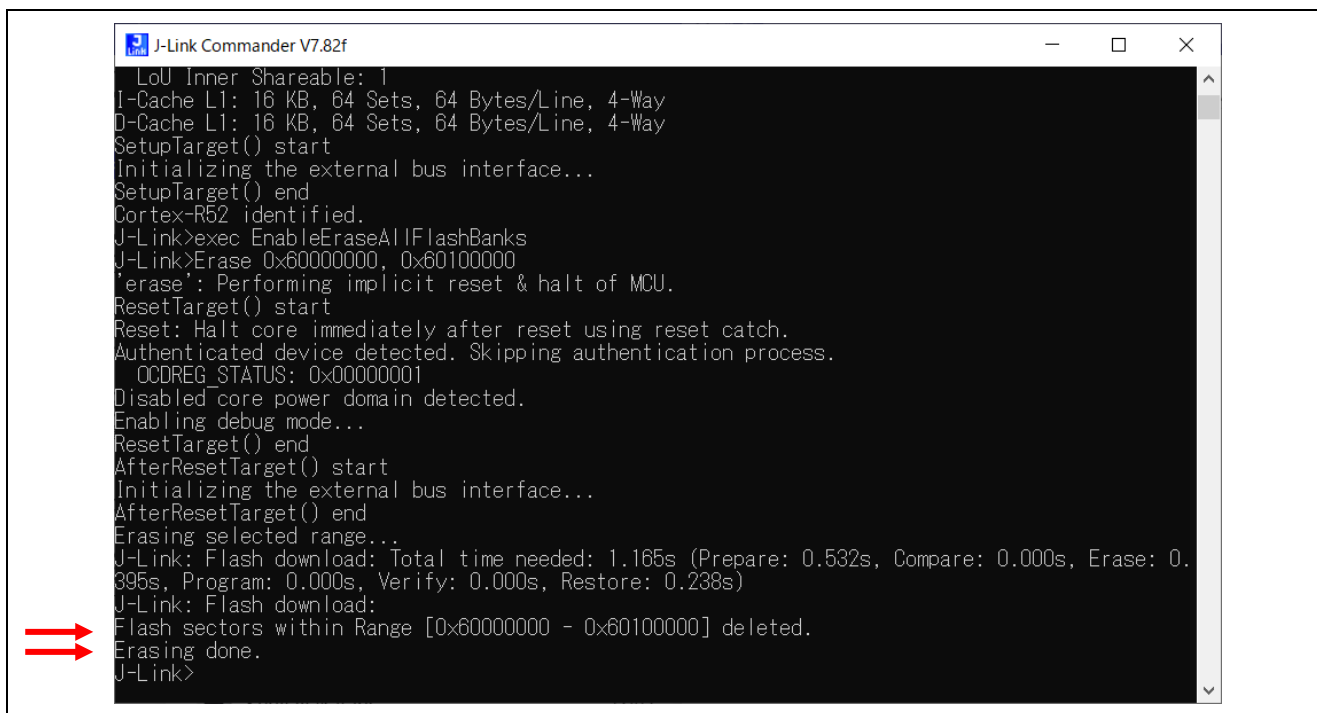


Figure 5-5 Erase flash memory (2/2)

## 5.2.2 Setting sample code for GCC

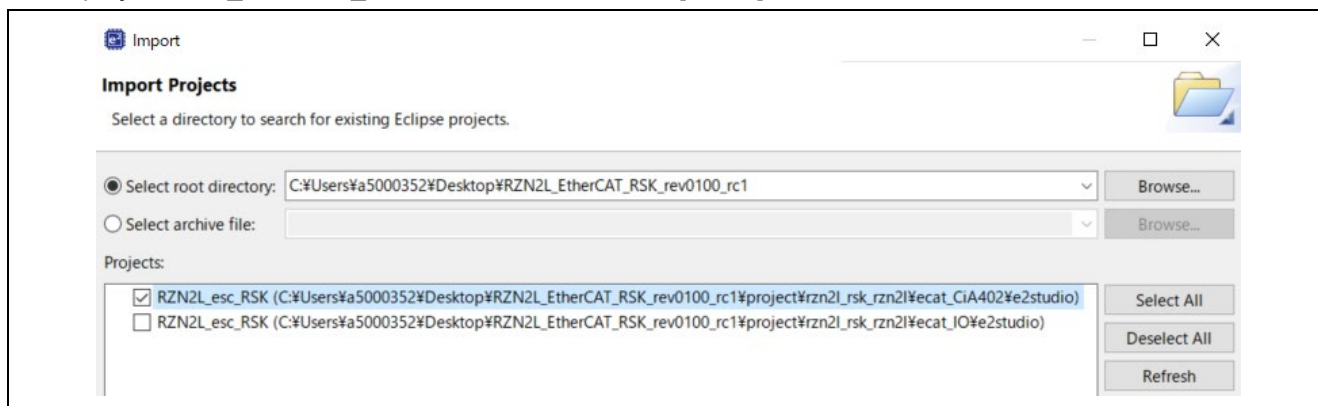
Build the sample code and load it into RAM using Renesas Electronics e<sup>2</sup> studio.

Note). Please install e2studio and adapt the FSP\_Packs\_v1.0.0 in advance.

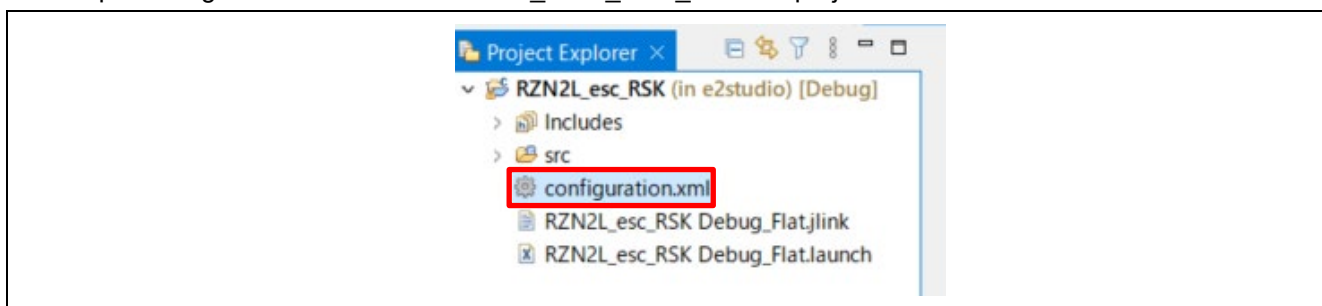
Refer to the latest getting started guide.( R01an6434ejxxx- rzt2-rzn2.pdf)

Replace the project name in the figure with the project name of this sample project

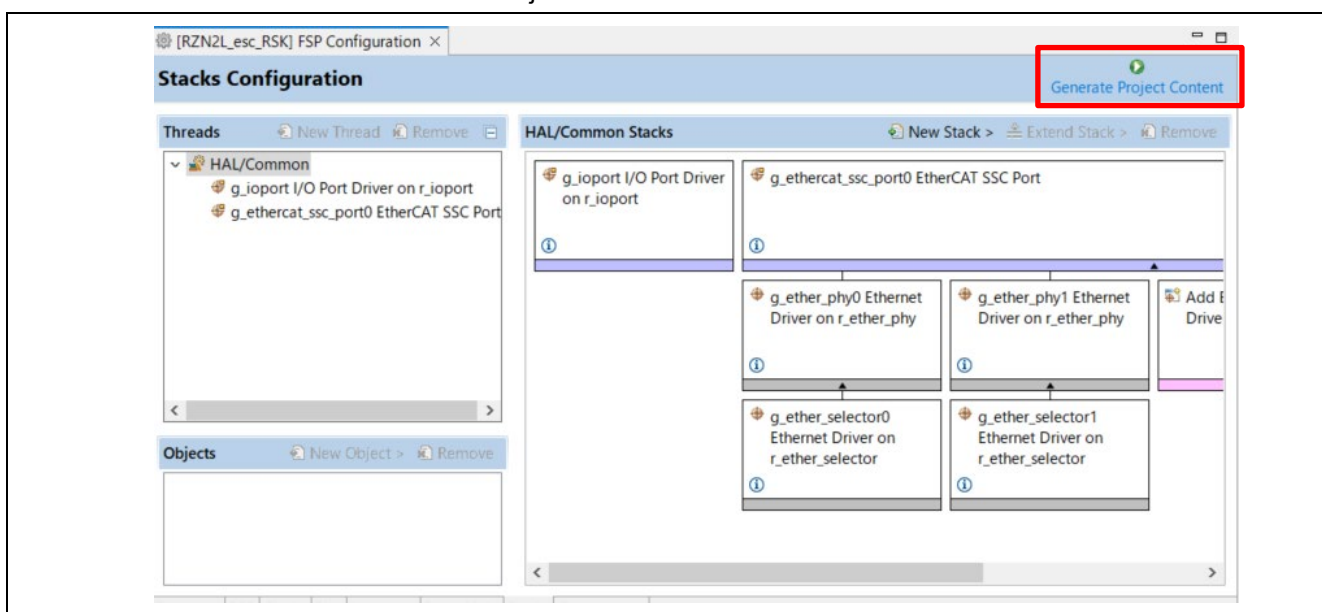
1. Import the sample project. After the program is started, by selecting [File] → [Import] → [Existing Projects into Workspace]. Check the "select root directory" and select "project\rzn2l\_som\ecat\_CiA402\e2studio" folder →[Finish].



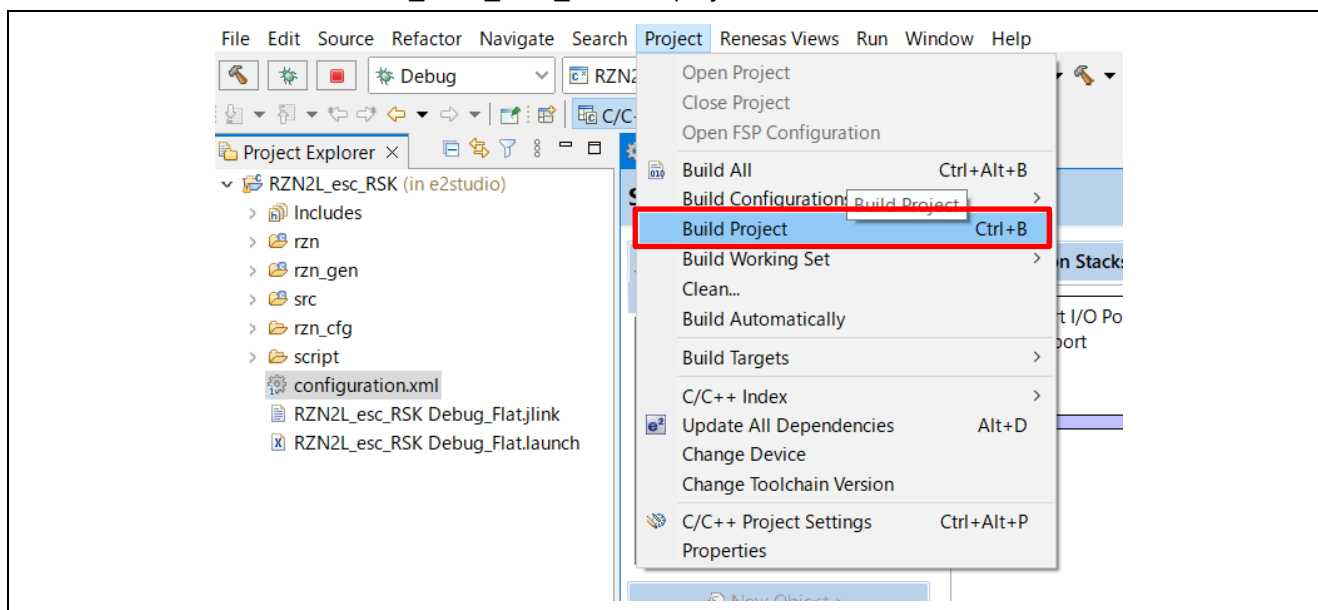
2. Open "configuration.xml" in the "RZN2L\_SOM\_ESC\_CiA402" project



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



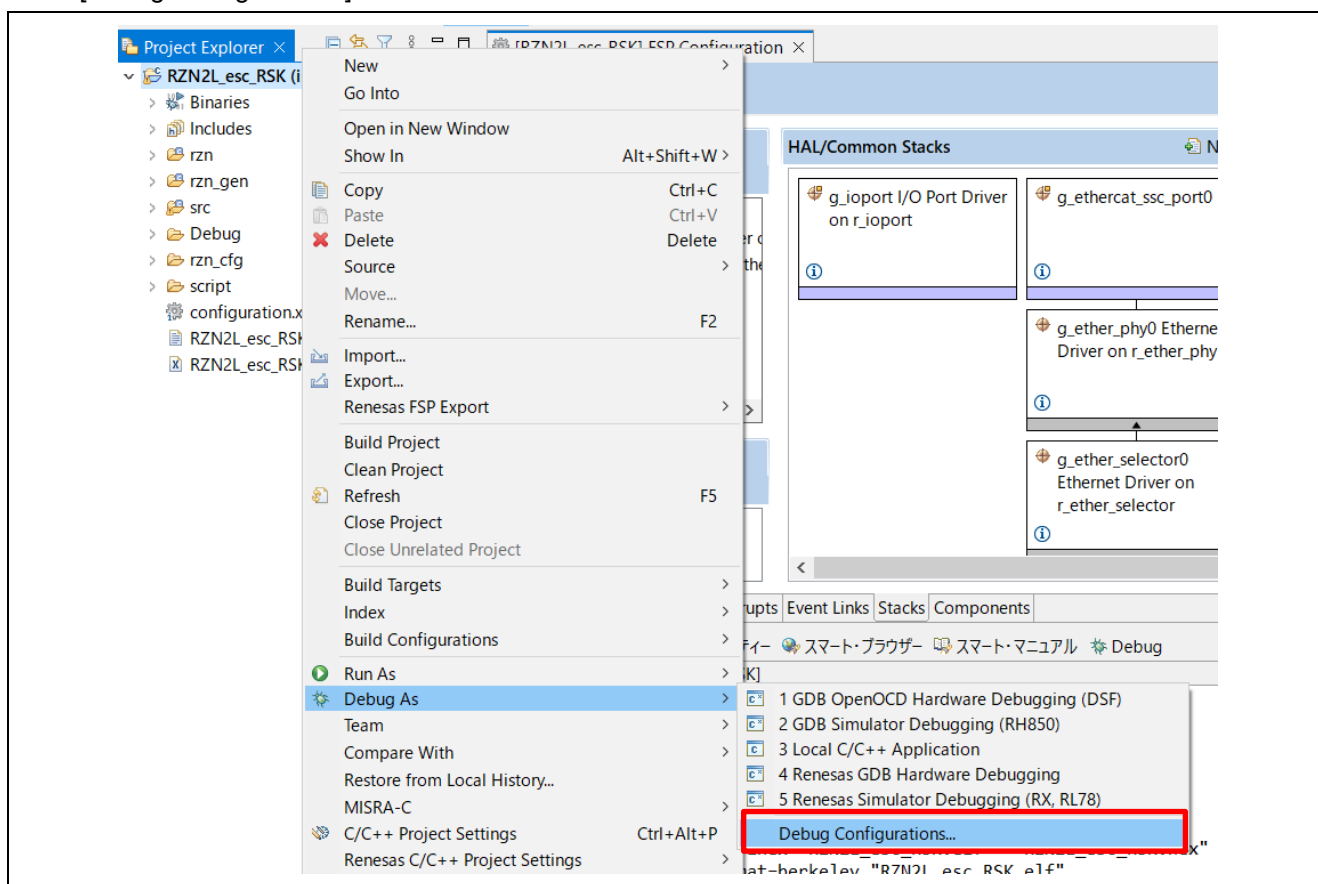
4. Select and build the "RZN2L\_SOM\_ESC\_CiA402" project.



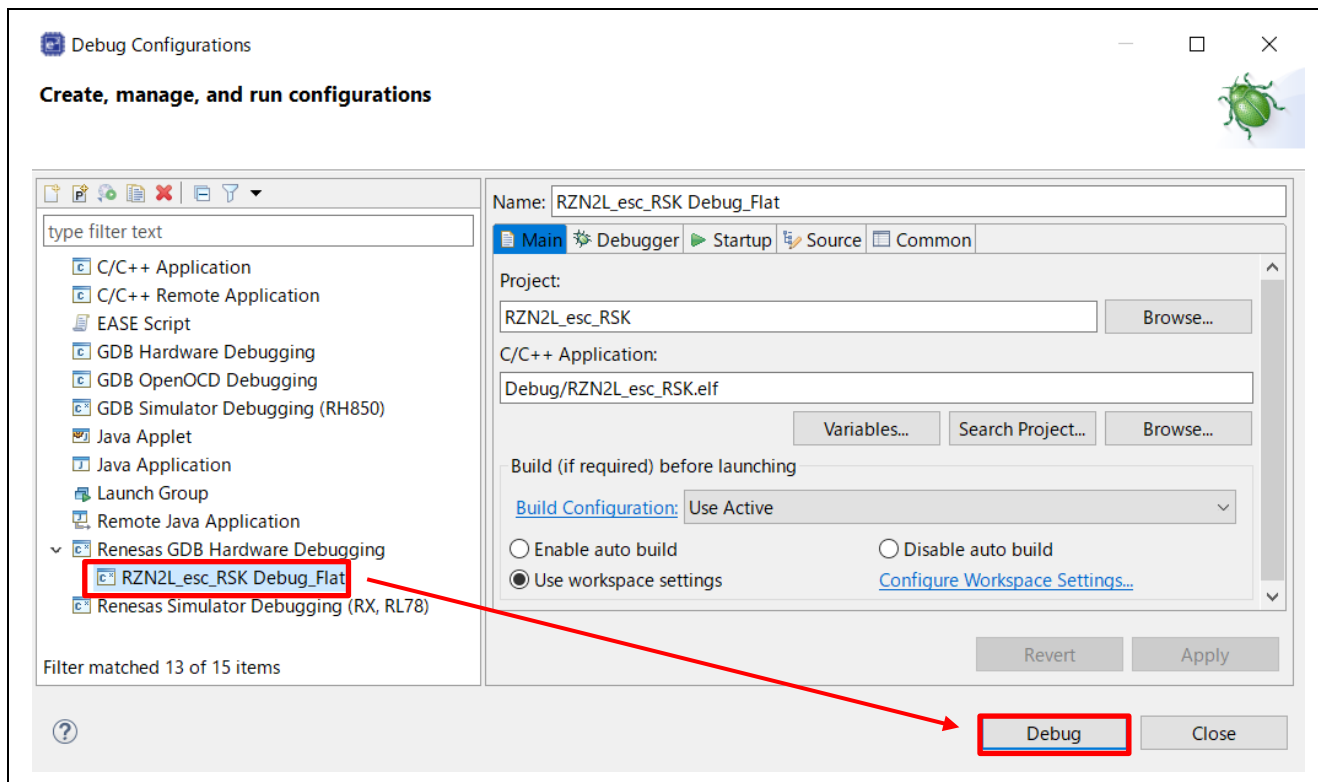
5. Press the "RESET" switch of the RZ/N2L Industrial Network SOM Kit.

6. Connect J-Link to the SOM Kit, start debugging in the following procedure.

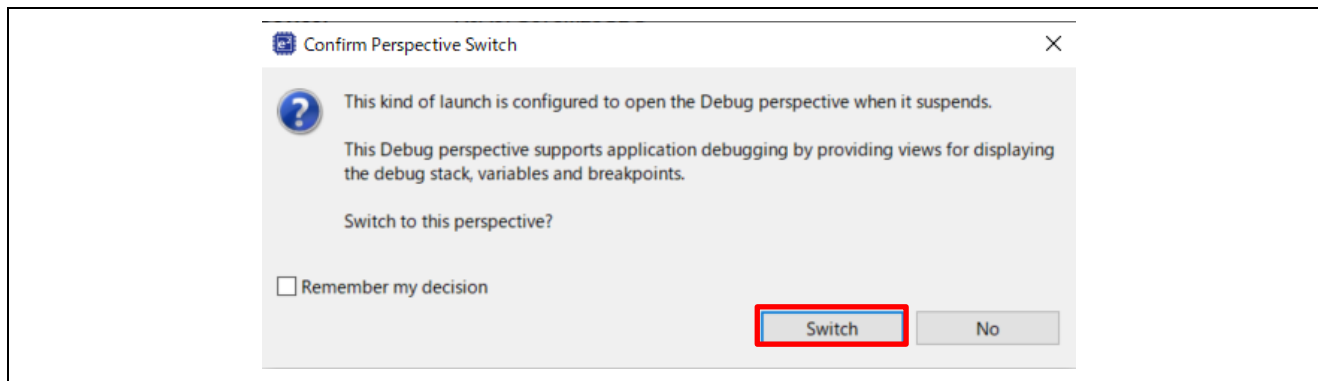
In [Project Explorer] view, right click the node of project to be debugged and select [Debug As] → [Debug Configurations].



[Renesas DBG Hardware Debugging] → [RZN2L\_SOM\_ESC\_CiA402 Debug\_Flat] item,  
then press [Debug]



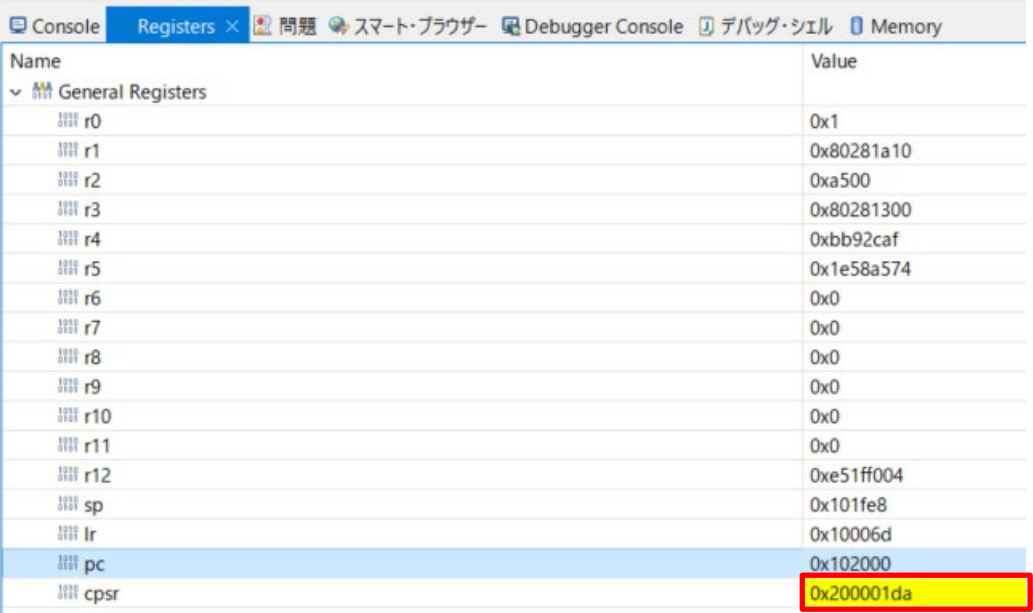
Following dialog will appear, so switch to the debug screen.



7. Before running the loaded program, change the CPSR register of CR52 general register on Registers tabs.

Change the register value from “0x200001fa” to “**0x200001da**”.

If the CPSR register value has not changed, program will stop at Default\_Handler () at run time.



The screenshot shows the 'Registers' tab in a debugger. The 'General Registers' section is expanded, displaying a list of registers from r0 to cpsr. The 'cpsr' register at the bottom is highlighted with a yellow background and a red border, showing its value as '0x200001da'. Other registers like 'pc' are highlighted in light blue.

| Name              | Value      |
|-------------------|------------|
| General Registers |            |
| r0                | 0x1        |
| r1                | 0x80281a10 |
| r2                | 0xa500     |
| r3                | 0x80281300 |
| r4                | 0xbb92caf  |
| r5                | 0x1e58a574 |
| r6                | 0x0        |
| r7                | 0x0        |
| r8                | 0x0        |
| r9                | 0x0        |
| r10               | 0x0        |
| r11               | 0x0        |
| r12               | 0xe51ff004 |
| sp                | 0x101fe8   |
| lr                | 0x10006d   |
| pc                | 0x102000   |
| cpsr              | 0x200001da |

8. Press the "Resume" button for the project. Program will stop at hal\_entry ().  
Press the "Resume" button again. Program is running.

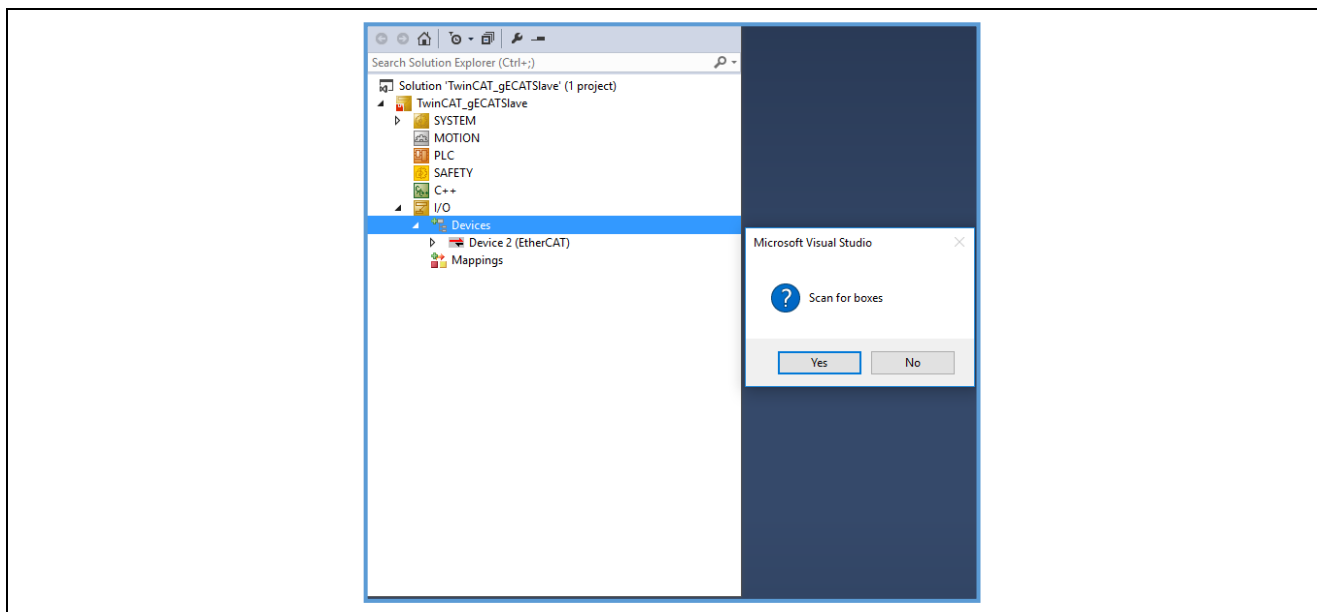
## 6. Connecting to TwinCAT3

Start TwinCAT3 by using the procedure described below,  
From the start menu, select [Beckhoff] → [TwinCAT3] → [TwinCAT XAE].

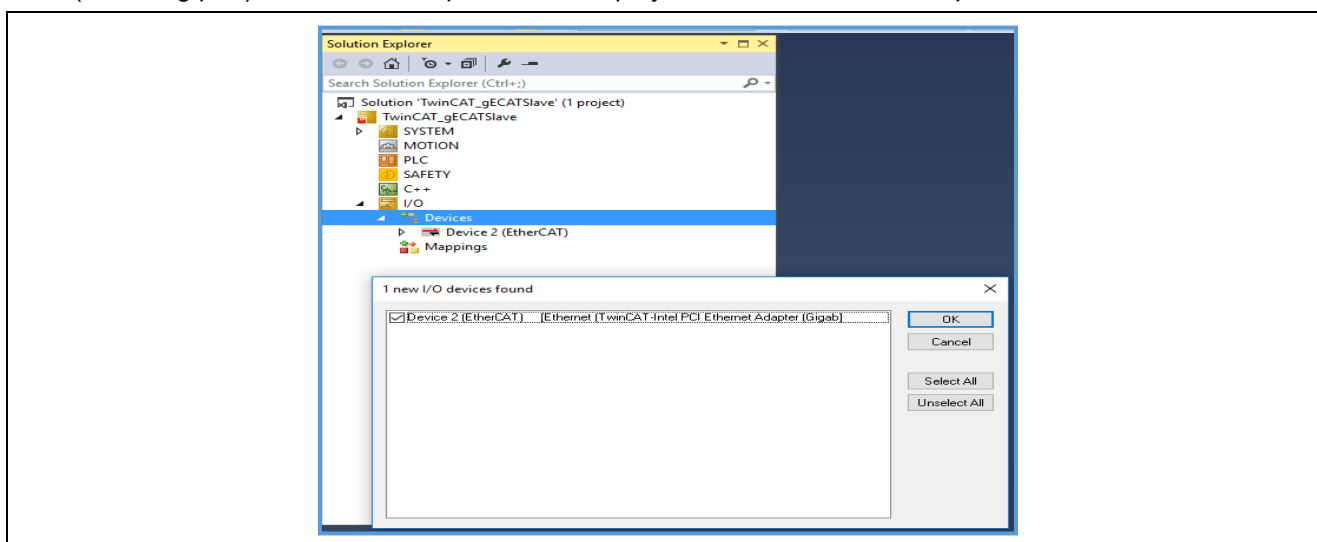
After the program is started, by selecting [File] → [New] → [Project], create a new project of the TwinCAT XAE Project type. The subsequent procedure is described below.

### 6.1 Scanning I/O Devices

1. (Scan for devices): Under solution explorer -> I/O -> Devices, select 'Scan' as in Figure below

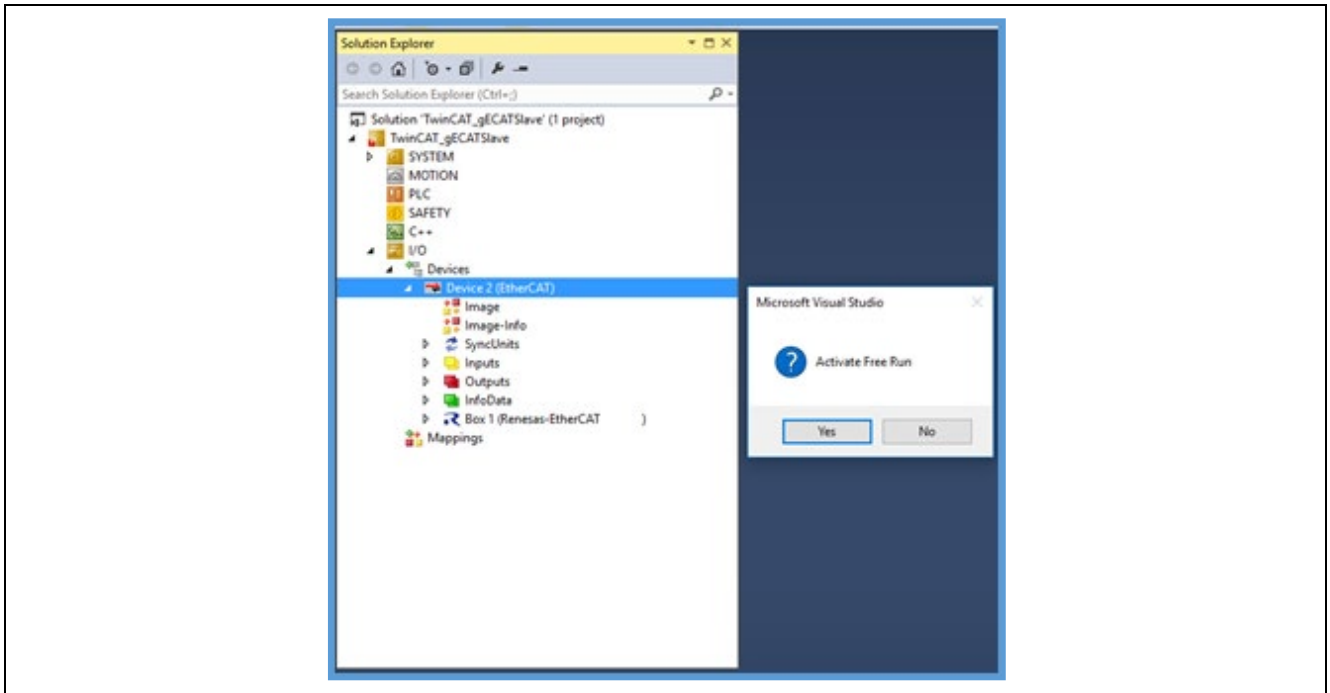


2. (Selecting port): The EtherCAT port will be displayed as below. Select and press OK.



Note). This will list EtherCAT master if a valid slave is present in the network.

3. (Activate slave): The slave is listed in the boxes, in our case “Renesas EtherCAT” in box1 shown in figure below. Press activate free run.





## 6.2 Updating EEPROM Data

If the data of another application has already been written to the EEPROM, replace the data.

The following shows the procedure for replacing the data on the EEPROM:

1. Double-click [Box 1] to display a panel on the right side of the window.
2. Select the [EtherCAT] tab.
3. Click the [Advanced Setting] button.
4. Select [ESC Access] → [EEPROM] → [Hex Editor].
5. Select [Download from List] → Select ESI File  
"common\ecat\_CiA402\ESI\Renesas EtherCAT RZN2 CiA402.xml"
6. Select "Renesas EtherCAT RZ/N2 CiA402 2port" or "Renesas EtherCAT RZ/N2 CiA402 3port"
7. OK and Download.

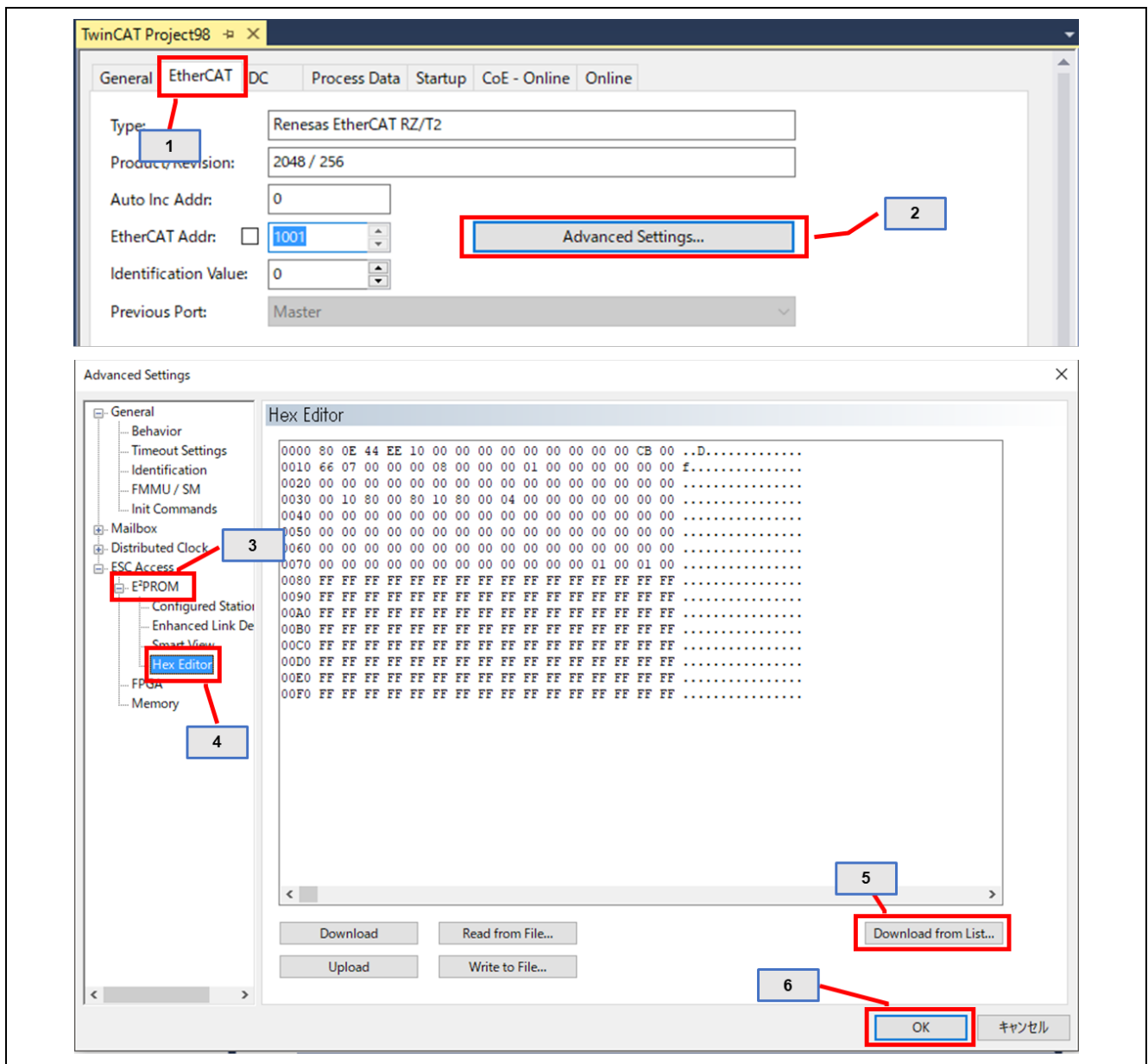


Figure 6.1: EEPROM update

**Option A** - Create ESI binary file from ESI XML and download.

1. SSC Tool → [Tool] → [EEPROM Programmer].
2. [FILE] → [OPEN] → Browse and select the ESI file.
3. [FILE] → [Save AS] → Select type as binary.
4. A binary file will be generated in the specified folder.
5. [Read from File] Select the ESI binary file → [Download].
6. Confirm the write status using [Upload] option.

After the data is replaced, restart the RZ/N2L (by turning it off and on, or resetting it) so that the new data is applied to the microcomputer. Execute [Restart TwinCAT System].

### 6.3 CiA402 Drive Profile check

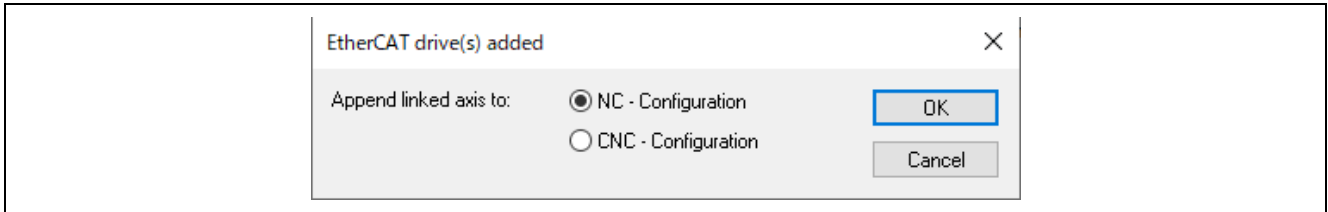
In this chapter, check the operation of the CiA402 drive profile.

#### 6.3.1 Rescanning the Device

1. Press the [Restart TwinCAT (Config Mode)] button.
2. In the [Restart TwinCAT System in Config Mode] dialog box, click on [OK].
3. In the [Load I/O Devices] dialog box, click on [Yes].
4. In the [Active Free Run] dialog box, click on [Yes].

This will be OK if "Box 1" in the System Manager tree has turned to "Box 1 (RZ/N2 EtherCAT CiA402)".

Note). When scanning the device, the CiA402's ESI is used, so the axis configuration settings are displayed.  
Select [NC-Configuration]



#### 6.3.2 Checking the Operation Mode

- (1) If double-click on [Box 1] in the System Manager tree, panel will be displayed on the right side of the screen.
- (2) Select the [Online] tab and check that "Current Status" has turned to "OP".
- (3) In the System Manager tree, expand + on the left side of "Box 1".

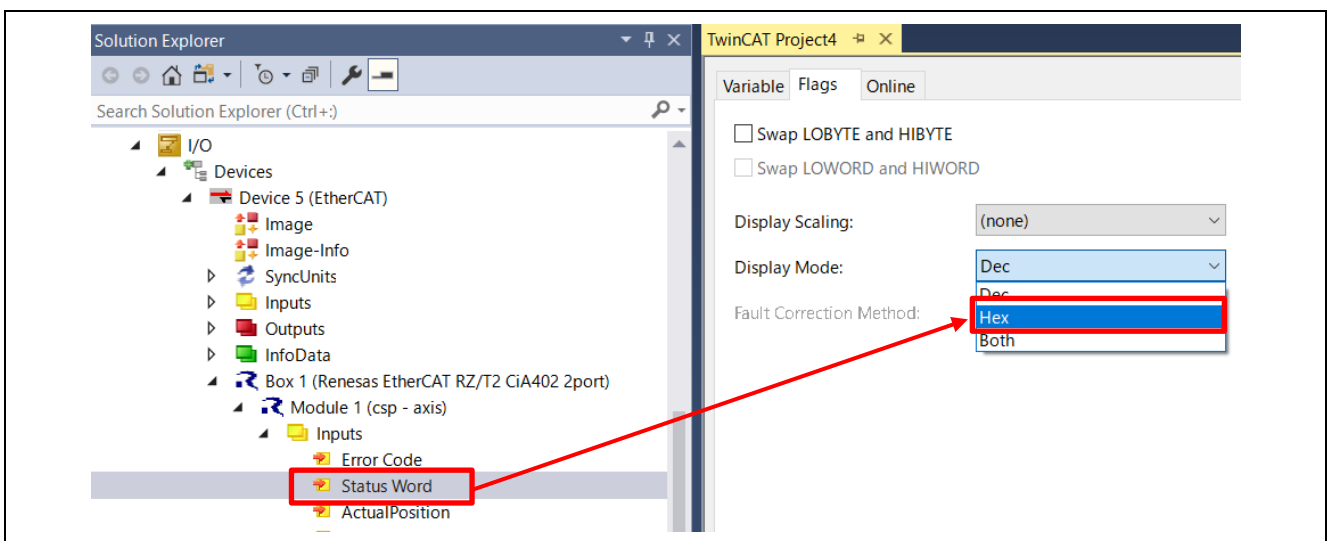
#### 6.3.3 CiA402 State Transition

To check the operation in csp and csv modes, the state must be changed to "Operation Enabled" in both modes.

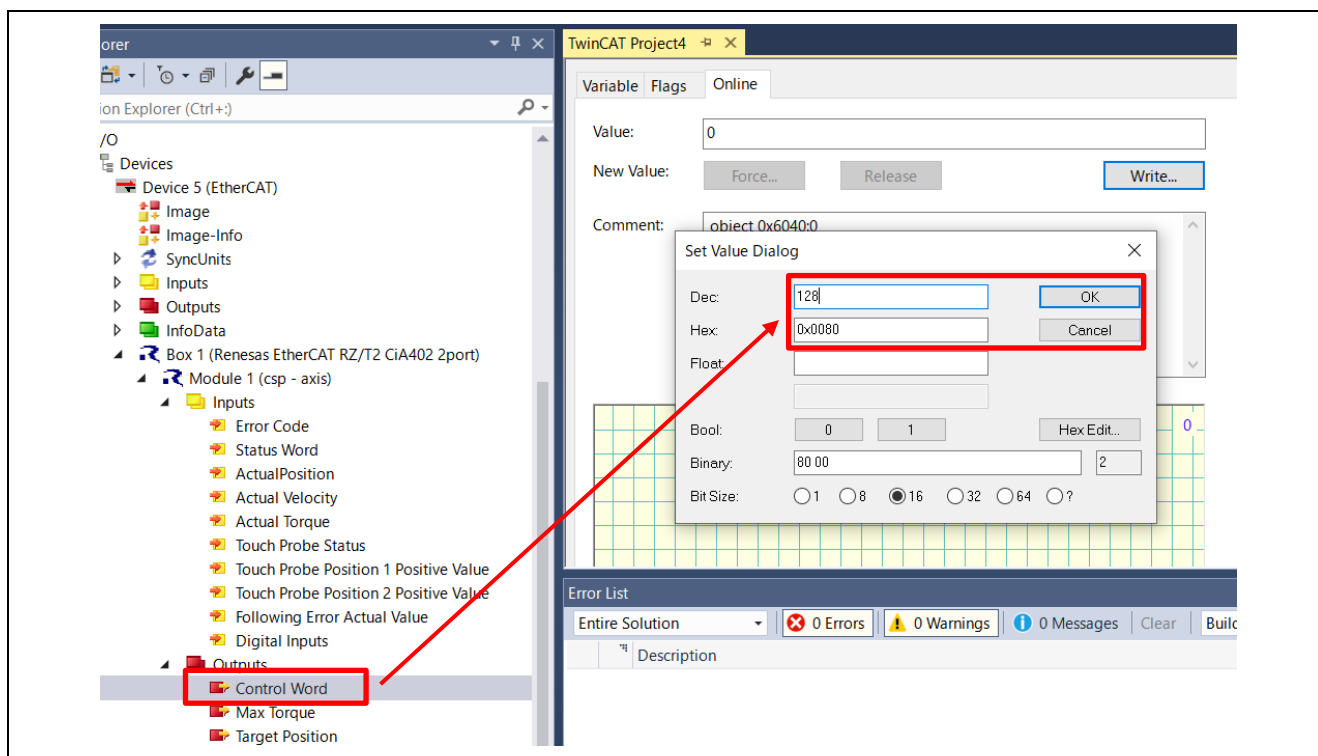
Change the state by setting a value in the "Control Word" object and check the state by confirming the value of the "Status Word" object.

- (1) Select "Inputs" → "Status Word" in the Solution Explorer tree and then select the [Flags] tab on the right-side panel. value will then be displayed.

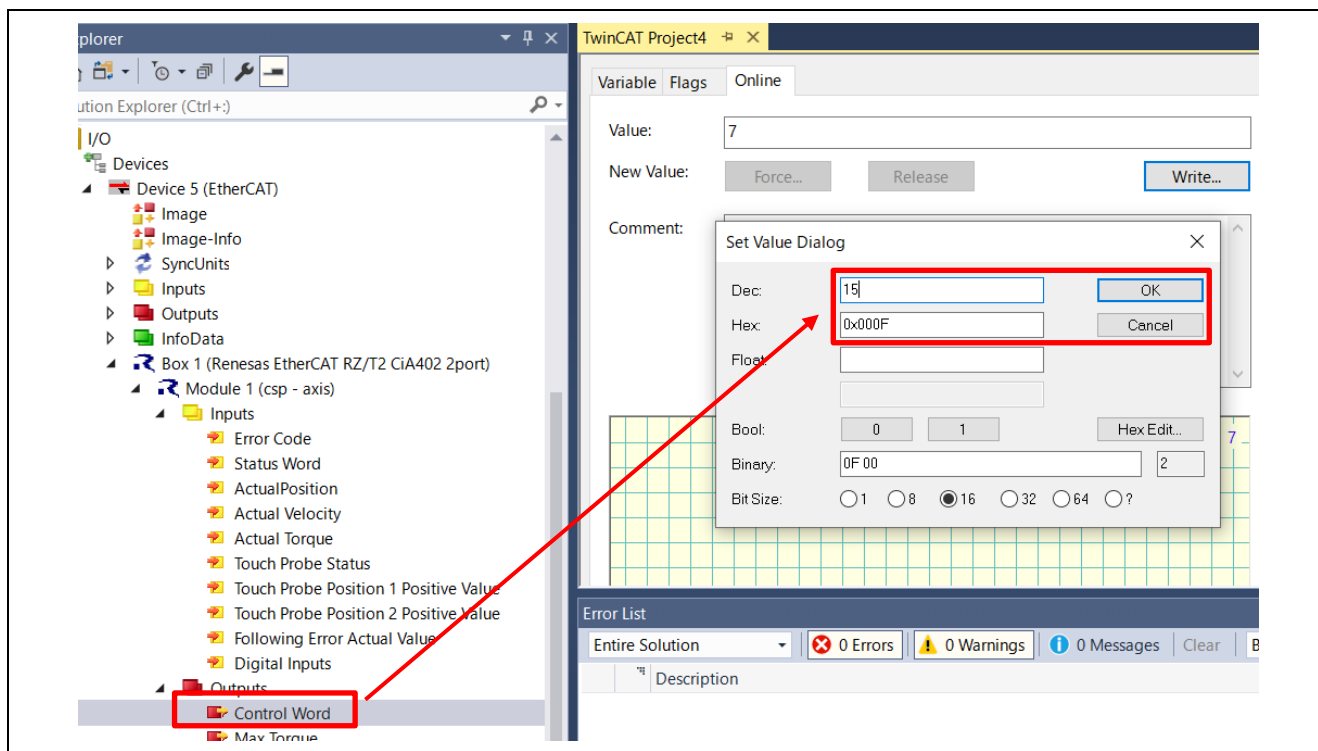
Change the display mode from [Dec] to [Hex]



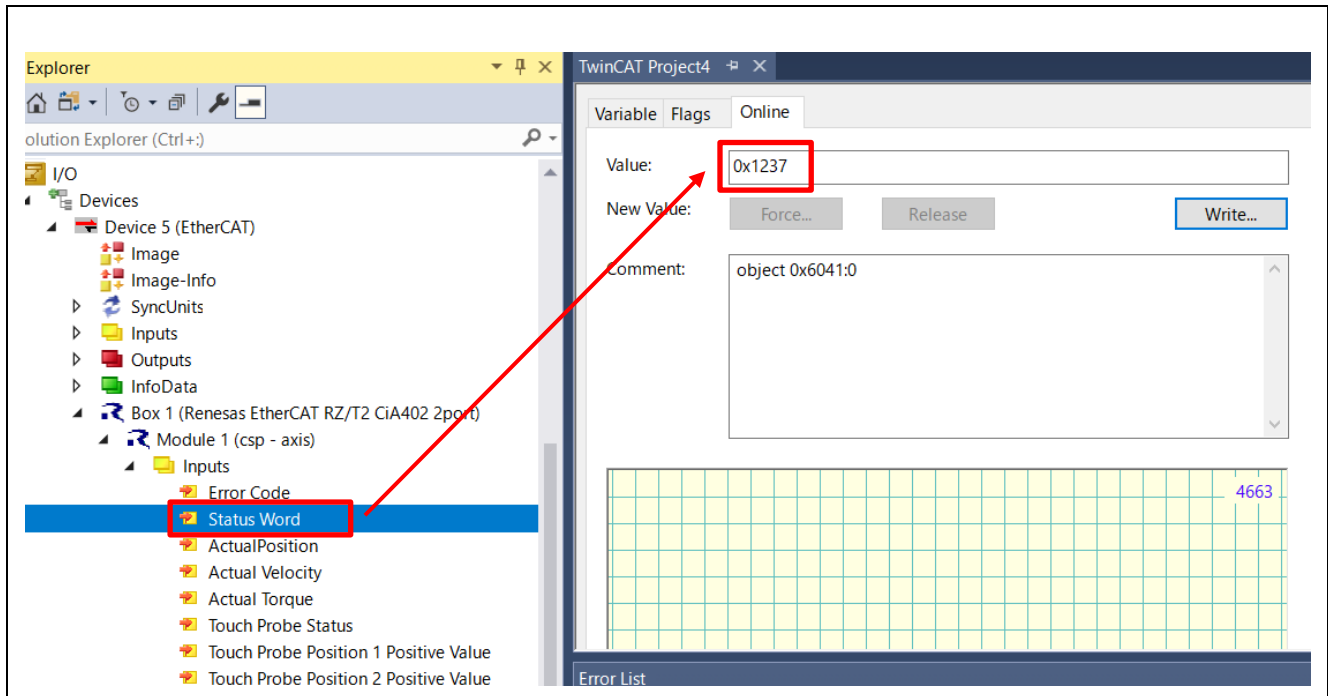
- (2) Check the operation of the profile. Initialize the control word by setting it to 128 (Dec).



- (3) Select "Outputs" → "Control Word" in the System Manager tree and then select the [Online] tab on the right-side panel. value will then be displayed.  
Click on [Write] and set values from [7] to [15] in that order.



- (4) Select "Inputs" → "Status Word" in the System Manager tree and then select the [Online] tab on the right-side panel. value will then be displayed.  
 If the value is [0x1237], the state is "Operation Enabled". Proceed to the next step.  
 If the value is [0x1208], the state is "Fault" for some reason. Set "Control Word" to [128] once and return to step (1).

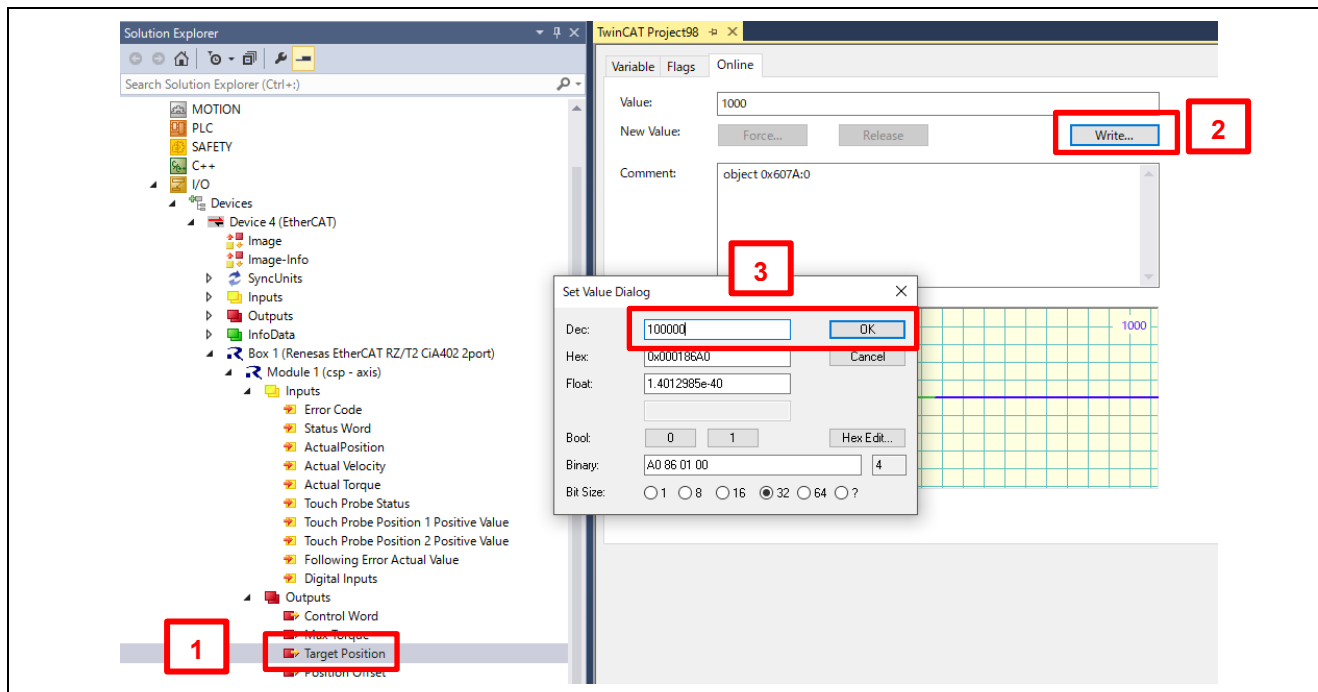


### 6.3.4 csp Mode

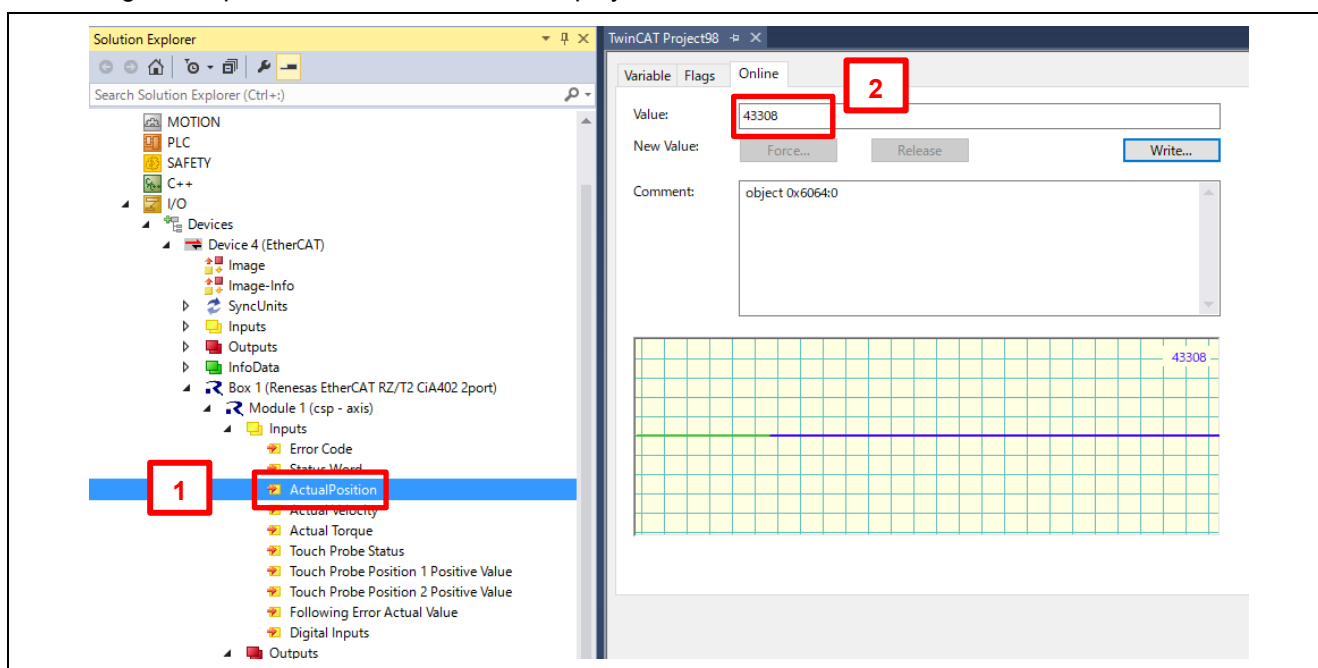
Check that "Module 1" is displayed as "Module 1 (csp-axis)".

- (1) Select "Outputs" → "Target Position" in the System Manager tree and then select the [Online] tab on the right-side panel. A value will then be displayed.

Click on [Write] and set a desired value. As an example, set [100000] here.



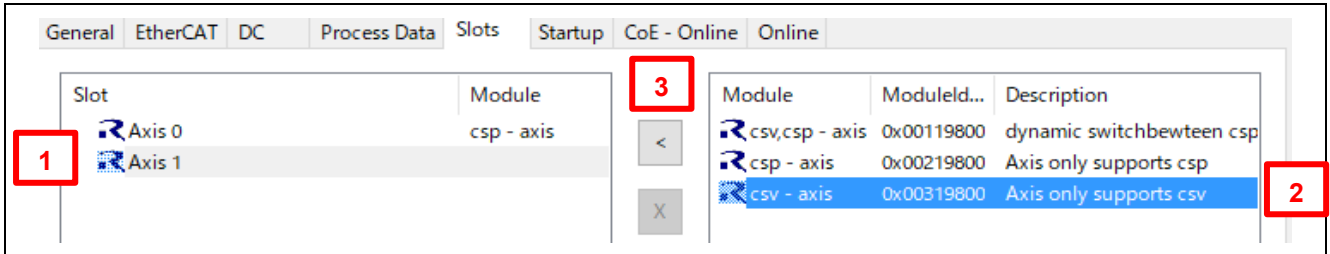
- (2) Select "Inputs" → "Actual Position" in the System Manager tree and then select the [Online] tab on the right-side panel. A value will then be displayed.



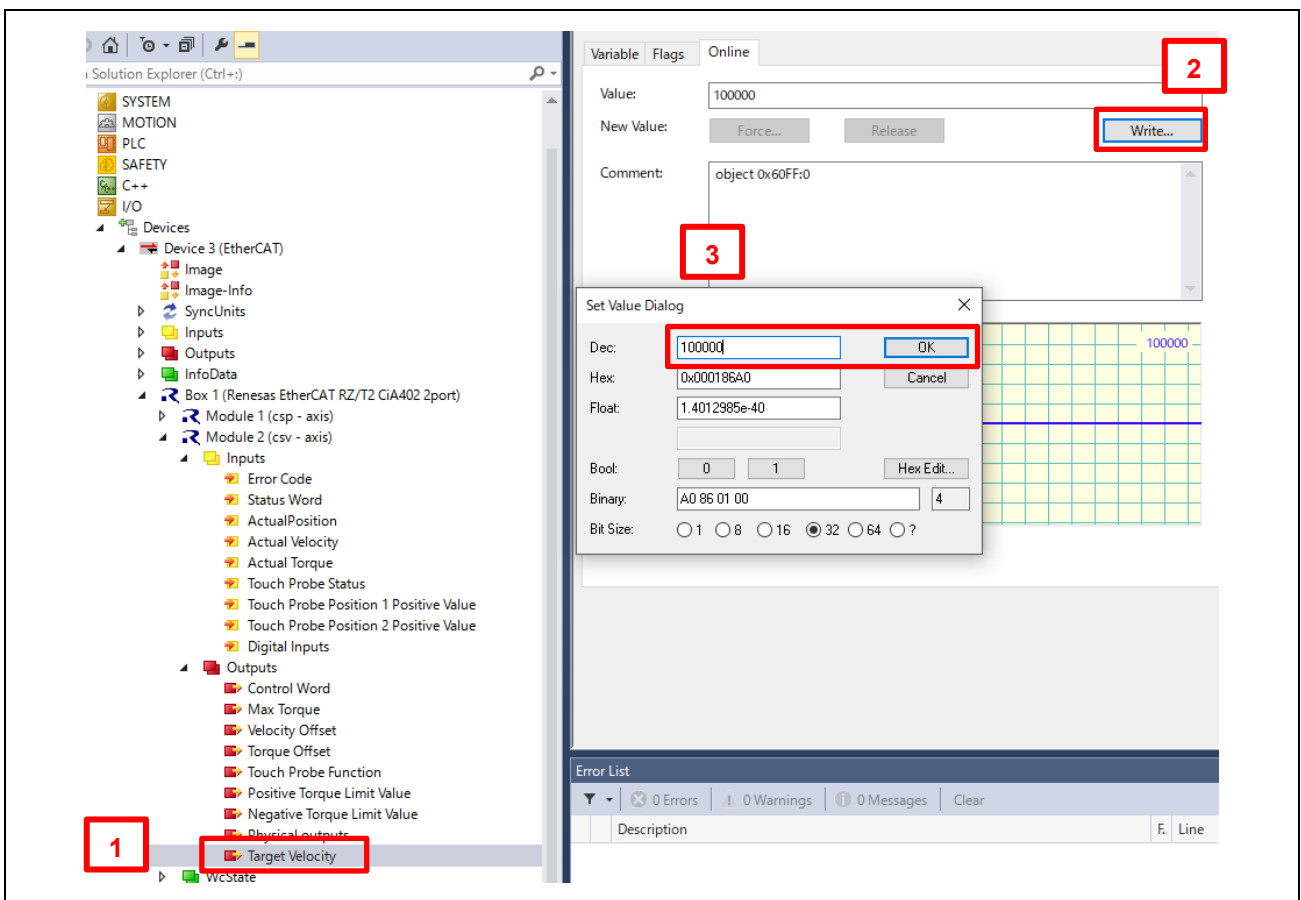
### 6.3.5 csv Mode

Change the operation mode

- (1) In the System Manager tree, select "Box 1 (RZ/N2 EtherCAT CiA402)" and then select the [Slots] tab on the right-side panel.
- (2) If select "Axis 1" under "Slot" in the left frame of the tabbed page, modules which can be added will be displayed in the right frame of the page, so add "csv-axis".

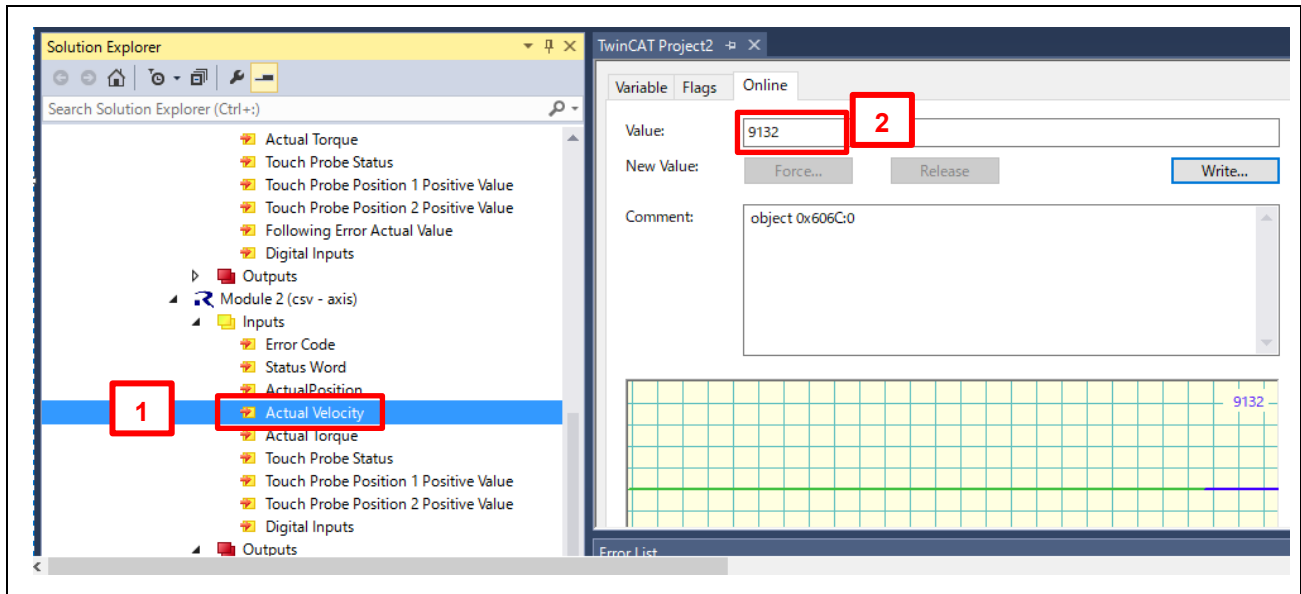


- (3) Check that "Module 2 (csv-axis)" has been added in the System Manager tree.
- (4) Execute "Reload Devices" to reflect the configuration.
- (5) Follow the procedure described in section 4.7 to change the state to "Operation Enabled".
- (6) Select "Outputs" → "Target Velocity" in the System Manager tree and then select the [Online] tab on the right-side panel. A value will then be displayed.  
Click on [Write] and set a desired value. As an example, set [100000] here.



- (7) Select "Inputs" → "Actual Velocity" in the System Manager tree and then select the [Online] tab on the right-side panel. A value will then be displayed.

Check that the value set in "Target Velocity" allows incrementation up to [100000].





## 7. CiA402 Drive Profile

The CiA402 drive profile is a device profile for driving motors and motion control and mainly defines functional operations for servo drives, sine-wave inverters and stepping motor controllers. In this profile, the multiple operation modes and corresponding parameters are defined as an object dictionary. Also, Finite State Automaton (FSA) to define the internal and external behavior in every state is included. When changing the state, the result after transition is reflected in the status word object that shows the current state by specifying the state through the control word object. The control word and various command values (such as speed) are assigned to RxPDO, and the status word and various real values (such as position) are assigned to TxPDO. Please see the contents of the CiA402 standard for more details.

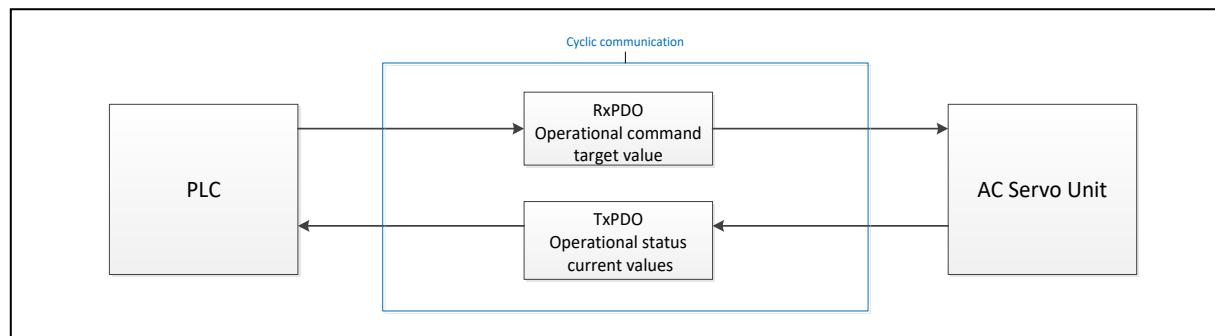


Figure 7-1 CiA402 Communication Flow

### 7.1 Operation Modes

In the application note, the following modes are supported from among the operation modes defined in the CiA402 standard.

Table 7-1 List of Supported Operation Modes

| Operation Mode                                        | Support |
|-------------------------------------------------------|---------|
| Profile position mode                                 | No      |
| Velocity mode (frequency converter)                   | No      |
| Profile velocity mode                                 | No      |
| Profile torque mode                                   | No      |
| Homing mode                                           | No      |
| Interpolated position mode                            | No      |
| Cyclic synchronous position mode                      | Yes     |
| Cyclic synchronous velocity mode                      | Yes     |
| Cyclic synchronous torque mode                        | No      |
| Cyclic synchronous torque mode with commutation angle | No      |
| Manufacturer specific mode                            | No      |

## 7.2 State Transition

In this application note, the following is supported as FSA defined in the CiA402 standard.

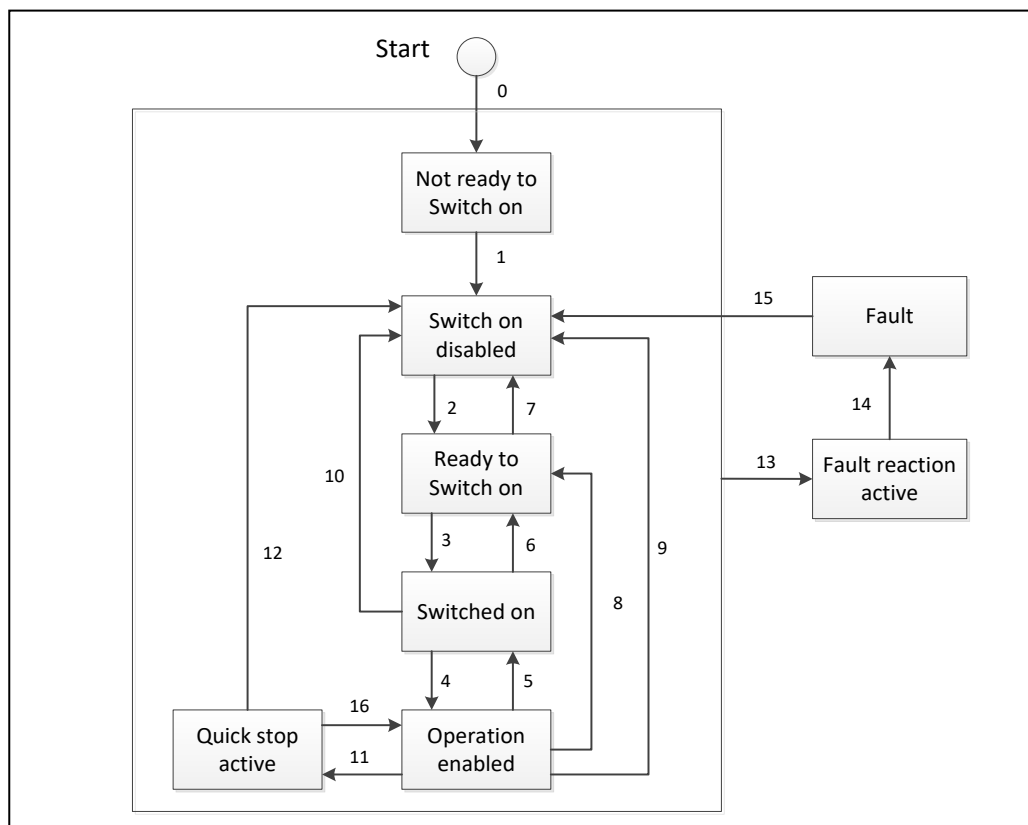


Figure 7-2 CiA402 State Transition Diagram

## 7.3 Object Dictionary

The following is the list of the object dictionaries supported in this application note.

Table 7-2 List of Supported Object Dictionaries

| Operation Mode                                                            | OBJECT Name                  | INDEX  | Category    | Access | Data Type | PDO Mapping |
|---------------------------------------------------------------------------|------------------------------|--------|-------------|--------|-----------|-------------|
| Cyclic synchronous position mode<br>+<br>Cyclic synchronous velocity mode | Position actual value        | 0x6064 | Mandatory   | ro     | INT32     | Yes         |
|                                                                           | Following error window       | 0x6065 | Optional    | rw     | UINT32    | No          |
|                                                                           | Velocity actual value        | 0x606C | Conditional | ro     | INT32     | Yes         |
|                                                                           | Max torque                   | 0x6072 | Optional    | rw     | UINT16    | Yes         |
|                                                                           | Torque actual value          | 0x6077 | Conditional | ro     | INT16     | Yes         |
|                                                                           | Target position              | 0x607A | Optional    | rw     | INT32     | Yes         |
|                                                                           | Software position limit      | 0x607D | Optional    | c,rw   | INT32     | No          |
|                                                                           | Position offset              | 0x60B0 | Optional    | rw     | INT32     | Yes         |
|                                                                           | Velocity offset              | 0x60B1 | Optional    | rw     | INT32     | Yes         |
|                                                                           | Torque offset                | 0x60B2 | Optional    | rw     | INT16     | Yes         |
|                                                                           | Following error actual value | 0x60F4 | Optional    | ro     | INT32     | Yes         |
|                                                                           | Target velocity              | 0x60FF | Conditional | rw     | INT32     | Yes         |

| Function Group                     | OBJECT Name                    | INDEX  | Category    | Access | Data Type | PDO Mapping |
|------------------------------------|--------------------------------|--------|-------------|--------|-----------|-------------|
| Torque Limiting                    | Positive torque limit value    | 0x60E0 | Conditional | rw     | UINT16    | Yes         |
|                                    | Negative torque limit value    | 0x60E1 | Conditional | rw     | UINT16    | Yes         |
| Homing                             | Home Offset                    | 0x607C | Optional    | rw     | INT32     | No          |
|                                    | Homing speeds                  | 0x6099 | Conditional | c,rw   | UINT32    | No          |
| Touch Probe                        | Touch probe function           | 0x60B8 | Optional    | rw     | UINT16    | Yes         |
|                                    | Touch probe status             | 0x60B9 | Optional    | ro     | UINT16    | Yes         |
|                                    | Touch probe pos 1 pos value    | 0x60BA | Optional    | ro     | INT32     | Yes         |
|                                    | Touch probe pos 2 pos value    | 0x60BC | Optional    | ro     | INT32     | Yes         |
| Gear ratio                         | Gear ratio                     | 0x6091 | Optional    | c,rw   | UINT32    | No          |
| Other object                       | OBJECT Name                    | INDEX  | Category    | Access | Data Type | PDO Mapping |
| Controlling the power drive system | Error code                     | 0x603F | Optional    | ro     | UINT16    | Yes         |
|                                    | Controlword                    | 0x6040 | Mandatory   | rw     | UINT16    | Yes         |
|                                    | Statusword                     | 0x6041 | Mandatory   | ro     | UINT16    | Yes         |
|                                    | Quick stop option code         | 0x605A | Optional    | rw     | INT16     | No          |
|                                    | Shutdown option code           | 0x605B | Optional    | rw     | INT16     | No          |
|                                    | Disable operation option code  | 0x605C | Optional    | rw     | INT16     | No          |
|                                    | Halt option code               | 0x605D | Optional    | rw     | INT16     | No          |
|                                    | Fault reaction option code     | 0x605E | Optional    | rw     | INT16     | No          |
|                                    | Modes of operation             | 0x6060 | Optional    | rw     | INT8      | Yes         |
|                                    | Modes of operation disp        | 0x6061 | Optional    | ro     | INT8      | Yes         |
|                                    | Supported drive modes          | 0x6502 | Mandatory   | ro     | INT32     | No          |
| General object                     | Motor type                     | 0x6402 | Optional    | rw     | INT16     | No          |
| Position control function          | Position demand value          | 0x6062 | Optional    | ro     | INT32     | No          |
|                                    | Position actual internal value | 0x6063 | Optional    | ro     | INT32     | No          |
|                                    | Position window                | 0x6067 | Optional    | rw     | UINT32    | No          |
| Optional application FE            | Digital inputs                 | 0x60FD | Optional    | ro     | UINT32    | Yes         |
|                                    | Digital outputs                | 0x60FE | Optional    | c,rw   | UINT32    | No, Yes     |

## 7.4 Implementing the Motor Control Program

According to the CiA402 standard from the list of CiA402 protocol stack I/F functions in Table 7-3, implement the motor control application. Each function links the number of each state transition of CiA402 FSA shown in Figure 7-2 and the corresponding function is called in case of state transition. In each function, describe the processing that calls the motor control program or the relevant processing of the main CPU.

**Table 7-3 List of CiA402 Protocol Stack I/F Functions**

|                         |                                                                                                                                                                                                                                                                |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiA402_StateTransition1 |                                                                                                                                                                                                                                                                |
|                         | <u>Description</u><br>This function is used when state transition 1 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                               |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                                        |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                                  |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                                 |
|                         | <u>Remark</u> <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                                |
| CiA402_StateTransition2 |                                                                                                                                                                                                                                                                |
|                         | <u>Description</u><br>This function is used when state transition 2 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                               |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                                        |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                                  |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                                 |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur.               |
|                         |                                                                                                                                                                                                                                                                |

|                         |                                                                                                                                                                                                                                                  |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiA402_StateTransition3 |                                                                                                                                                                                                                                                  |
|                         | <u>Description</u><br>This function is used when state transition 3 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition4 |                                                                                                                                                                                                                                                  |
|                         | <u>Description</u><br>This function is used when state transition 4 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition5 |                                                                                                                                                                                                                                                  |
|                         | <u>Description</u><br>This function is used when state transition 5 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                  |

|                         |                                                                                                                                                                                                                                                  |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiA402_StateTransition6 |                                                                                                                                                                                                                                                  |
|                         | <u>Description</u><br>This function is used when state transition 6 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition7 |                                                                                                                                                                                                                                                  |
|                         | <u>Description</u><br>This function is used when state transition 7 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition8 |                                                                                                                                                                                                                                                  |
|                         | <u>Description</u><br>This function is used when state transition 8 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                         | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                         | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                         | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                         | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                         |                                                                                                                                                                                                                                                  |

|                          |                                                                                                                                                                                                                                                  |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiA402_StateTransition9  |                                                                                                                                                                                                                                                  |
|                          | <u>Description</u><br>This function is used when state transition 9 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                 |
|                          | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                          | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                          | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                          | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                          |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition10 |                                                                                                                                                                                                                                                  |
|                          | <u>Description</u><br>This function is used when state transition 10 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                |
|                          | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                          | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                          | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                          | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                          |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition11 |                                                                                                                                                                                                                                                  |
|                          | <u>Description</u><br>This function is used when state transition 11 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                |
|                          | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                          | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                          | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                          | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                          |                                                                                                                                                                                                                                                  |

|                          |                                                                                                                                                                                                                                 |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiA402_StateTransition12 |                                                                                                                                                                                                                                 |
| <u>Description</u>       | This function is used when state transition 12 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                     |
| <u>Usage</u>             | #include "cia402appl.h"                                                                                                                                                                                                         |
| <u>Parameters</u>        | TCiA402Axis *pCiA402Axis                                                                                                                                                                                                        |
| <u>Return Value</u>      | 0 Normal end<br>1 Error                                                                                                                                                                                                         |
| <u>Remark</u>            | In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
| CiA402_LocalError        |                                                                                                                                                                                                                                 |
| <u>Description</u>       | This function is used when state transition 13 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                     |
| <u>Usage</u>             | #include "cia402appl.h"                                                                                                                                                                                                         |
| <u>Parameters</u>        | UINT16 ErrorCode                                                                                                                                                                                                                |
| <u>Return Value</u>      | None                                                                                                                                                                                                                            |
| <u>Remark</u>            | If the error corresponding to state transition 13 occurs,<br>call this function after processing required and saving data at error location.                                                                                    |
| CiA402_StateTransition14 |                                                                                                                                                                                                                                 |
| <u>Description</u>       | This function is used when state transition 14 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                     |
| <u>Usage</u>             | #include "cia402appl.h"                                                                                                                                                                                                         |
| <u>Parameters</u>        | TCiA402Axis *pCiA402Axis                                                                                                                                                                                                        |
| <u>Return Value</u>      | 0 Normal end<br>1 Error                                                                                                                                                                                                         |
| <u>Remark</u>            | In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |



|                               |                                                                                                                                                                                                                                                  |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiA402_StateTransition15      |                                                                                                                                                                                                                                                  |
|                               | <u>Description</u><br>This function is used when state transition 15 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                |
|                               | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                               | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                               | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                               | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                               |                                                                                                                                                                                                                                                  |
| CiA402_StateTransition16      |                                                                                                                                                                                                                                                  |
|                               | <u>Description</u><br>This function is used when state transition 16 has occurred.<br>Describe the operation in the case of the state transition.                                                                                                |
|                               | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                               | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                               | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                               | <u>Remark</u><br>In the case of error occurrence during processing, exit the function by setting the appropriate values for each object in accordance with the CiA402 standard.<br>If 1 is set to return value, state transition does not occur. |
|                               |                                                                                                                                                                                                                                                  |
| APPL_MOTOR_MotionControl_Main |                                                                                                                                                                                                                                                  |
|                               | <u>Description</u><br>Implement the motion control code when the state of CiA402 FSA is "Operation enabled". Describe the process for each mode of operation.                                                                                    |
|                               | <u>Usage</u><br>#include "cia402appl.h"                                                                                                                                                                                                          |
|                               | <u>Parameters</u><br>TCiA402Axis *pCiA402Axis                                                                                                                                                                                                    |
|                               | <u>Return Value</u><br>0 Normal end<br>1 Error                                                                                                                                                                                                   |
|                               | <u>Remark</u><br>At the initial state, this function is described in "main.c" and calls "CiA402_DummyMotionControl" function for reference.                                                                                                      |
|                               |                                                                                                                                                                                                                                                  |

## 8. Appendix: FSP Configuration for VSC8531

RZ/N2L Industrial Network SOM Kit has VSC8531 as PHY chip.

If reconfiguring by latest FSP, FSP configuration and source code needs to change from default.

### (1) Regenerate source files by latest FSP

Remove the following four folders. After that, open the project according to section 5.

- When using e2studio, \project\rzn2l\_som\ecat\_CiA402\e2studio
- When using EWARM, \project\rzn2l\_som\ecat\_CiA402\ewarm

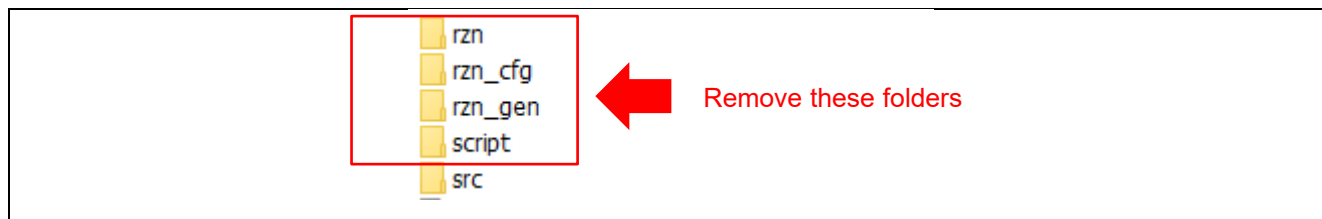


Figure 8-1 Remove folder generated by FSP

### (2) Change ethernet driver configuration for VSC8531

Configure g\_ether\_phy0 Ethernet Driver on r\_ether\_phy for VSC8531 as shown in Figure 8-2.

Configuration value for VSC8531 shows in Table 8-1.

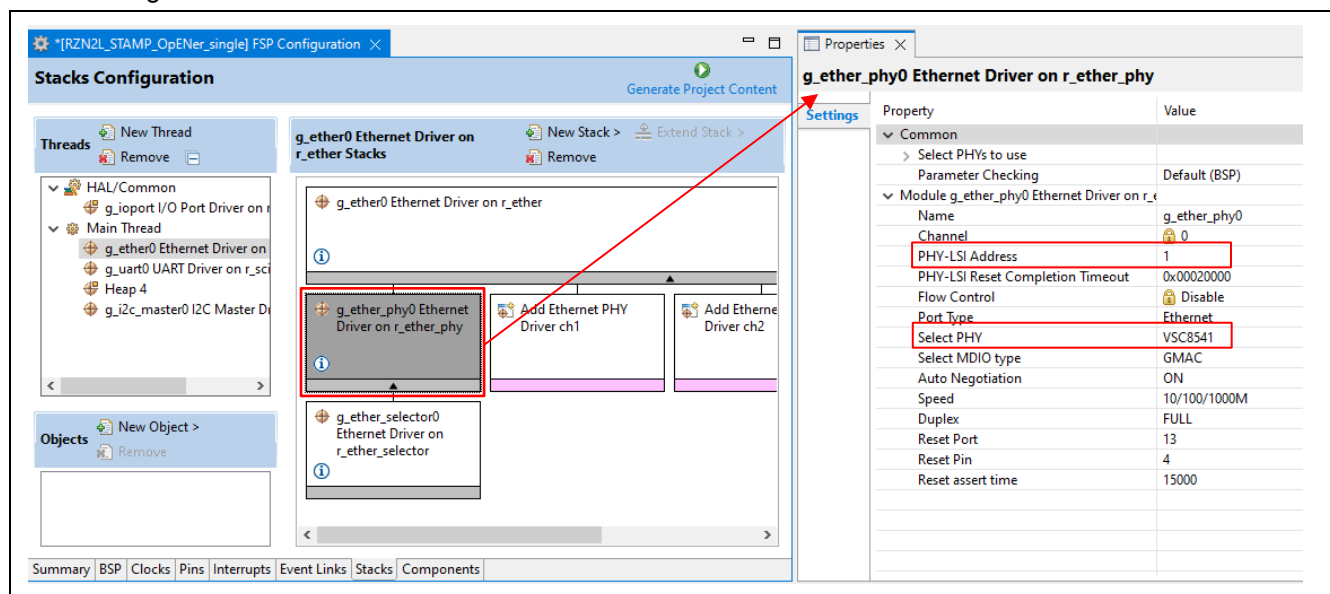


Figure 8-2 Ethernet Driver Configuration for VSC8531 (e.g. ETH0)

Table 8-1 FSP Configuration Value for VSC8531

| Items           | Default value | Config value for VSC8531 |         |
|-----------------|---------------|--------------------------|---------|
|                 |               | ETH0                     | ETH1    |
| PHY-LSI Address | 0             | 0                        | 1       |
| Select PHY      | Default       | VSC8541                  | VSC8541 |

## (3) Add initialization code for VSC8531

The following code for VSC8531 initialization should be added to “ether\_phy\_targets\_initialize\_vsc8541” function in rzn/fsp/src/r\_ether\_phy/r\_ether\_phy.c.

The inclusion of “board\_som.h” is also required for code activation.

```
#include "board_som.h"

                                ~~ Omission ~~

void ether_phy_targets_initialize_vsc8541 (ether_phy_instance_ctrl_t * p_instance_ctrl)
{

                                ~~ Omission ~~

    /* LED Behavior */
    reg = ether_phy_read(p_instance_ctrl, ETHER_PHY_REG_LED_BEHAVIOR);
    reg &= ~(1U << ETHER_PHY_REG_LED0_FEATURE_DISABLE_OFFSET);
    reg |= 1U << ETHER_PHY_REG_LED1_FEATURE_DISABLE_OFFSET;
    ether_phy_write(p_instance_ctrl, ETHER_PHY_REG_LED_BEHAVIOR, reg);
    #if defined(BOARD_RZN2L_SOM_KIT) /* for VSC8531 */
    /* select extended page 2 register */
    ether_phy_write(p_instance_ctrl, ETHER_PHY_REG_EXTEND_GPIO_PAGE, 0x02);

    /* read WoL and MAC Interface Control */
    reg = ether_phy_read(p_instance_ctrl, 0x1b);

    /* set control to slow */
    reg &= 0xFF9F;
    ether_phy_write(p_instance_ctrl, 0x1b, reg);

    /* Configure RX_CLK delay and TX_CLK delay to 2.0ns */
    ether_phy_write(p_instance_ctrl, ETHER_PHY_REG_EXPAGE2_RGMII_CTRL, 0x0044);

    /* select extended page 0 register */
    ether_phy_write(p_instance_ctrl, ETHER_PHY_REG_EXTEND_GPIO_PAGE, 0x00);
    #endif
}

                                /* End of function ether_phy_targets_initialize() */
```

## Revision History

| Rev. | Date        | Description |                           |
|------|-------------|-------------|---------------------------|
|      |             | Page        | Summary                   |
| 1.00 | Feb 6, 2023 | -           | First edition issued      |
| 1.10 | Aug 7.2023  | -           | Support RZ/N2L FSP v1.2.0 |
|      |             |             |                           |

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

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

## 1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity.

Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

## 2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

## 3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

## 4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

## 5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

## 6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.).

## 7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

## 8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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