User's Manual

32

RX24U Group

Renesas Starter Kit Code Generator Tutorial Manual
For e^2 studio

RENESAS 32-Bit MCU
RX Family / RX200 Series

Renesas Electronics
www.renesas.com

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Precautions

The following precautions should be observed when operating any RSK product:

This Renesas Starter Kit is only intended for use in a laboratory environment under ambient temperature and humidity conditions. A safe separation distance should be used between this and any sensitive equipment. Its use outside the laboratory, classroom, study area or similar such area invalidates conformity with the protection requirements of the Electromagnetic Compatibility Directive and could lead to prosecution.

The product generates, uses, and can radiate radio frequency energy and may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment causes harmful interference to radio or television reception, which can be determined by turning the equipment off or on, you are encouraged to try to correct the interference by one or more of the following measures;

- ensure attached cables do not lie across the equipment
- reorient the receiving antenna
- increase the distance between the equipment and the receiver
- connect the equipment into an outlet on a circuit different from that which the receiver is connected
- power down the equipment when not in use
- consult the dealer or an experienced radio/TV technician for help NOTE: It is recommended that wherever possible shielded interface cables are used.

The product is potentially susceptible to certain EMC phenomena. To mitigate against them it is recommended that the following measures be undertaken;

- The user is advised that mobile phones should not be used within 10m of the product when in use.
- The user is advised to take ESD precautions when handling the equipment.

The Renesas Starter Kit does not represent an ideal reference design for an end product and does not fulfil the regulatory standards for an end product.

How to Use This Manual

1. Purpose and Target Readers

This manual is designed to provide the user with an understanding of how to use Application Leading Tool (Code Generator) for RX together with the e^2 studio IDE to create a working project for the RSK platform. It is intended for users designing sample code on the RSK platform, using the many different incorporated peripheral devices.

The manual comprises of step-by-step instructions to generate code and import it into e^2 studio, but does not intend to be a complete guide to software development on the RSK platform. Further details regarding operating the RX24U microcontroller may be found in the Hardware Manual and within the provided sample code.

Particular attention should be paid to the precautionary notes when using the manual. These notes occur within the body of the text, at the end of each section, and in the Usage Notes section.

The revision history summarizes the locations of revisions and additions. It does not list all revisions. Refer to the text of the manual for details.

The following documents apply to the RX24U Group. Make sure to refer to the latest versions of these documents. The newest versions of the documents listed may be obtained from the Renesas Electronics Web site.

Document Type	Description	Document Title	Document No.
User's Manual	Describes the technical details of the RSK hardware.	RSKRX24U User's Manual	R20UT3758EG
Tutorial Manual	Provides a guide to setting up RSK environment, running sample code and debugging programs.	RSKRX24U Tutorial Manual	R20UT3762EG
Quick Start Guide	Provides simple instructions to setup the RSK and run the first sample.	RSKRX24U Quick Start Guide	R20UT3763EG
Code Generator Tutorial	Provides a guide to code generation and importing into the e^2 studio IDE.	RSKRX24U Code Generator Tutorial Manual	R20UT3764EG
Schematics	Full detail circuit schematics of the RSK.	RSKRX24U Schematics	R20UT3757EG
Hardware Manual	Provides technical details of the RX24U microcontroller.	RX24U Group Hardware Manual	R01UH0658EJ

2. List of Abbreviations and Acronyms

Abbreviation	Full Form
ADC	Analog-to-Digital Converter
API	Application Programming Interface
bps	bits per second
CMT	Compare Match Timer
COM	COMmunications port referring to PC serial port
CPU	Central Processing Unit
DVD	Digital Versatile Disc
E1 / E2 Lite	Renesas On-chip Debugging Emulator
GUI	Graphical User Interface
IDE	Integrated Development Environment
IRQ	Interrupt Request
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LSB	Least Significant Bit
LVD	Low Voltage Detect
MCU	Micro-controller Unit
MSB	Most Significant Bit
PC	Personal Computer
PLL	Phase-locked Loop
Pmod™	This is a Digilent Pmod™ Compatible connector. Pmod™ is registered to Digilent Inc. Digilent-Pmod_Interface_Specification
RAM	Random Access Memory
ROM	Read Only Memory
RSK	Renesas Starter Kit
RTC	Real Time Clock
SAU	Serial Array Unit
SCI	Serial Communications Interface
SPI	Serial Peripheral Interface
TAU	Timer Array Unit
TFT	Thin Film Transistor
TPU	Timer Pulse Unit
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
WDT	Watchdog Timer

Table of Contents

1. Overview

1.1 Purpose

This RSK is an evaluation tool for Renesas microcontrollers. This manual describes how to use the e^2 studio IDE code generator plug in to create a working project for the RSK platform.

1.2 Features

This RSK provides an evaluation of the following features:

- Project Creation with e^2 studio.
- Code Generation using the code generator plug in.
- User circuitry such as switches, LEDs and a potentiometer.

The RSK board contains all the circuitry required for microcontroller operation.

2. Introduction

This manual is designed to answer, in tutorial form, how to use the code generator plug in for the RX family together with the e^2 studio IDE to create a working project for the RSK platform. The tutorials help explain the following:

- Project generation using the e^2 studio
- Detailed use of the code generator plug in for e^2 studio
- Integration with custom code
- Building the project e^2 studio

The project generator will create a tutorial project with two selectable build configurations:

- 'HardwareDebug' is a project built with the debugger support included. Optimisation is set to zero.
- 'Release' is a project with optimised compile options (level two) and no outputs debugging information options selected, producing code suitable for release in a product.

These tutorials are designed to show you how to use the RSK and are not intended as a comprehensive introduction to the e^2 studio debugger, compiler toolchains or the E2 emulator Lite. Please refer to the relevant user manuals for more in-depth information.

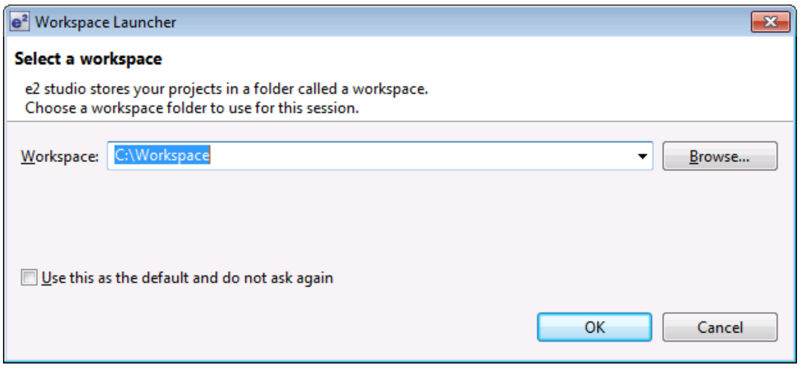
3. Project Creation with e2 studio

3.1 Introduction

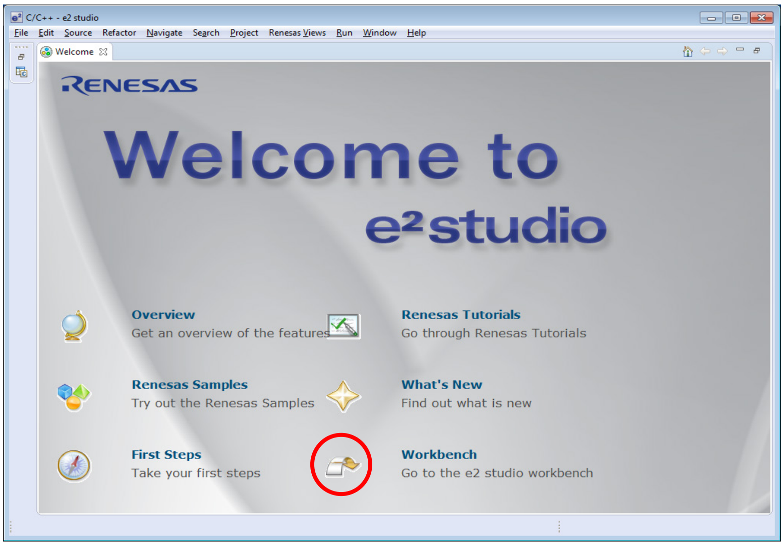
In this section the user will be guided through the steps required to create a new C project for the RX24U MCU, ready to generate peripheral driver code using Code Generator. This project generation step is necessary to create the MCU-specific source, project and debug files.

3.2 Creating the Project

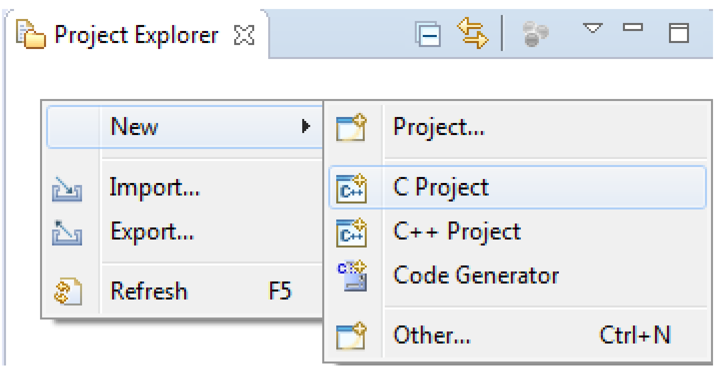
- Start e2 studio and select a suitable location for the project workspace.



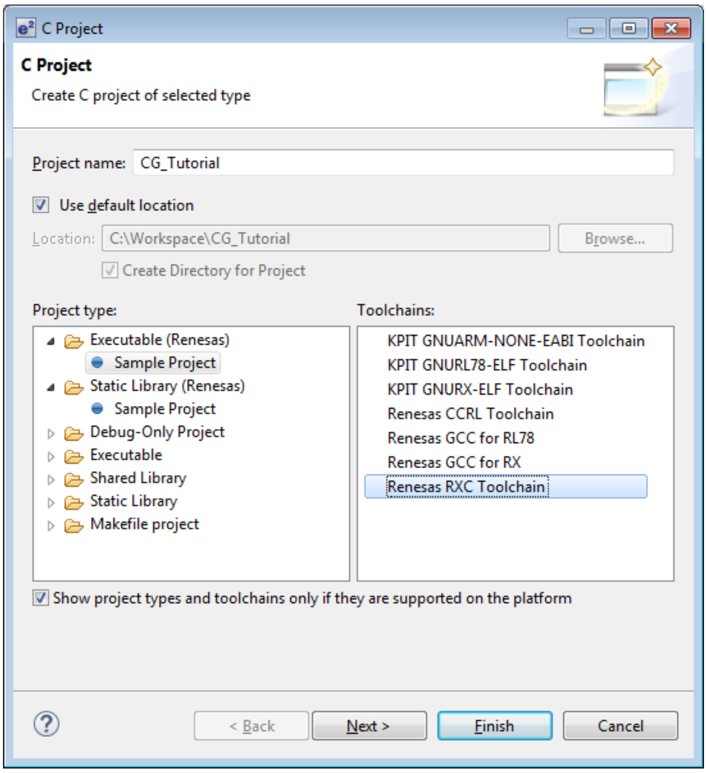
- In the Welcome page, click ‘Go to the e2 studio workbench’.



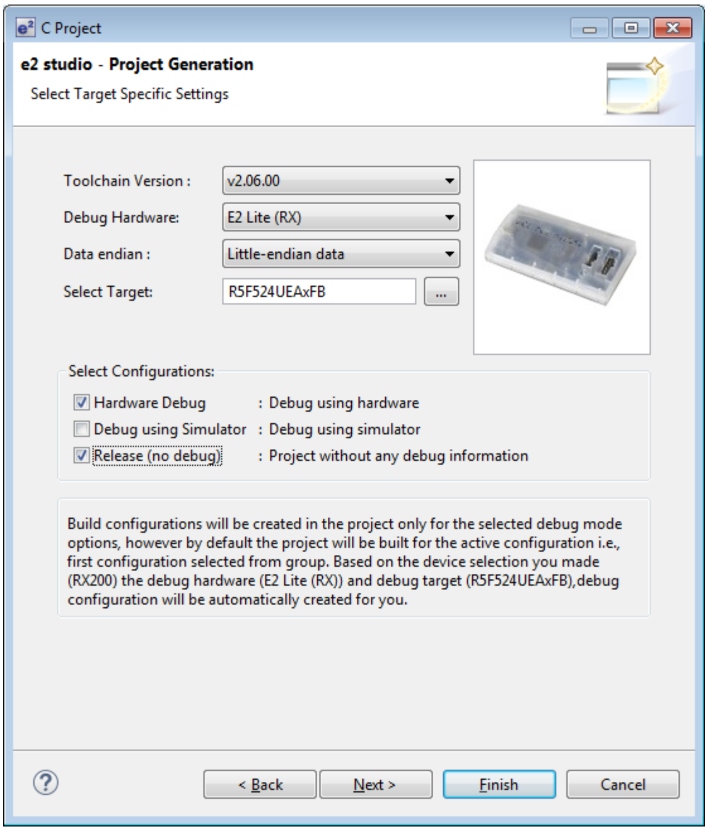
- Create a new C project by right-clicking in the Project Explorer pane and selecting ‘New -> C Project’ as shown. Alternatively, use the menu item ‘File -> New -> C Project’.



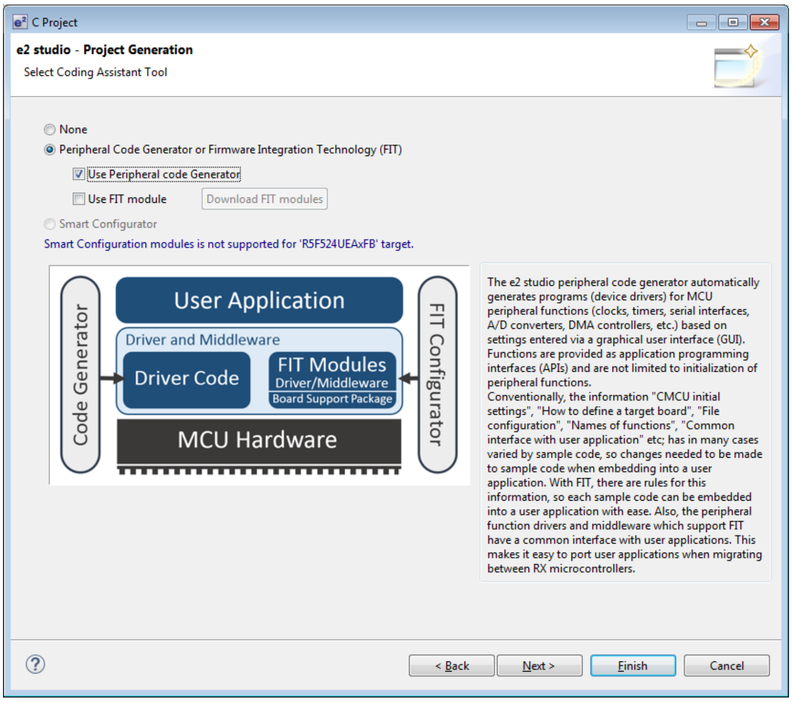
- Enter the project name 'CG_Tutorial'. In 'Project type:' choose 'Sample Project'. In 'Toolchains' choose 'Renesas RXC Toolchain'. Click 'Next'.



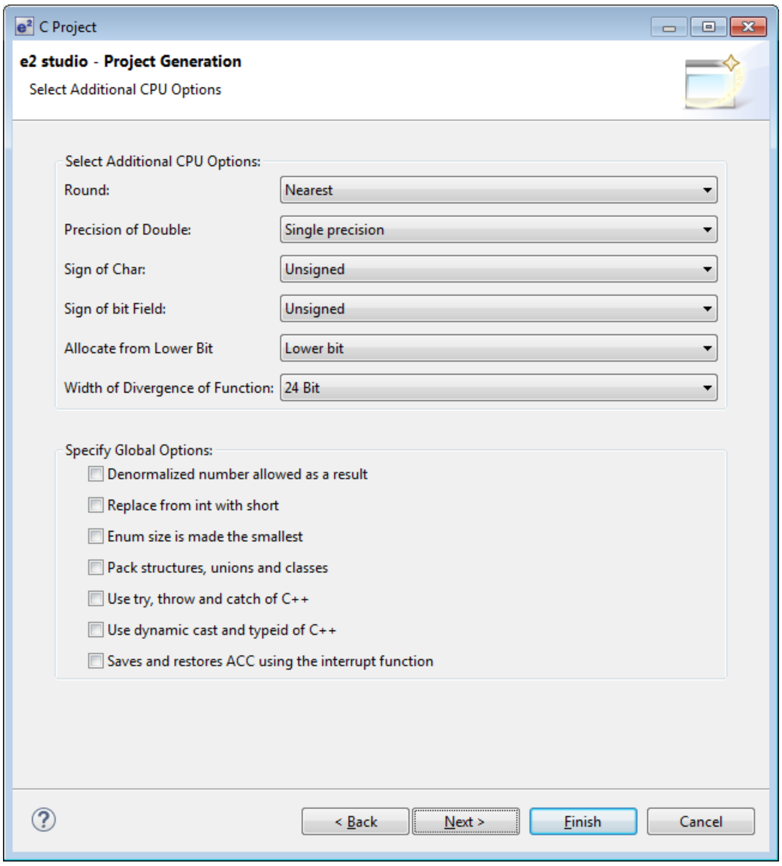
- In the 'Target Specific Settings' dialog, select the options as shown in the screenshot opposite.
- The R5F524UEAxFB MCU is found under RX200 -> RX24U -> RX24U - 144 pin.
- Click 'Next'.



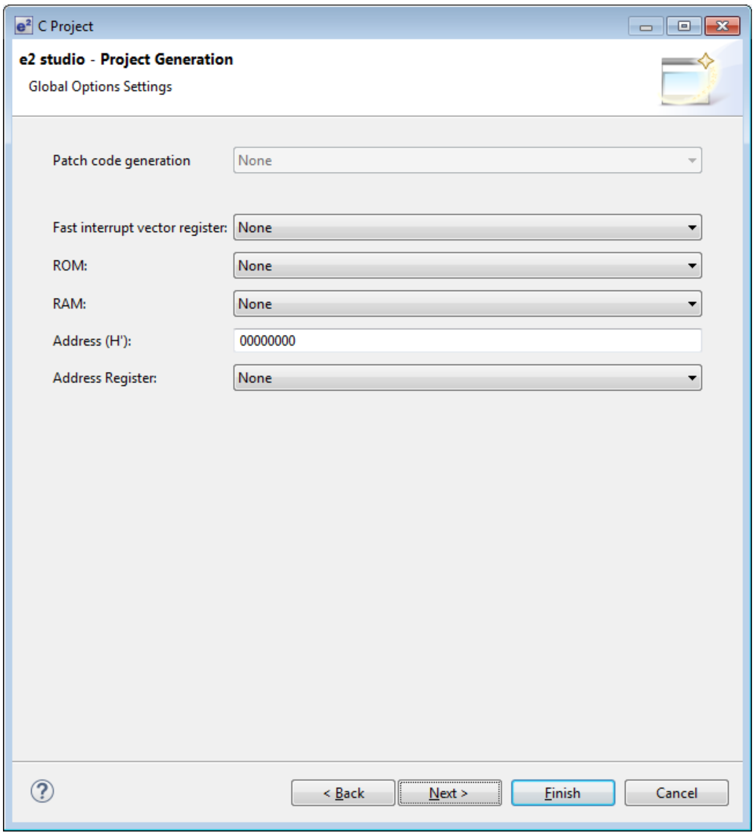
- In the ‘Select Coding Assistant Tool’ dialog, select ‘Peripheral Code Generator or Firmware Integration Technology (FIT)’ then ensure the ‘Use Peripheral code Generator’ is checked.
- Click ‘Next’.



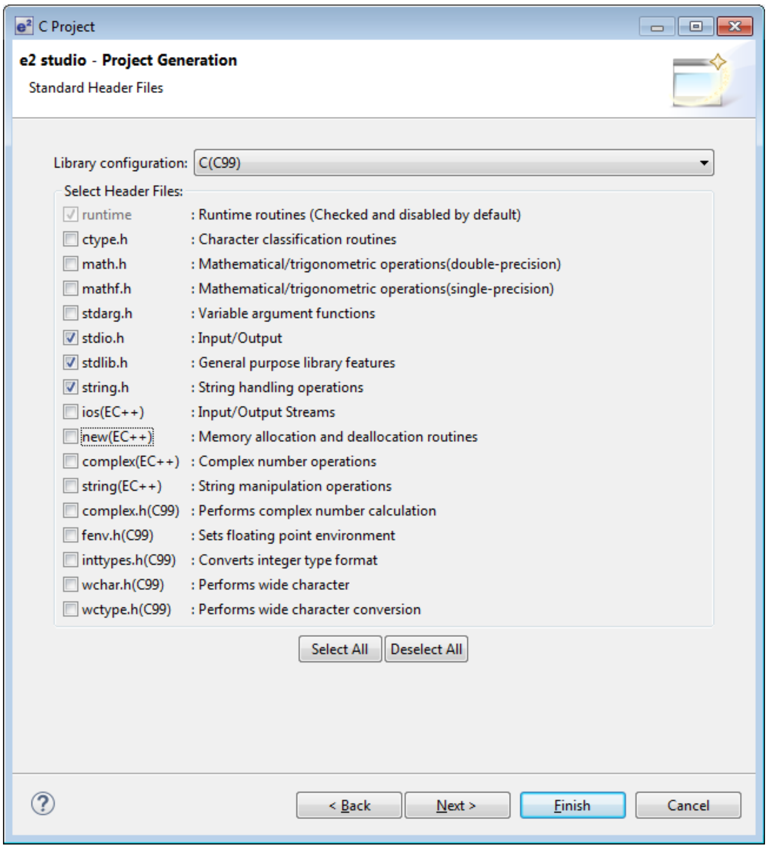
- In ‘Select Additional CPU Options’ leave everything at default values.
- Click ‘Next’.



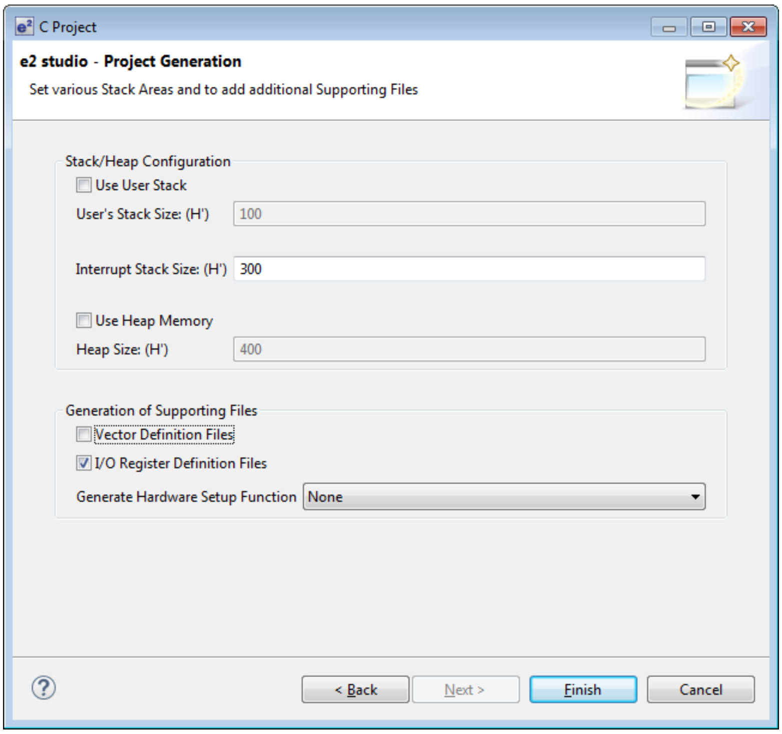
- In the 'Global Options Settings' leave everything at default values.
- Click 'Next'.



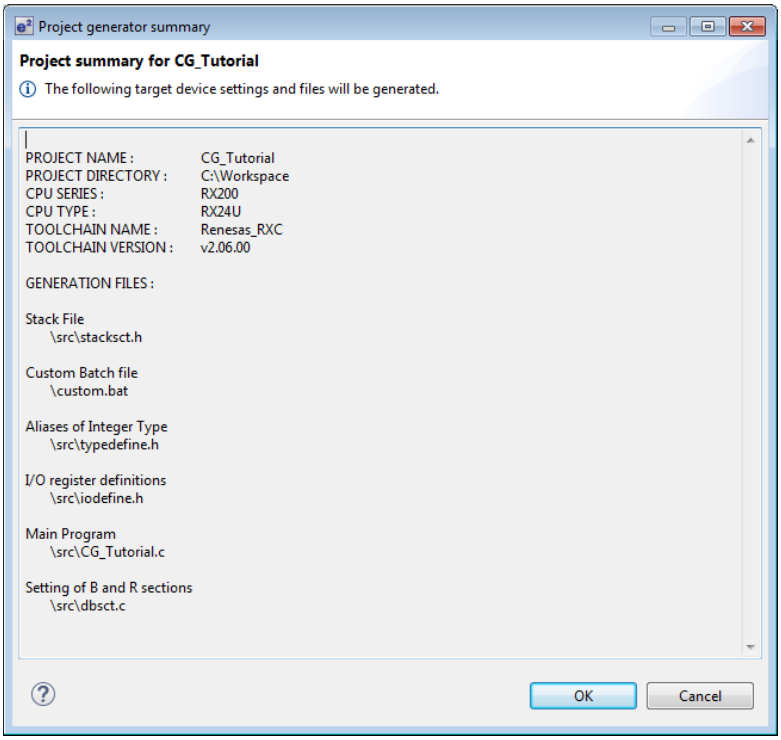
- In the 'Standard Header Files' dialog, select C99 for 'Library Configuration'. Untick 'new(EC++)' and leave all others at defaults.
- Click 'Next'.



- In the next dialog, untick all check boxes except 'I/O Register Definition Files' as shown opposite. Click 'Finish'.



- A summary dialog will appear, click 'OK' to complete the project generation.



4. Code Generation Using the e2 studio plug in

4.1 Introduction

Code Generator is an e2 studio plug in GUI tool for generating template ‘C’ source code for the RX24U. When using Code Generator, the user is able to configure various MCU features and operating parameters using intuitive GUI controls, thereby bypassing the need in most cases to refer to sections of the Hardware Manual.

Once the user has configured the project, the ‘Generate Code’ function is used to generate three code modules for each specific MCU feature selected. These code modules are name ‘r_cg_xxx.h’, ‘r_cg_xxx.c’, and ‘r_cg_xxx_user.c’, where ‘xxx’ is a three letter acronym for the relevant MCU feature, for example ‘adc’. Within these code modules, the user is then free to add custom code to meet their specific requirement. Custom code should be added, whenever possible, in between the following comment delimiters:

```
/* Start user code for adding. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
```

Code Generator will locate these comment delimiters, and preserve any custom code inside the delimiters on subsequent code generation operations. This is useful if, after adding custom code, the user needs to re-visit Code Generator to change any MCU operating parameters.

By following the steps detailed in this Tutorial, the user will generate an e2 studio project called CG_Tutorial. The fully completed Tutorial project is contained on the RSK Web Installer (https://www.renesas.com/rskrx24u/install) and may be imported into e2 studio by following the steps in the Quick Start Guide. This Tutorial is intended as a learning exercise for users who wish to use the Code Generator to generate their own custom projects for e2 studio.

The CG_Tutorial project uses interrupts for switch inputs, the ADC module, the Compare Match Timer (CMT), the Serial Communications Interface (SCI) and uses these modules to perform A/D conversion and display the results via the Virtual COM port to a terminal program and also on the LCD display on the RSK.

Following a tour of the key user interface features of Code Generator in §4.2, the reader is guided through each of the peripheral function configuration dialogs in §4.3. In §5, the reader is familiarised with the structure of the template code, as well as how to add their own code to the user code areas provided by the code generator.

The Code Generator installer is contained on the RSK Web Installer. This installer must be run before proceeding to the next section.

4.2 Code Generator Tour

This section presents a brief tour of Code Generator. For further details of the Code Generator paradigm and reference, refer to the Application Leading Tool Common Operations manual.
You can download the latest document from: https://www.renesas.com/applilet
Application Leading Tool is the stand-alone version of Code Generator and this manual is applicable to the Code Generator.

From the e2 studio menus, select ‘Window -> Perspective -> Open Perspective -> Other. In the ‘Open Perspective’ dialog shown in **Figure 4-1**, select ‘Code Generator’ and click ‘OK’.

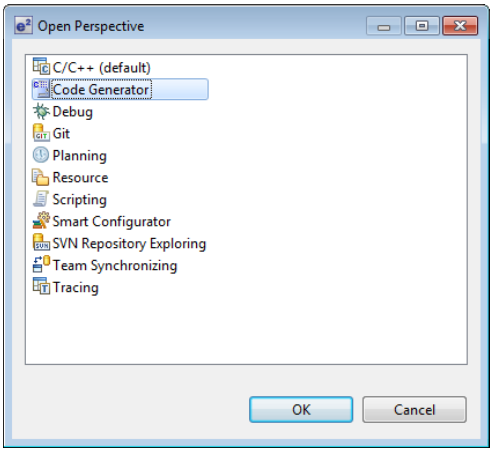


Figure 4-1 Open Perspective Dialog

In the Project Explorer pane, expand the ‘Code Generator’ and ‘Peripheral Functions’ node. The Code Generator initial view is displayed as illustrated in **Figure 4-2**.

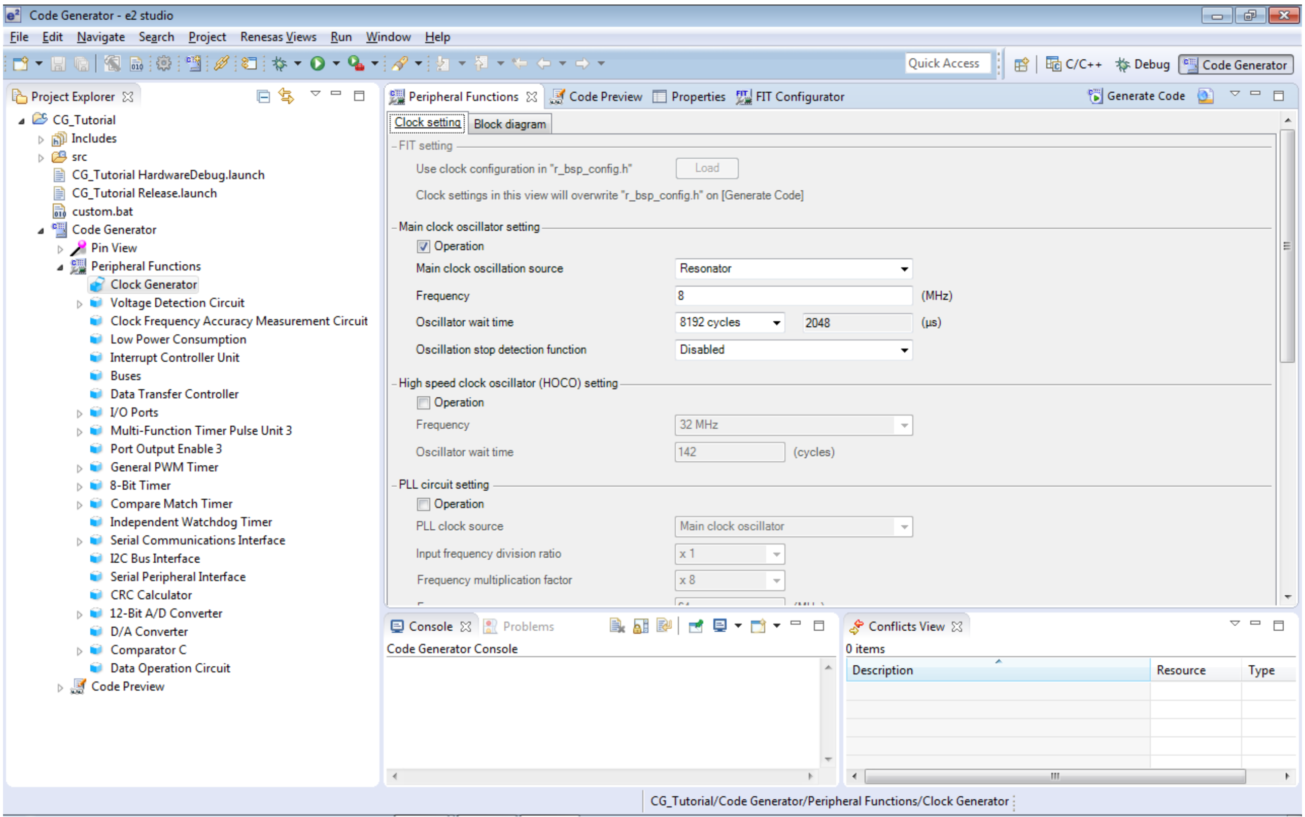


Figure 4-2 Initial View

Code Generator provides GUI features for configuration of MCU sub systems. Once the user has configured all required MCU sub systems and peripherals, the user can click the ‘Generate Code’ button, resulting in a fully configured e² studio project that builds and runs without error.

Navigation to the MCU peripheral configuration screens may be performed by double-clicking the required function in the Code Generator -> Peripheral Function on the left.

It is also possible to see a preview of the code that will be generated for the current peripheral function settings by double-clicking the required function in the Code Generator -> Code Preview on the left.

4.3 Code Generation

In the following sub-sections, the reader is guided through the steps to configure the MCU for a simple project containing interrupts for switch inputs, timers, ADC and a SCI.

4.3.1 Clock Generator

Figure 4-3 shows a screenshot of Code Generator with the Clock Generator function open. Click on the 'Clock setting' sub tab. Configure the system clocks as shown in the figure. In this tutorial we are using the on board 20 MHz crystal resonator for our main clock oscillation source and the PLL circuit is in operation. The PLL output is used as the main system clock and the divisors should be set as shown in **Figure 4-3**.

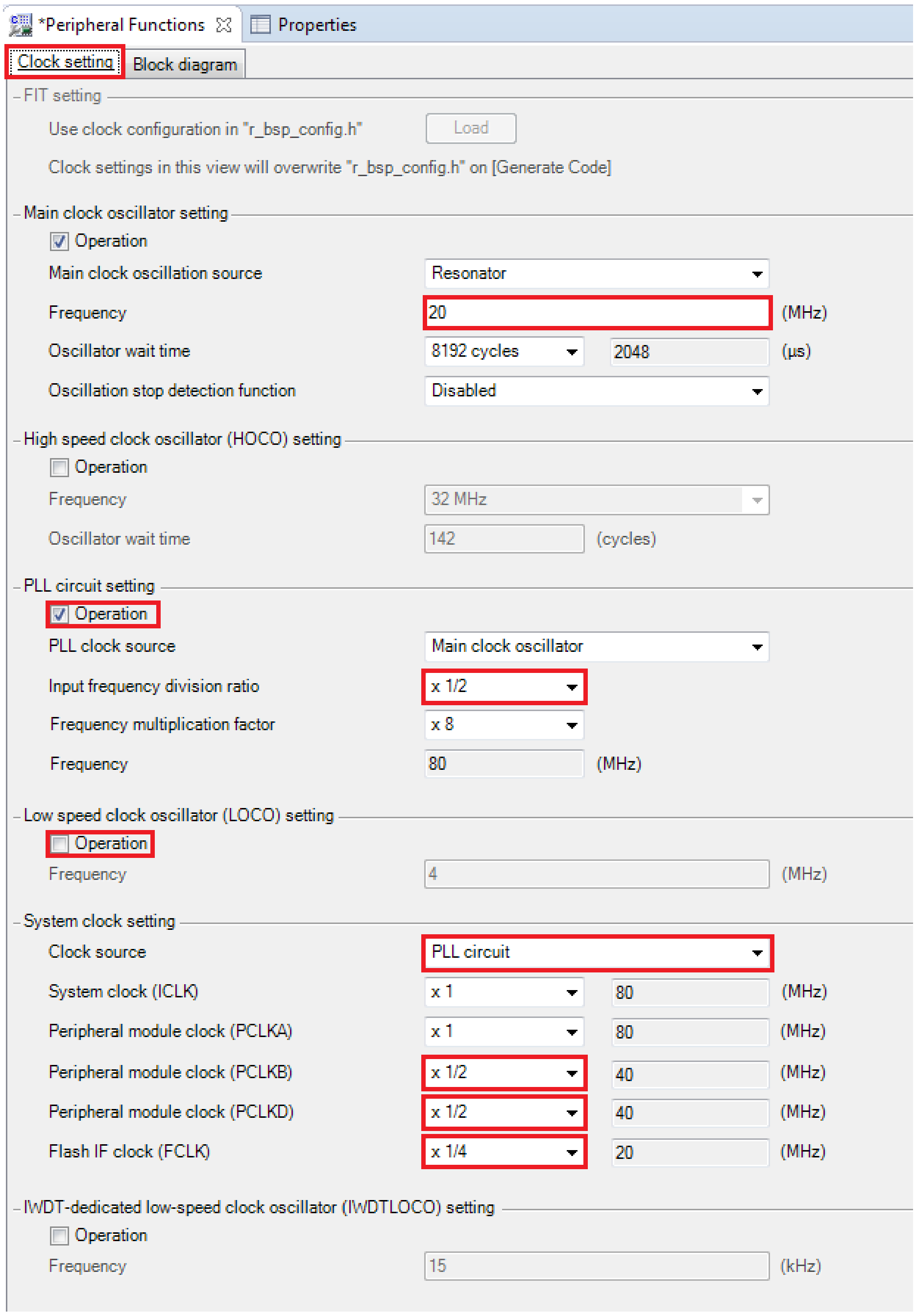


Figure 4-3 Clock setting tab

Click the arrow next to the Generate Report icon. Select ‘Interrupt Controller Unit’ as shown in **Figure 4-4** below. Proceed to the next section on the Interrupt Controller Unit.

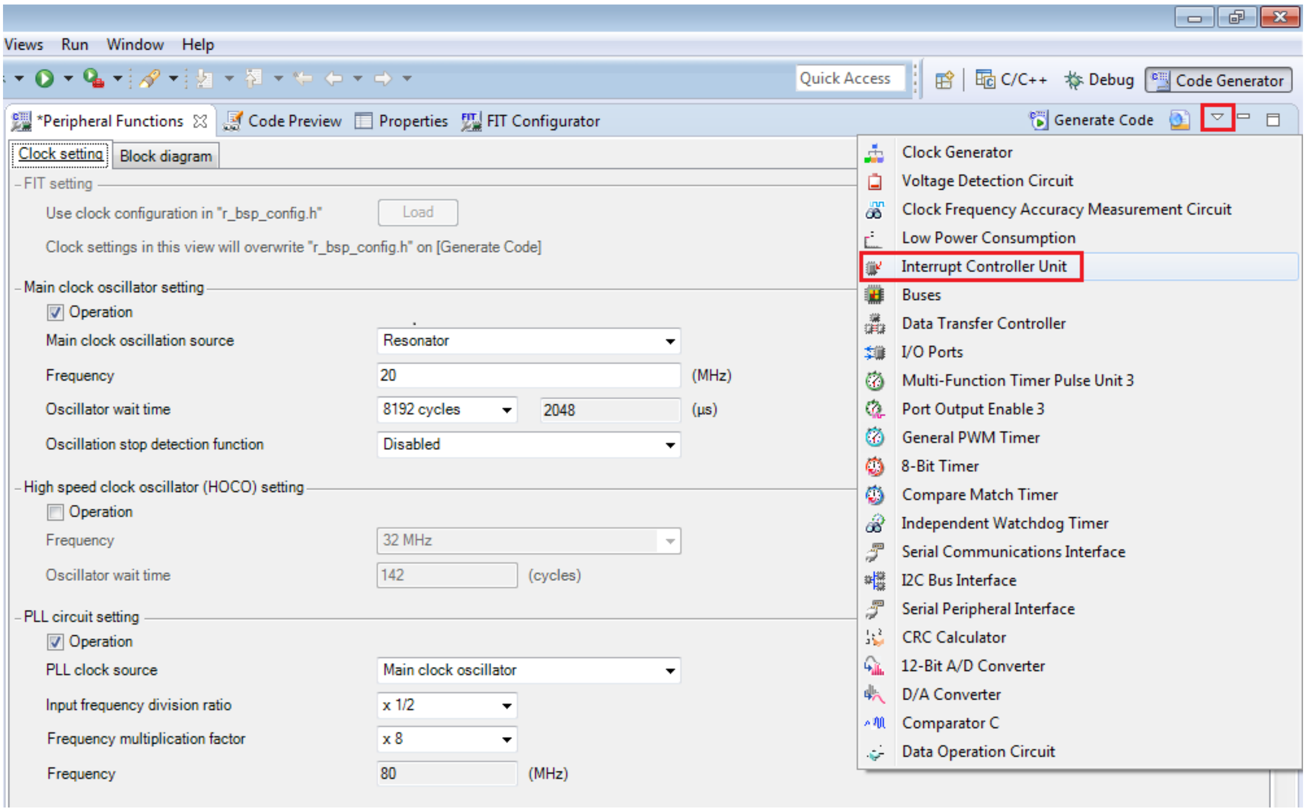


Figure 4-4 Select Interrupt Controller Unit

4.3.2 Interrupt Controller Unit

Referring to the RSK schematic, SW1 is connected to IRQ0 (P10) and SW2 is connected to IRQ4 (P60). SW3 is connected directly to the ADTRG0n and will be configured later in §4.3.4. Navigate to the 'Interrupt Controller Unit' node in Code Generator and in the 'General' tab, configure these two interrupts as falling edge triggered as shown in **Figure 4-5** below.

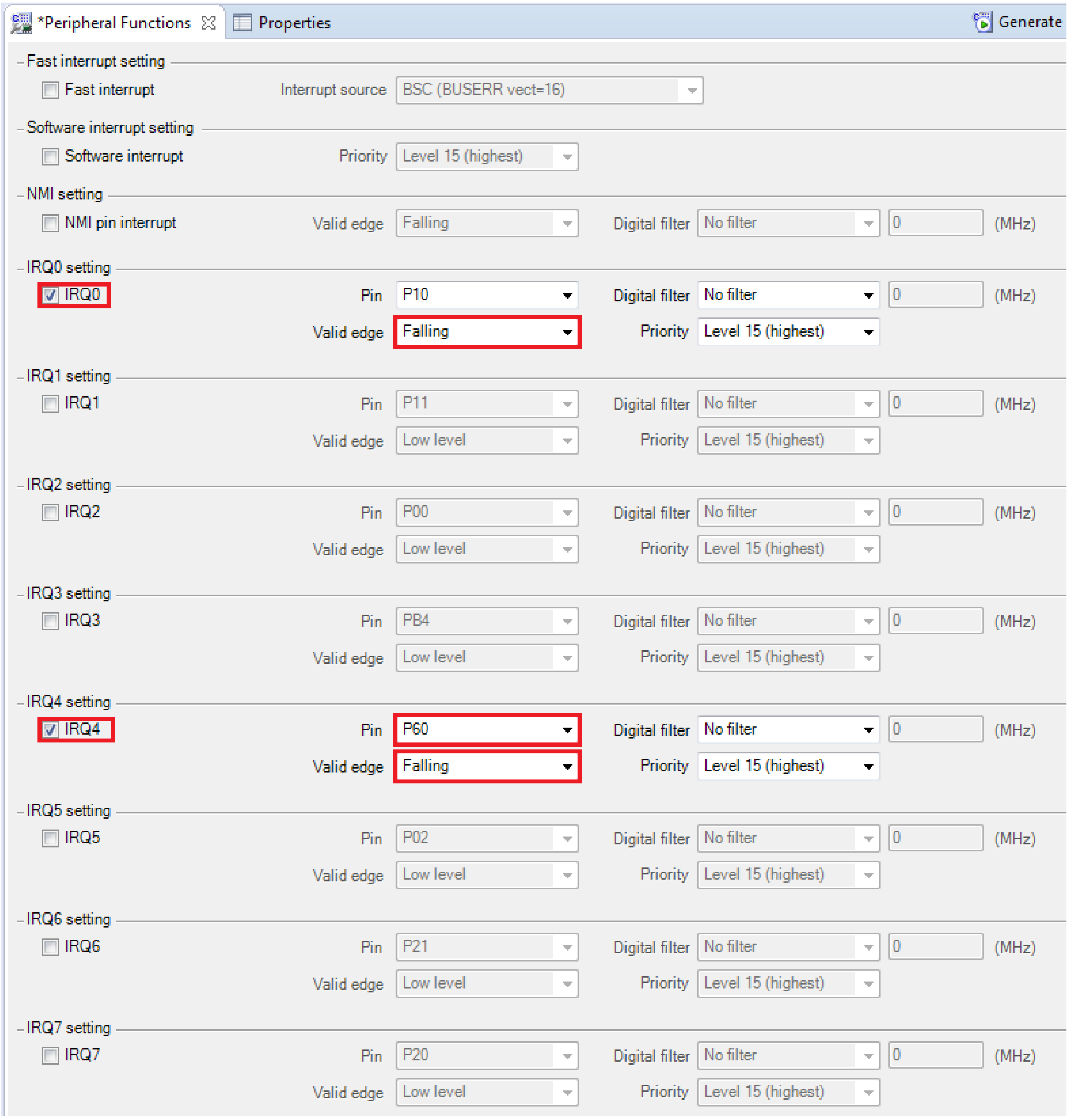


Figure 4-5 Interrupt Functions tab

Click the arrow next to the Generate Report icon. Select 'Compare Match Timer' as shown in **Figure 4-6** below. Proceed to the next section on the Compare Match Timer.

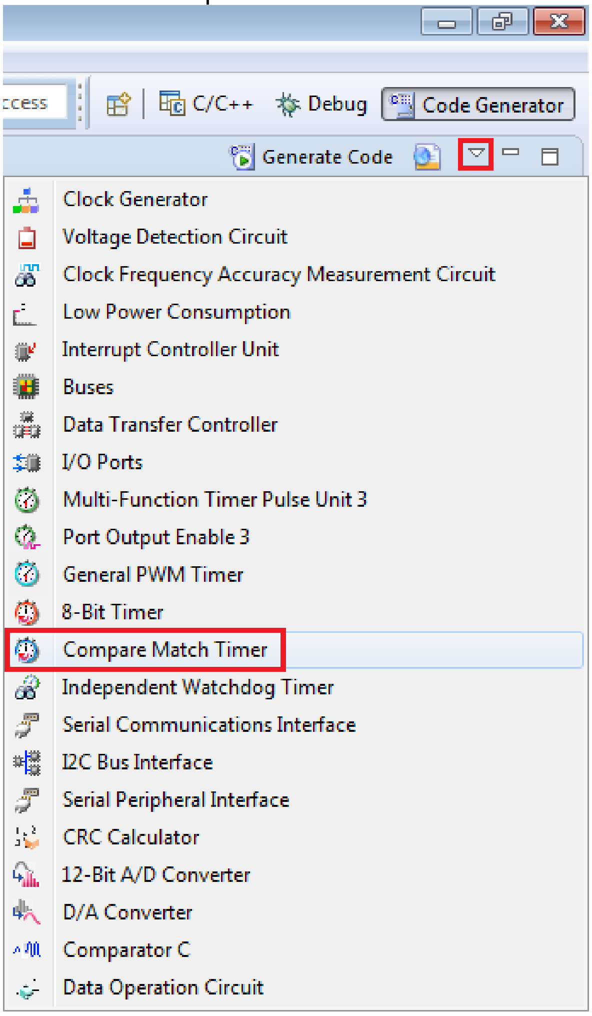


Figure 4-6 Select Compare Match Timer

4.3.3 Compare Match Timer

Navigate to the 'Compare Match Timer' node in Code Generator. CMT0 will be used as an interval timer for generation of accurate delays. CMT1 and CMT2 will be used as timers in de-bouncing of switch interrupts.

In the 'CMT0' sub-tab configures CMT0 as shown in **Figure 4-7**. This timer is configured to generate a high priority interrupt every 1ms. We will use this interrupt later in the tutorial to provide an API for generating high accuracy delays required in our application.

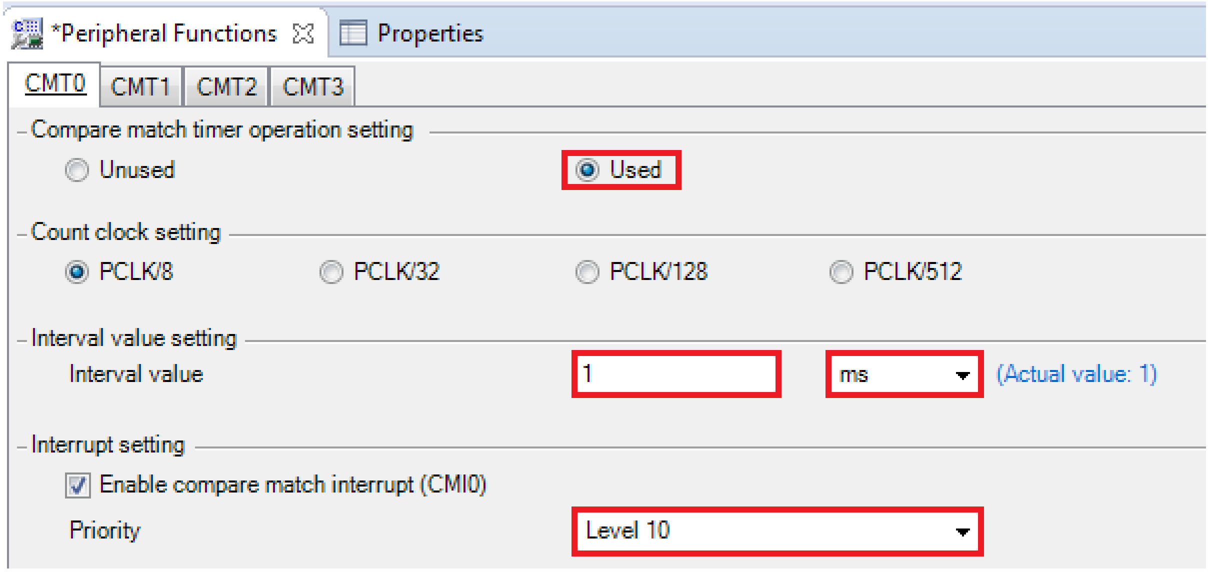


Figure 4-7 CMT0 tab

Navigate to the 'CMT1' sub-tab and configure CMT1 as shown in **Figure 4-8**. This timer is configured to generate a high priority interrupt after 20ms. This timer is used as our short switch de-bounce timer later in this tutorial.

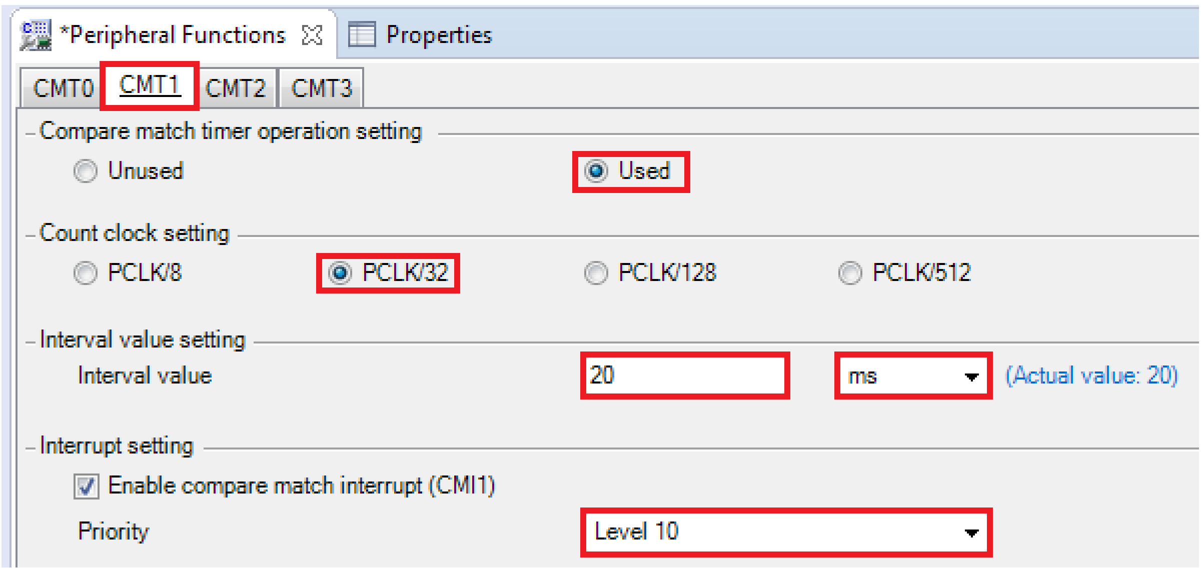


Figure 4-8 CMT1 tab

Navigate to the ‘CMT2’ sub-tab and configure CMT2 as shown in **Figure 4-9**. This timer is configured to generate a high priority interrupt after 200ms. This timer is used as our long switch de-bounce timer later in this tutorial.

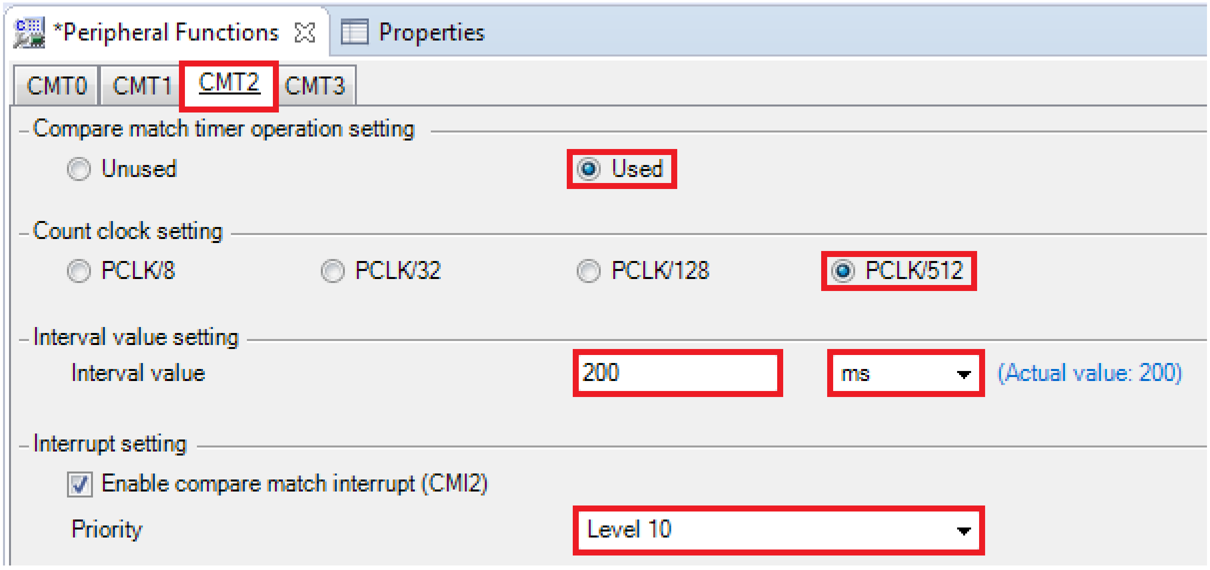


Figure 4-9 CMT2 tab

Click the arrow next to the Generate Report icon. Select ‘12-Bit A/D Converter’ as shown in **Figure 4-10** below. Proceed to the next section on the 12-Bit A/D Converter.

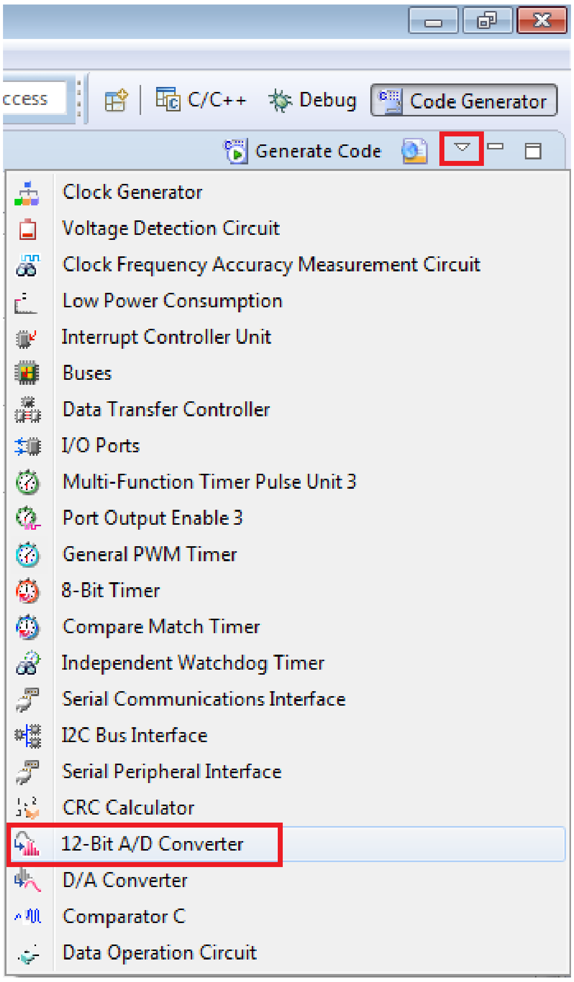


Figure 4-10 Select 12-Bit A/D Converter

4.3.4 12-Bit A/D Converter

Navigate to the '12-Bit A/D Converter' node in Code Generator. In the 'S12AD0' sub-tab configures S12AD0 as shown in **Figure 4-11, Figure 4-12** and configure the S12AD0 as shown. We will be using the S12AD0 in Single scan mode on the AN000 input, which is connected to the RV1 potentiometer output on the RSK. The conversion start trigger will be via the pin connected to SW3.

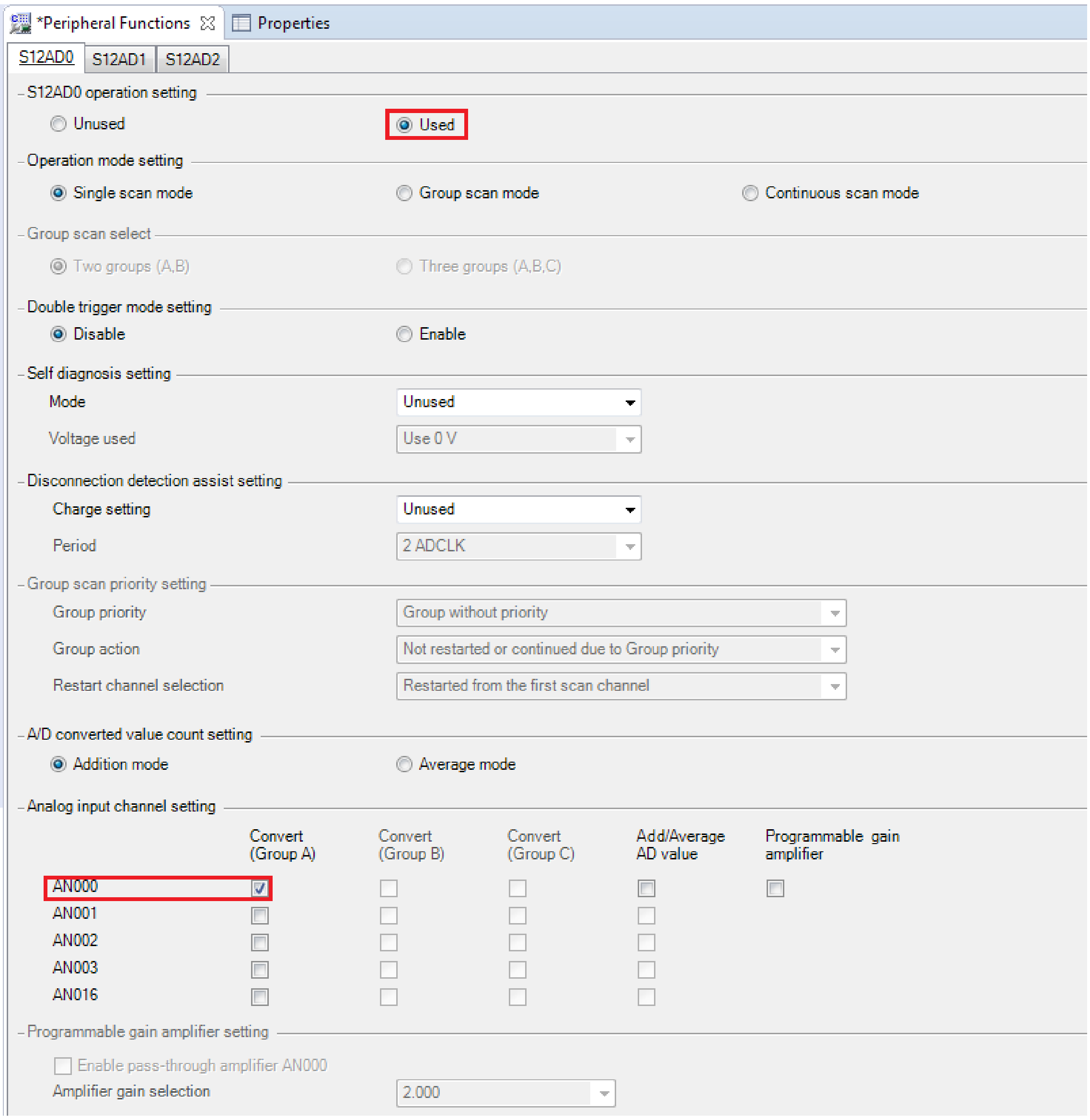


Figure 4-11 S12AD0 tab (1)

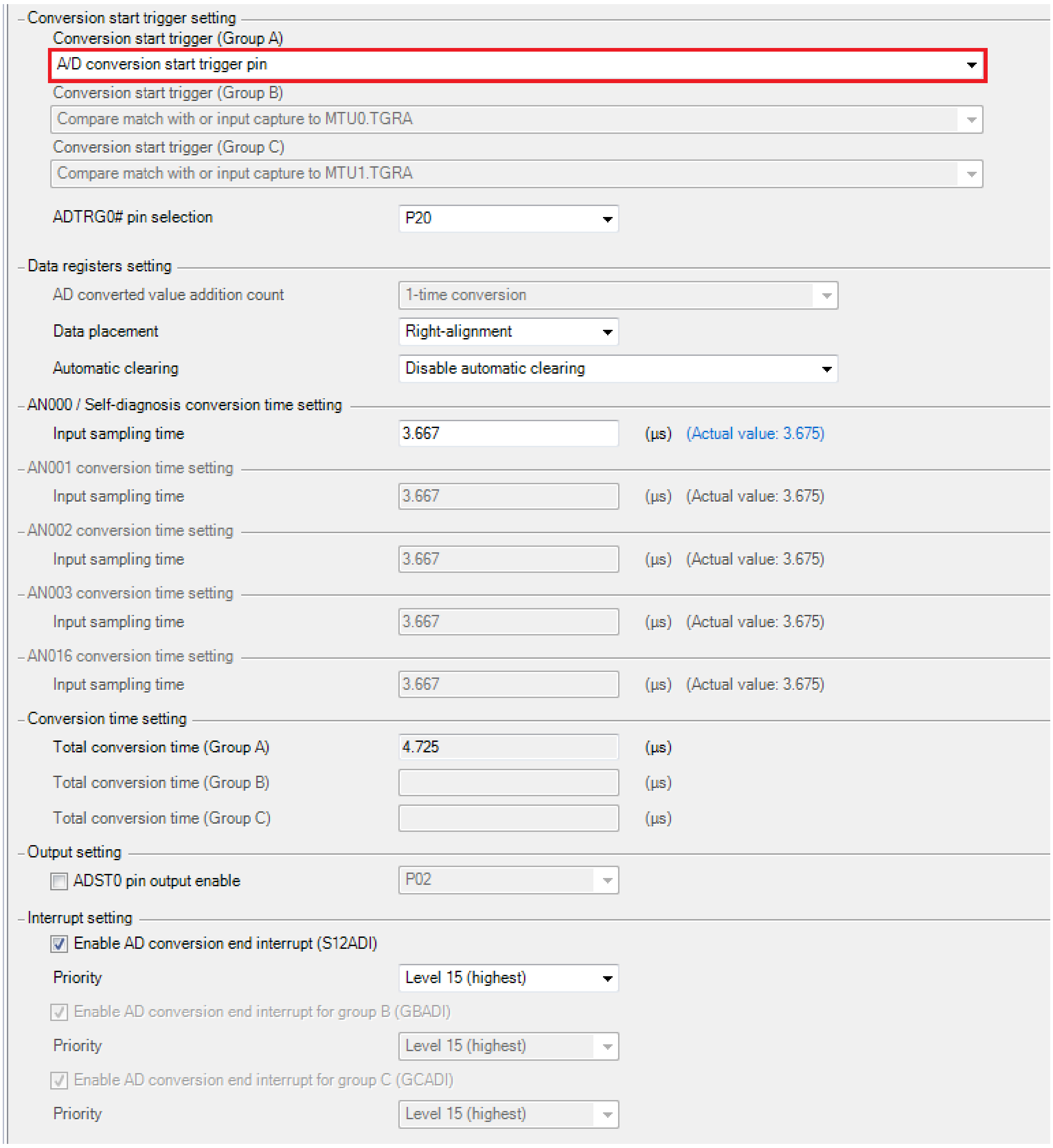


Figure 4-12 S12AD0 tab (2)

Click the arrow next to the Generate Report icon. Select ‘Serial Communications Interface’ as shown in **Figure 4-13** below. Proceed to the next section on the Serial Communications Interface.

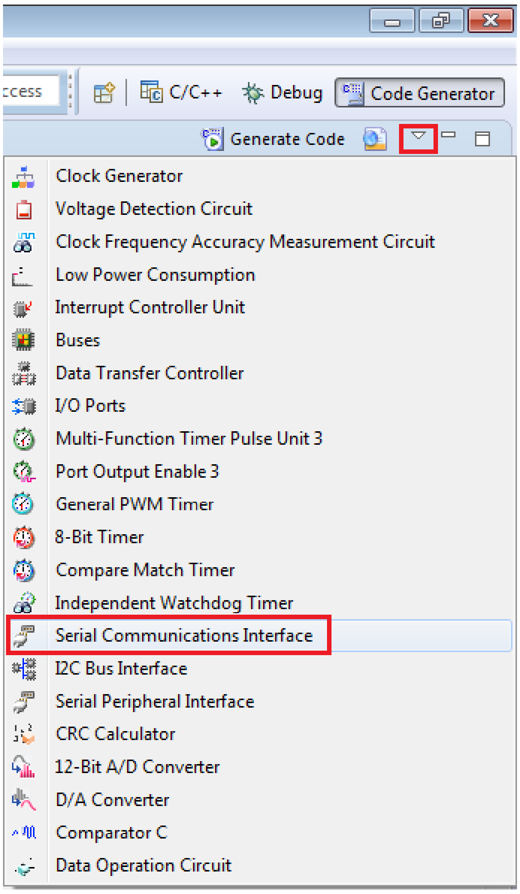


Figure 4-13 Select Serial Communications Interface

4.3.5 Serial Communications Interface

Navigate to the ‘Serial Communications Interface’ tab in Code Generator, select the SCI9 sub-tab and apply the settings shown in **Figure 4-14**. In the RSKRX24U SCI9 is used as an SPI master for the Pmod LCD on the PMOD1 connector as shown in the schematic.

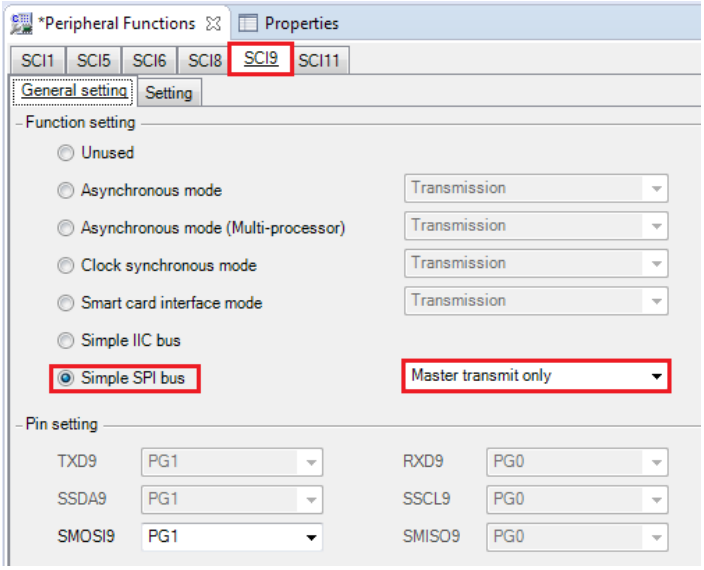


Figure 4-14 SCI9 General Setting tab

Select the SCI9 ‘Setting’ sub-tab and configure the SPI Master as illustrated in **Figure 4-15**. Make sure the ‘Transfer direction setting’ is set to ‘MSB-first’ and the ‘Bit rate’ is set to10000000. All other settings remain at their defaults.

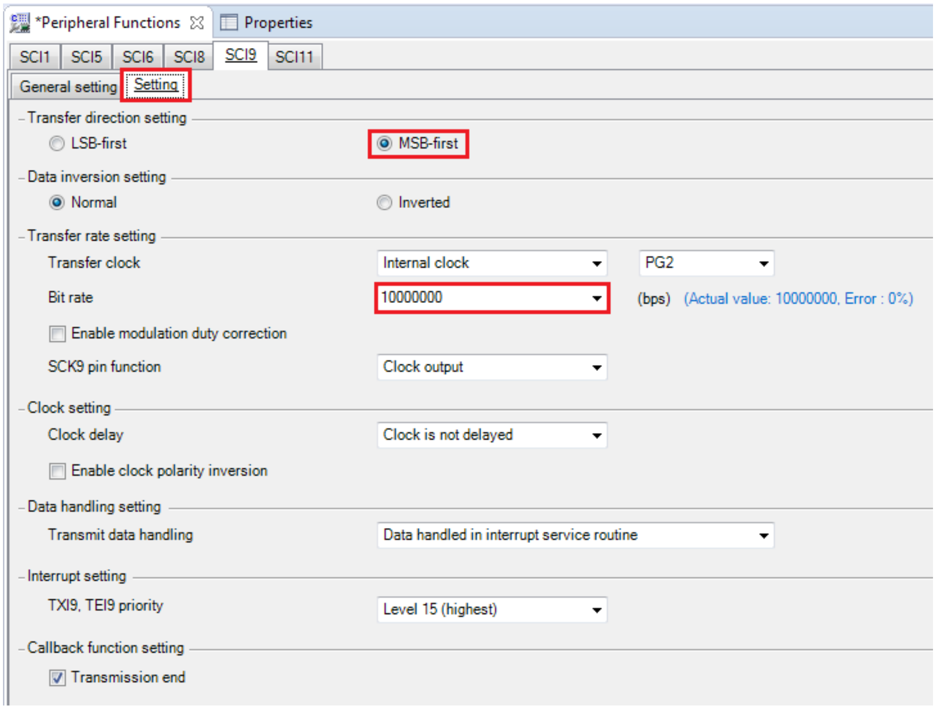


Figure 4-15 SCI9 SPI Master Setting

Staying in the 'Serial Communications Interface' tab in Code Generator, select the SCI1 sub-tab and apply the settings shown in **Figure 4-16**. In the RSKRX24U SCI1 is connected via a Renesas RL78/G1C to provide a USB virtual COM port as shown in the schematic.

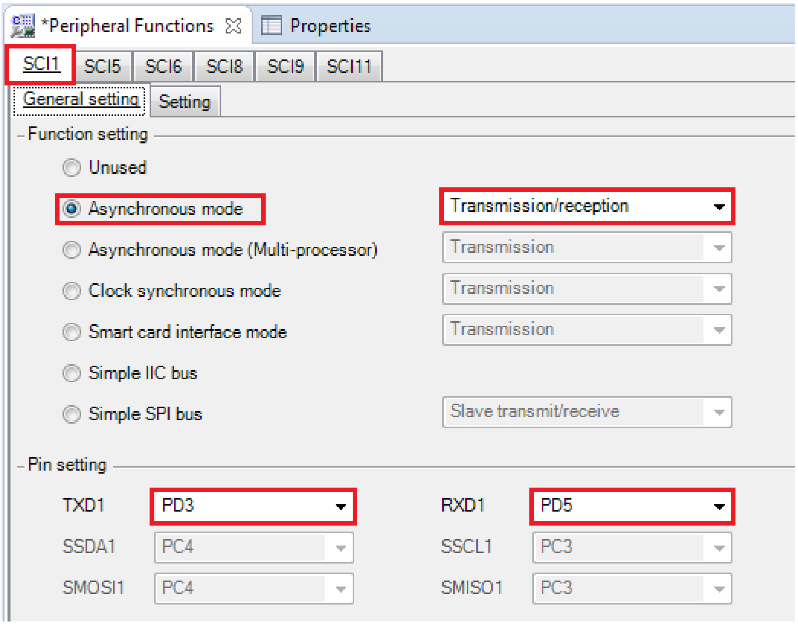


Figure 4-16 SCI1 General Setting tab

Select the SCI1 'Setting' sub-tab and configure SCI1 as illustrated in **Figure 4-17**. Make sure the 'Start bit edge detection' is set as 'Falling edge on RXD1 pin' and the 'Bit rate' is set to 19200 bps. All other settings remain at their defaults.

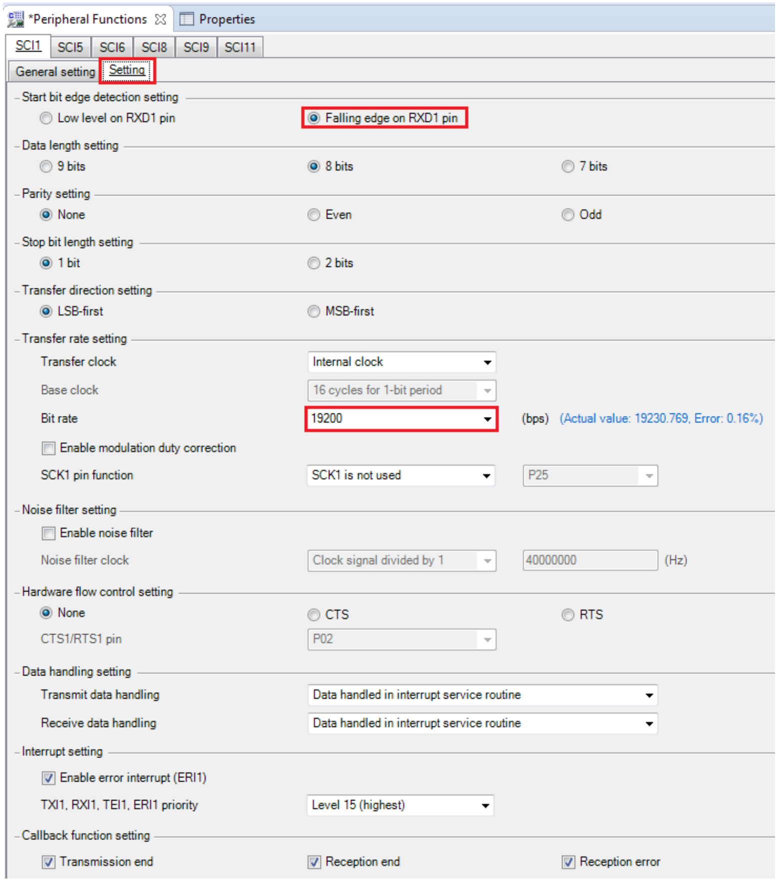


Figure 4-17 SCI1 Setting tab

Click the arrow next to the Generate Report icon. Select 'I/O Ports' as shown in **Figure 4-18** below. Proceed to the next section on the I/O Ports.

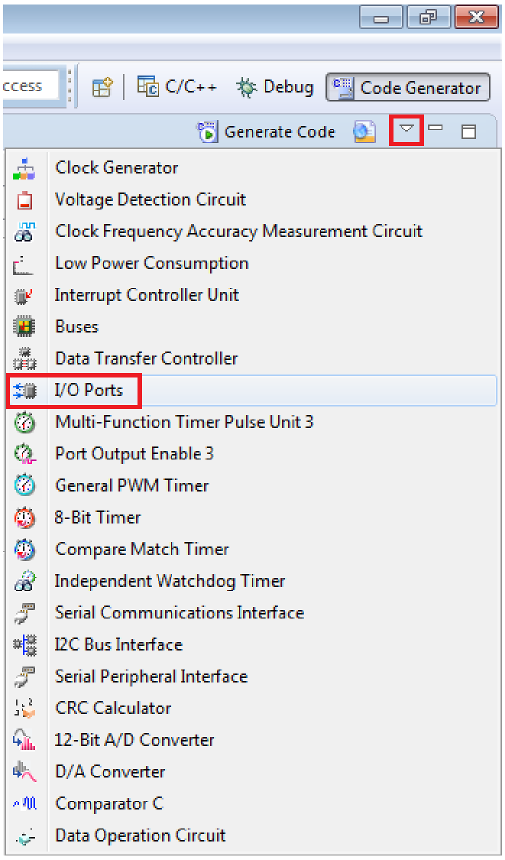


Figure 4-18 Select I/O Ports

4.3.6 I/O Ports

Referring to the RSK schematic, LED0 is connected to P21, LED1 is connected to P22, LED2 is connected to PC3 and LED3 is connected to PC4. Navigate to the 'I/O Ports' tab in Code Generator and configure these four I/O lines as shown in **Figure 4-19** and **Figure 4-20** below. Ensure that the 'Output 1' tick box is checked. This ensures that the code is generated to set LEDs initially off.

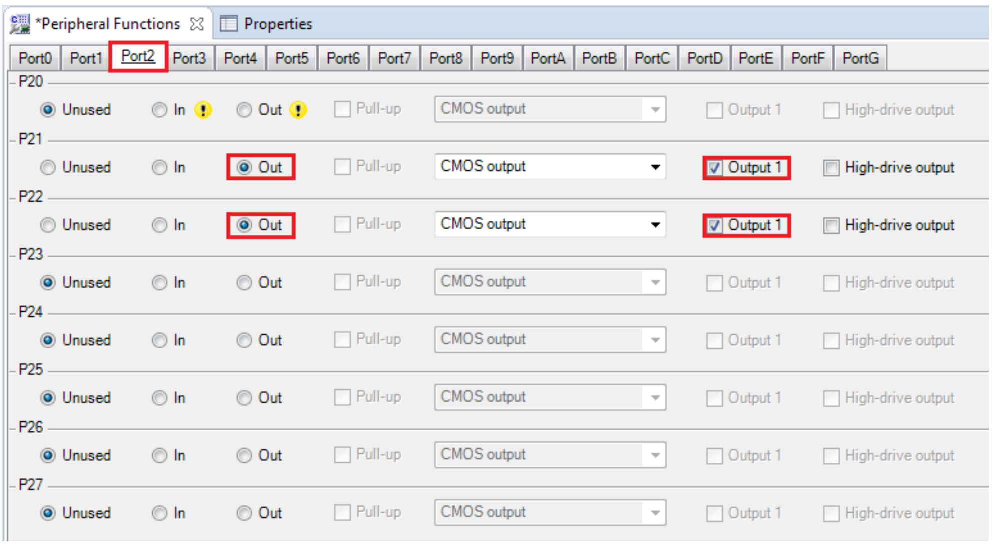


Figure 4-19 I/O ports – Port2

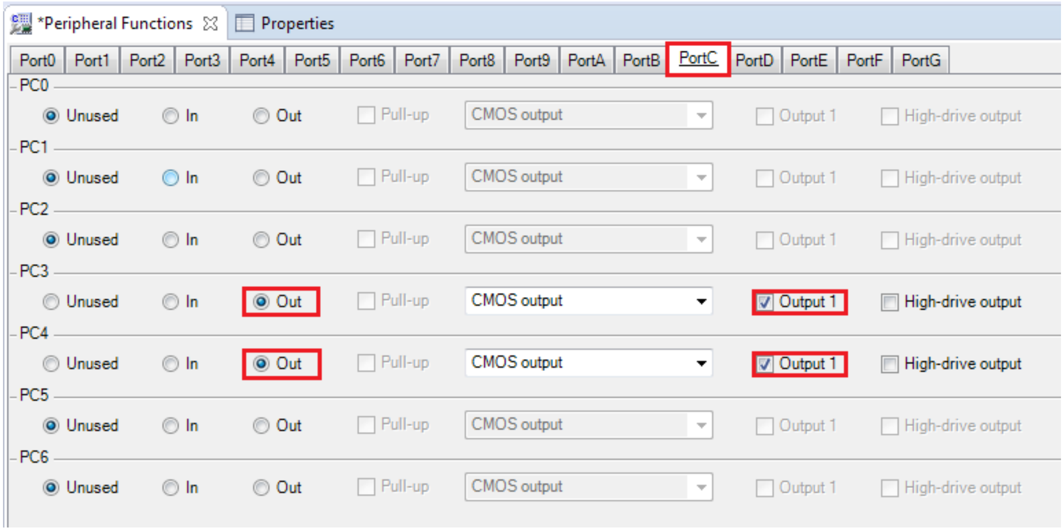


Figure 4-20 I/O ports – PortC

P27 is used as one of the LCD control lines, together with P34, P55 and P65. Configure these lines as shown in **Figure 4-21, Figure 4-22** and **Figure 4-23**.

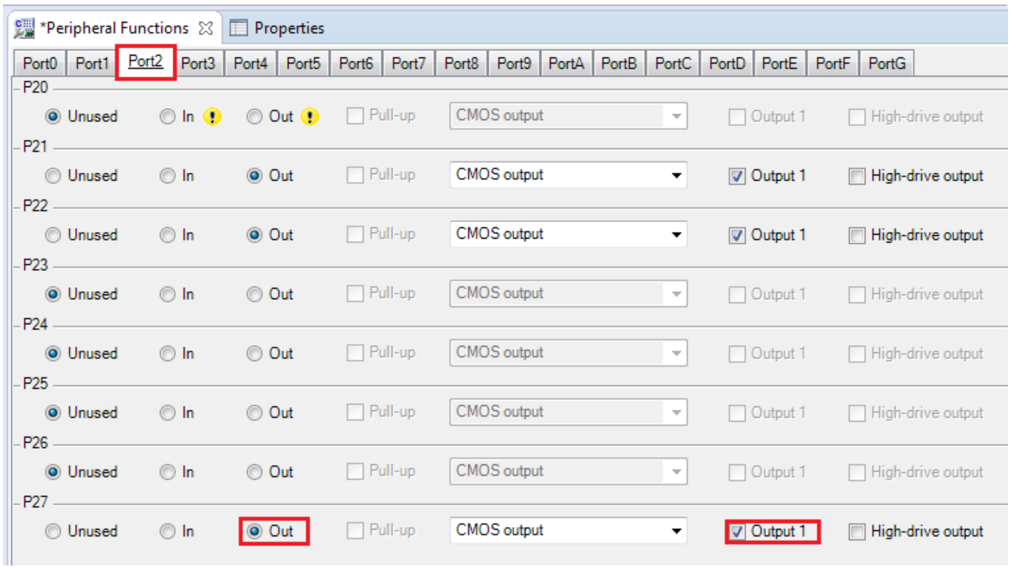


Figure 4-21 I/O ports – Port2

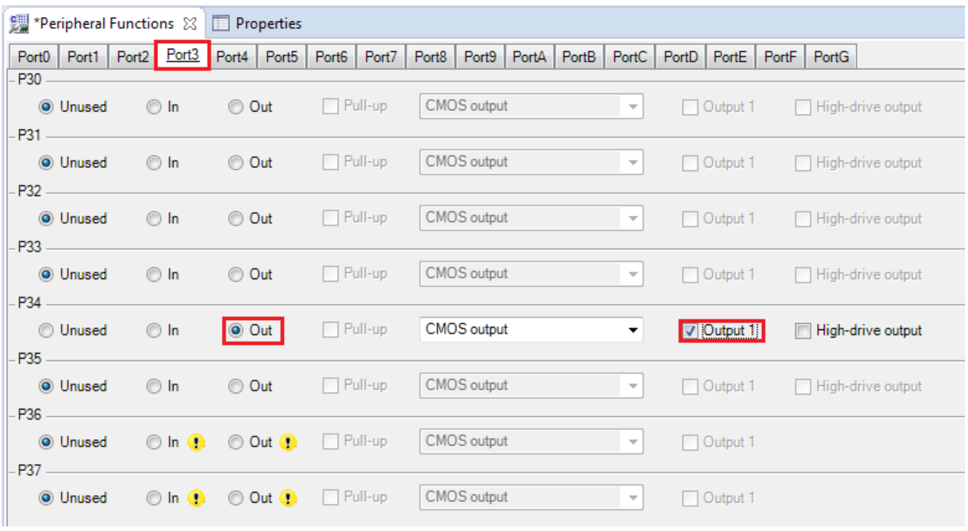


Figure 4-22 I/O ports – Port3

Figure 4-23 I/O ports – Port5

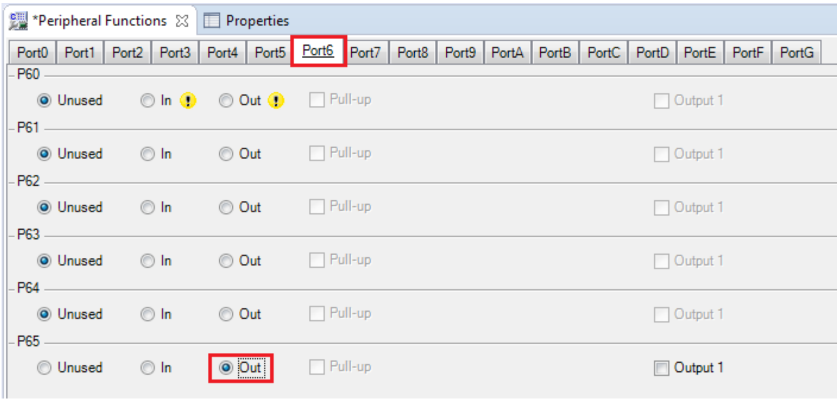


Figure 4-24 I/O ports – Port6

Peripheral function configuration is now complete. Save the project using the File -> Save, then click 'Generate Code'. The Console pane should report 'The operation of generating file was successful', as shown **Figure 4-25** below.

Figure 4-25 Code generator console

4.4 Building the Project

The project template created by Code Generator can now be built. In the Project Explorer pane expand the 'src' folder. The four files created by the New Project Wizard in §3.2 have been excluded from the build automatically as part of the code generation procedure as shown in **Figure 4-26**. This is because the main function now resides in r_cg_main.c in the cg_src folder and the type definitions and setting of sections has been handled by the Code Generator.

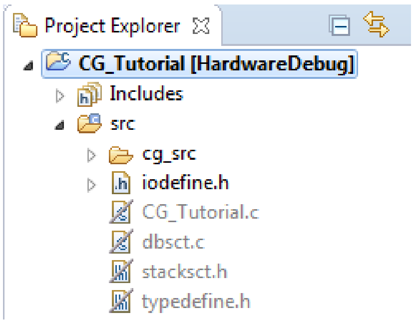


Figure 4-26 Files excluded from the build by Code Generator

Switch back to the 'C/C++' perspective using the 

button on the top right of the e^2 studio workspace. Use 'Build Project' from the 'Project' menu or the  button to build the tutorial. The project will build with no errors.

5. User Code Integration

In this section the remaining application code is added to the project. Source files found on the RSK Web Installer are copied into the workspace and the user is directed to add code in the user areas of the code generator files.

Code must be inserted in to the user code area in many files in this project, in the areas delimited by comments as follows:

```
/* Start user code for _xxxxx_. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
```

Where _xxxx_ depends on the particular area of code, i.e. 'function' for insertion of user functions and prototypes, 'global' for insertion of user global variable declarations, or 'include' for insertion of pre-processor include directives. User code inserted inside these comment delimiters is protected from being overwritten by Code Generator, if the user needs to subsequently change any of the Code Generator-generated code.

5.1 LCD Code Integration

API functions for the Okaya LCD display are provided with the RSK. Locate the files ascii.h, r_okaya_lcd.h, ascii.c, and r_okaya_lcd.c on the RSK Web Installer. These files can be found in the Tutorial project for e^2 studio. Copy these files into the C:\Workspace\CG_Tutorial\src directory. The files will be automatically added to the project as shown in **Figure 5-1**.

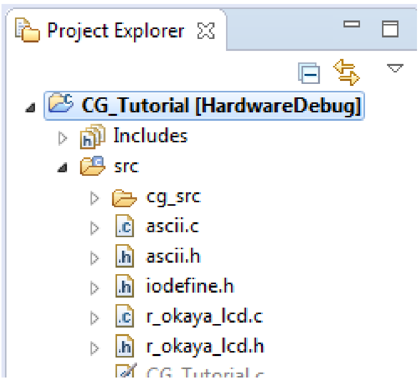


Figure 5-1 Adding files to the project

In the e[2] studio Project Tree, expand the 'src/cg_src' folder and open the file 'r_cg_userdefine.h' by double-clicking on it. Insert the following #defines in between the user code delimiter comments as shown below.

```
/* Start user code for function. Do not edit comment generated here */

#define TRUE            (1)
#define FALSE           (0)

/* End user code. Do not edit comment generated here */
```

In the same folder open the file 'r_cg_main.c' by double-clicking on it. Insert the following code in between the user code delimiter comments as shown below.

```
/* Start user code for include. Do not edit comment generated here */

#include "r_okaya_lcd.h"

/* End user code. Do not edit comment generated here */
```

Scroll down to the 'main' function and insert the highlighted code as shown below into the beginning of the user code area of the 'main' function:

```
void main(void)
{
    R_MAIN_UserInit();
    /* Start user code. Do not edit comment generated here */

    /* Initialize the debug LCD */
    R_LCD_Init();

    /* Displays the application name on the debug LCD */
    R_LCD_Display(0, (uint8_t *)" RSKRX24U ");
    R_LCD_Display(1, (uint8_t *)" Tutorial ");
    R_LCD_Display(2, (uint8_t *)" Press Any Switch ");
    while (1U)
    {
        ;
    }
    /* End user code. Do not edit comment generated here */
}
```

5.1.1 SPI Code

The Okaya LCD display is driven by the SPI Master that was configured using Code Generator in §4.3.5. In the e[2] studio Project Tree, open the file ‘r_cg_sci.h’ by double-clicking on it. Insert the following code in the user code area at the end of the file:

```
/* Start user code for function. Do not edit comment generated here */

MD_STATUS R_SCI9_SPIMasterTransmit(uint8_t * const tx_buf, const uint16_t tx_num);

/* End user code. Do not edit comment generated here */
```

Now, open the r_cg_sci_user.c file and insert the following code in the user area for global:

```
/* Start user code for global. Do not edit comment generated here */

/* Flag used locally to detect transmission complete */
static volatile uint8_t sci9_txdone;

/* End user code. Do not edit comment generated here */
```

Insert the following code in the transmit end call-back function for SCI9:

```
void r_sci9_callback_transmitend(void)
{
    /* Start user code. Do not edit comment generated here */
    sci9_txdone = TRUE;

    /* End user code. Do not edit comment generated here */
}
```

Now insert the following function in the user code area at the end of the file:

```
/* Start user code for adding. Do not edit comment generated here */

/********************************************************************************
* Function Name: R_SCI9_SPIMasterTransmit
* Description  : This function sends SPI9 data to slave device.
* Arguments    : tx_buf -
*                    transfer buffer pointer
*                tx_num -
*                    buffer size
* Return Value : status -
*                    MD_OK or MD_ARGERROR
********************************************************************************/
MD_STATUS R_SCI9_SPIMasterTransmit (uint8_t * const tx_buf, const uint16_t tx_num)
{
    MD_STATUS status = MD_OK;

    /* Clear the flag before initiating a new transmission */
    sci9_txdone = FALSE;

    /* Send the data using the API */
    status = R_SCI9_SPI_Master_Send(tx_buf, tx_num);

    /* Wait for the transmit end flag */
    while (FALSE == sci9_txdone)
    {
        /* Wait */
    }

    return (status);
}

/********************************************************************************
* End of function R_SCI9_SPIMasterTransmit
********************************************************************************/
```

This function uses the transmit end callback function to perform flow control on the SPI transmission to the LCD, and is used as the main API call in the LCD code module.

5.1.2 CMT Code

The LCD code needs to insert delays to meet the timing requirements of the display module. This is achieved using the dedicated timer which was configured using Code Generator in §4.3.3. Open the file r_cg_cmt.h and insert the following code in the user area for function at the end of the file:

```
/* Start user code for function. Do not edit comment generated here */

void R_CMT_MsDelay(const uint16_t millisec);

/* End user code. Do not edit comment generated here */
```

Open the file r_cg_cmt_user.c and insert the following code in the user area for global at the beginning of the file:

```
/* Start user code for global. Do not edit comment generated here */

static volatile uint8_t one_ms_delay_complete = FALSE;

/* End user code. Do not edit comment generated here */
```

Scroll down to the r_cmt_cmi0_interrupt function and insert the following line in the user code area:

```
static void r_cmt_cmi0_interrupt(void)
{
    /* Start user code. Do not edit comment generated here */

    one_ms_delay_complete = TRUE;

    /* End user code. Do not edit comment generated here */
}
```

Then insert the following function in the user code area at the end of the file:

```
/* Start user code for adding. Do not edit comment generated here */
/********************************************************************************
* Function Name: R_CMT_MsDelay
* Description  : Uses CMT0 to wait for a specified number of milliseconds
* Arguments    : uint16_t millisecs, number of milliseconds to wait
* Return Value : None
********************************************************************************/
void R_CMT_MsDelay (const uint16_t millisec)
{
    uint16_t ms_count = 0;

    do
    {
        R_CMT0_Start();
        while (FALSE == one_ms_delay_complete)
        {
            /* Wait */
        }
        R_CMT0_Stop();
        one_ms_delay_complete = FALSE;
        ms_count++;
    } while (ms_count < millisec);


}
/********************************************************************************
End of function R_CMT_MsDelay
********************************************************************************/
```

5.2 Additional include paths

Before the project can be built the compiler needs some additional include paths added. Select the CG_Tutorial project in the Project Explorer pane. Use the button in the toolbar to open the project settings. Navigate to 'C/C++ Build -> Settings ->Compiler -> Source and click the button as shown in **Figure 5-2**.

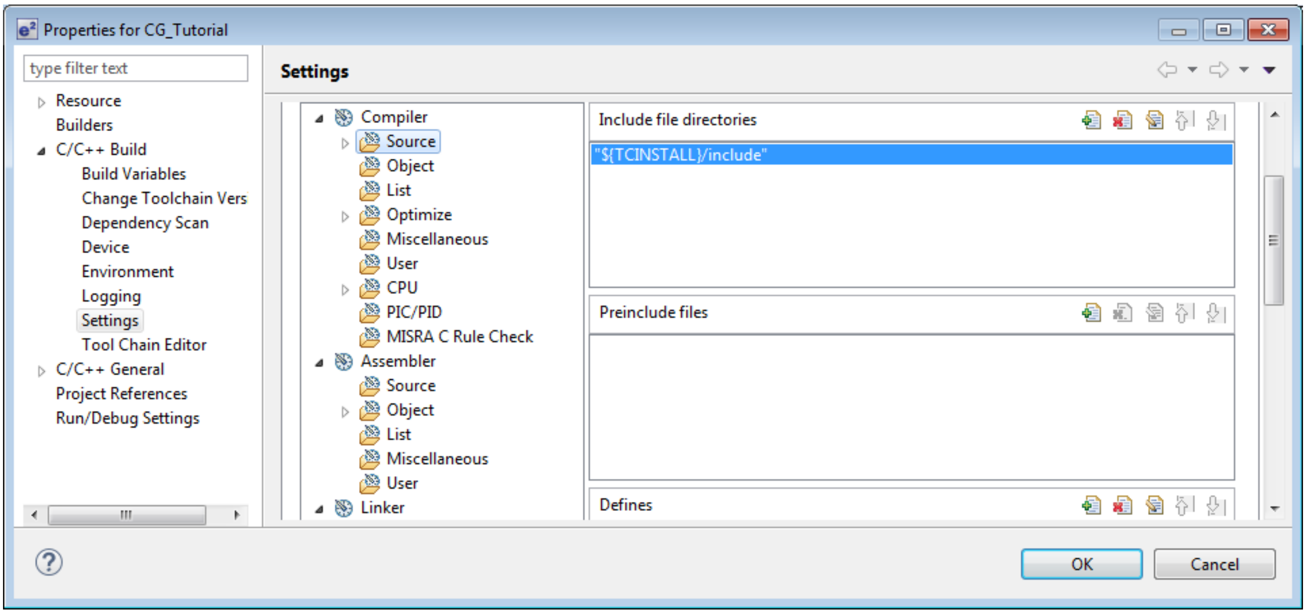


Figure 5-2 Adding additional search paths

In the 'Add directory path' dialog, click the 'Workspace' button and in the 'Folder selection' dialog browse to the 'CG_Tutorial/src' folder and click 'OK'. e² studio formats the path as show in **Figure 5-3** below.

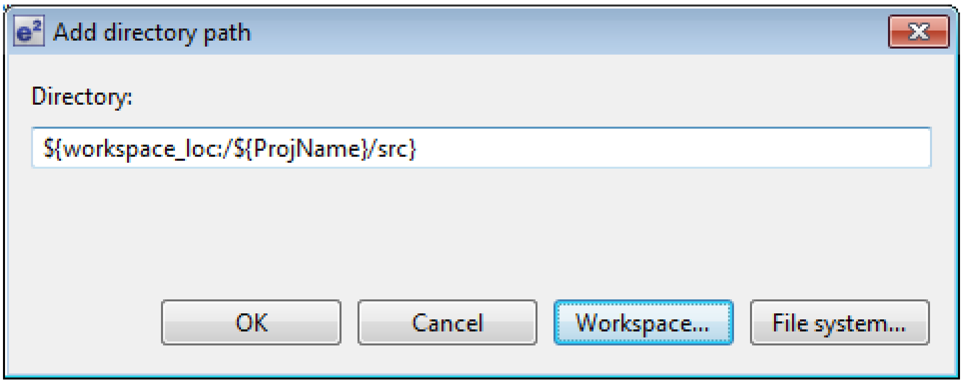


Figure 5-3 Adding workspace search path

Repeat the above steps to add the 'src/cg_src' workspace search path. Select 'Build Project' from the 'Project' menu, or use the button. e² studio will build the project with no errors.

The project may now be run using the debugger as described in §6. The program will display 'RSKRX24U Tutorial Press Any Switch' on 3 lines in the LCD display.

5.3 Switch Code Integration

API functions for user switch control are provided with the RSK. Locate the files rskrx24udef.h, r_rsk_switch.h and r_rsk_switch.c on the RSK Web Installer. These files can be found in the Tutorial project for e[2] studio. Copy these files into the C:\Workspace\CG_Tutorial\src directory. Import these three files into the project in the same way as the LCD files.

The switch code uses interrupt code in the files r_cg_icu.h, r_cg_icu.c and r_cg_icu_user.c and timer code in the files r_cg_cmt.h, r_cg_cmt.c and r_cg_cmt_user.c, as described in §4.3.2 and §4.3.3. It is necessary to provide additional user code in these files to implement the switch press/release detection and de-bouncing required by the API functions in r_rsk_switch.c.

5.3.1 Interrupt Code

In the e[2] studio Project Tree, expand the 'src/cg_src' folder and open the file 'r_cg_icu.h' by double-clicking on it. Insert the following code in the user code area at the end of the file:

```
/* Start user code for function. Do not edit comment generated here */

/* Function prototypes for detecting and setting the edge trigger of ICU_IRQ */
uint8_t R_ICU_IRQIsFallingEdge(const uint8_t irq_no);
void R_ICU_IRQSetFallingEdge(const uint8_t irq_no, const uint8_t set_f_edge);
void R_ICU_IRQSetRisingEdge(const uint8_t irq_no, const uint8_t set_r_edge);

/* End user code. Do not edit comment generated here */
```

Now, open the r_cg_icu.c file and insert the following code in the user code area at the end of the file:

```
/* Start user code for adding. Do not edit comment generated here */

/***********************************************************************
* Function Name: R_ICU_IRQIsFallingEdge
* Description  : This function returns 1 if the specified ICU_IRQ is set to
*                falling edge triggered, otherwise 0.
* Arguments    : uint8_t irq_no
* Return Value : 1 if falling edge triggered, 0 if not
***********************************************************************/
uint8_t R_ICU_IRQIsFallingEdge (const uint8_t irq_no)
{
    uint8_t falling_edge_trig = 0x0;

    if (ICU.IRQCR[irq_no].BYTE & _04_ICU_IRQ_EDGE_FALLING)
    {
        falling_edge_trig = 1;
    }

    return (falling_edge_trig);

}

/***********************************************************************
* End of function R_ICU_IRQIsFallingEdge
***********************************************************************/

/***********************************************************************
* Function Name: R_ICU_IRQSetFallingEdge
* Description  : This function sets/clears the falling edge trigger for the
*                specified ICU_IRQ.
* Arguments    : uint8_t irq_no
*                uint8_t set_f_edge, 1 if setting falling edge triggered, 0 if
*                clearing
* Return Value : None
***********************************************************************/
void R_ICU_IRQSetFallingEdge (const uint8_t irq_no, const uint8_t set_f_edge)
{
    if (1 == set_f_edge)
    {
        ICU.IRQCR[irq_no].BYTE |= _04_ICU_IRQ_EDGE_FALLING;
    }
    else
    {
        ICU.IRQCR[irq_no].BYTE &= (uint8_t) ~_04_ICU_IRQ_EDGE_FALLING;
    }
}

/***********************************************************************
* End of function R_ICU_IRQSetFallingEdge
***********************************************************************/

/***********************************************************************
* Function Name: R_ICU_IRQSetRisingEdge
* Description  : This function sets/clear the rising edge trigger for the
*                specified ICU_IRQ.
* Arguments    : uint8_t irq_no
*                uint8_t set_r_edge, 1 if setting rising edge triggered, 0 if
*                clearing
* Return Value : None
***********************************************************************/
void R_ICU_IRQSetRisingEdge (const uint8_t irq_no, const uint8_t set_r_edge)
{
    if (1 == set_r_edge)
    {
        ICU.IRQCR[irq_no].BYTE |= _08_ICU_IRQ_EDGE_RISING;
    }
    else
    {
        ICU.IRQCR[irq_no].BYTE &= (uint8_t) ~_08_ICU_IRQ_EDGE_RISING;
    }
}

/***********************************************************************
* End of function R_ICU_IRQSetRisingEdge
***********************************************************************/

/* End user code. Do not edit comment generated here */
```

Open the r_cg_icu_user.c file and insert the following code in the user code area for include near the top of the file:

```
/* Start user code for include. Do not edit comment generated here */

/* Defines switch callback functions required by interrupt handlers */
#include "r_rsk_switch.h"

/* End user code. Do not edit comment generated here */
```

In the same file insert the following code in the user code area inside the function r_icu_irq0_interrupt:

```
    /* Start user code. Do not edit comment generated here */

    /* Switch 1 callback handler */
    R_SWITCH_IsrCallback1();

    /* End user code. Do not edit comment generated here */
```

In the same file insert the following code in the user code area inside the function r_icu_irq4_interrupt:

```
    /* Start user code. Do not edit comment generated here */

    /* Switch 2 callback handler */
    R_SWITCH_IsrCallback2();

    /* End user code. Do not edit comment generated here */
```

5.3.2 De-bounce Timer Code

Open the r_cg_cmt_user.c file and insert the following code in the user code area for include near the top of the file:

```
/* Start user code for include. Do not edit comment generated here */

/* Defines switch callback functions required by interrupt handlers */
#include "r_rsk_switch.h"

/* End user code. Do not edit comment generated here */
```

In the same file insert the following code in the user code area inside the function r_cmt_cmi1_interrupt:

```
    /* Start user code. Do not edit comment generated here */

    /* Stop this timer - we start it again in the de-bounce routines */
    R_CMT1_Stop();

    /* Call the de-bounce call back routine */
    R_SWITCH_DebounceIsrCallback();

    /* End user code. Do not edit comment generated here */
```

In the same file insert the following code in the user code area inside the function r_cmt_cmi2_interrupt:

```
    /* Start user code. Do not edit comment generated here */

    /* Stop this timer - we start it again in the de-bounce routines */
    R_CMT2_Stop();

    /* Call the de-bounce call back routine */
    R_SWITCH_DebounceIsrCallback();

    /* End user code. Do not edit comment generated here */
```

5.3.3 Main Switch and ADC Code

In this part of the tutorial we add the code to act on the switch presses to activate A/D conversions and display the result on the LCD. In §4.3.4 we configured the ADC to be triggered from the ADTRG0# pin, SW3. In this code, we also perform software triggered A/D conversion from the user switches SW1 and SW2, by reconfiguring the ADC trigger source on-the-fly once an SW1 or SW2 press is detected.

In the e[2] studio Project Tree open the file 'r_cg_userdefine.h'. Insert the following code the user code area, resulting in the code shown below

```
/* Start user code for function. Do not edit comment generated here */

#define TRUE            (1)
#define FALSE           (0)

extern volatile uint8_t g_adc_trigger;

/* End user code. Do not edit comment generated here */
```

Open the file 'r_cg_main.c' and insert #include "r_rsk_switch.h" in the user code area for include, resulting in the code shown below:

```
/* Start user code for include. Do not edit comment generated here */

#include "r_okaya_lcd.h"
#include "r_rsk_switch.h"

/* End user code. Do not edit comment generated here */
```

Next add the switch module initialization function call highlighted in the user code area inside the main function, resulting in the code shown below:

```
void main(void)
{
    R_MAIN_UserInit();
    /* Start user code. Do not edit comment generated here */

    /* Initialize the switch module */
    R_SWITCH_Init();

    /* Initialize the debug LCD */
    R_LCD_Init();

    /* Displays the application name on the debug LCD */
    R_LCD_Display(0, (uint8_t *)" RSKRX24U ");
    R_LCD_Display(1, (uint8_t *)" Tutorial ");
    R_LCD_Display(2, (uint8_t *)" Press Any Switch ");

    while (1U)
    {
        ;
    }
    /* End user code. Do not edit comment generated here */
}
```

In the same file, insert the declarations in the user code area for global, resulting in the code shown below:

```
/* Start user code for global. Do not edit comment generated here */

/* Variable for flagging user requested ADC conversion */
volatile uint8_t g_adc_trigger = FALSE;

/* Prototype declaration for cb_switch_press */
static void cb_switch_press (void);

/* Prototype declaration for get_adc */
static uint16_t get_adc(void);

/* Prototype declaration for lcd_display_adc */
static void lcd_display_adc (const uint16_t adc_result);

/* End user code. Do not edit comment generated here */
```

Next add the highlighted code below in the user code area inside the main function and the code inside the while loop, resulting in the code shown below:

```
void main(void)
{
    R_MAIN_UserInit();
    /* Start user code. Do not edit comment generated here */

    /* Initialize the switch module */
    R_SWITCH_Init();

    /* Set the call back function when SW1 or SW2 is pressed */
    R_SWITCH_SetPressCallback(cb_switch_press);

    /* Initialize the debug LCD */
    R_LCD_Init ();

    /* Displays the application name on the debug LCD */
    R_LCD_Display(0, (uint8_t *)" RSKRX24U ");
    R_LCD_Display(1, (uint8_t *)" Tutorial ");
    R_LCD_Display(2, (uint8_t *)" Press Any Switch ");

    /* Start the A/D converter */
    R_S12AD0_Start();

    while (1U)
    {
        uint16_t adc_result;

        /* Wait for user requested A/D conversion flag to be set (SW1 or SW2) */
        if (TRUE == g_adc_trigger)
        {
            /* Call the function to perform an A/D conversion */
            adc_result = get_adc();

            /* Display the result on the LCD */
            lcd_display_adc(adc_result);

            /* Reset the flag */
            g_adc_trigger = FALSE;
        }

        /* SW3 is directly wired into the ADTRG0n pin so will
           cause the interrupt to fire */
        else if (TRUE == g_adc_complete)
        {
            /* Get the result of the A/D conversion */
            R_S12AD0_Get_ValueResult(ADCHANNEL0, &adc_result);

            /* Display the result on the LCD */
            lcd_display_adc(adc_result);

            /* Reset the flag */
            g_adc_complete = FALSE;
        }
        else
        {
            /* do nothing */
        }
    }

    /* End user code. Do not edit comment generated here */
}
```

Then add the definition for the switch call-back, get_adc and lcd_display_adc functions in the user code area for adding at the end of the file, as shown below:

```
/* Start user code for adding. Do not edit comment generated here */
```

```
/******************************************************************************
* Function Name : cb_switch_press
* Description   : Switch press callback function. Sets g_adc_trigger flag.
* Argument      : none
* Return value  : none
******************************************************************************/
static void cb_switch_press (void)
{
    /* Check if switch 1 or 2 was pressed */
    if (g_switch_flag & (SWITCHPRESS_1 | SWITCHPRESS_2))
    {
        /* Set the flag indicating a user requested A/D conversion is required */
        g_adc_trigger = TRUE;

        /* Clear flag */
        g_switch_flag = 0x0;
    }
}
/******************************************************************************
* End of function cb_switch_press
******************************************************************************/

/******************************************************************************
* Function Name : get_adc
* Description   : Reads the ADC result, converts it to a string and displays
*                 it on the LCD panel.
* Argument      : none
* Return value  : uint16_t adc value
******************************************************************************/
static uint16_t get_adc (void)
{
    /* A variable to retrieve the adc result */
    uint16_t adc_result;

    /* Stop the A/D converter being triggered from the pin ADTRG0n  */
    R_S12AD0_Stop();

    /* Start a conversion */
    R_S12AD0_SWTriggerStart();

    /* Wait for the A/D conversion to complete */
    while (FALSE == g_adc_complete)
    {
        /* Wait */
    }

    /* Stop conversion */
    R_S12AD0_SWTriggerStop();

    /* Clear ADC flag */
    g_adc_complete = FALSE;

    R_S12AD0_Get_ValueResult(ADCHANNEL0, &adc_result);

    /* Set AD conversion start trigger source back to ADTRG0n pin */
    R_S12AD0_Start();


    return (adc_result);
}
/******************************************************************************
* End of function get_adc
******************************************************************************/
```

```
/*******************************************************************************
* Function Name : lcd_display_adc
* Description   : Converts adc result to a string and displays
*                 it on the LCD panel.
* Argument      : uint16_t adc result
* Return value  : none
*******************************************************************************/
static void lcd_display_adc (const uint16_t adc_result)
{
    /* Declare a temporary variable */
    uint8_t a;

    /* Declare temporary character string */
    char    lcd_buffer[11] = " ADC: XXXH";

    /* Convert ADC result into a character string, and store in the local.
       Casting to ensure use of correct data type. */
    a = (uint8_t)((adc_result & 0x0F00) >> 8);
    lcd_buffer[6] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));
    a = (uint8_t)((adc_result & 0x00F0) >> 4);
    lcd_buffer[7] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));
    a = (uint8_t)(adc_result & 0x000F);
    lcd_buffer[8] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));

    /* Display the contents of the local string lcd_buffer */
    R_LCD_Display(3, (uint8_t *)lcd_buffer);

}
/*******************************************************************************
* End of function lcd_display_adc
*******************************************************************************/
```

Open the file 'r_cg_s12ad.h' by double-clicking on it. Insert the following code in the user code area for function, resulting in the code shown below:

```
/* Start user code for function. Do not edit comment generated here */

/* Flag indicates when A/D conversion is complete */
extern volatile uint8_t g_adc_complete;

/* Functions for starting and stopping software triggered A/D conversion */
void R_S12AD0_SWTriggerStart(void);
void R_S12AD0_SWTriggerStop(void);

/* End user code. Do not edit comment generated here */
```

Open the file 'r_cg_s12ad.c' by double-clicking on it. Insert the following code in the user code area for adding at the end of the file, as shown below:

```
/* Start user code for adding. Do not edit comment generated here */

/*******************************************************************************
* Function Name: R_S12AD0_SWTriggerStart
* Description  : This function starts the AD converter.
* Arguments    : None
* Return Value : None
*******************************************************************************/
void R_S12AD0_SWTriggerStart(void)
{
    IR(S12AD, S12ADI) = 0U;
    IEN(S12AD, S12ADI) = 1U;
    S12AD.ADCSR.BIT.ADST = 1U;
}
/*******************************************************************************
End of function R_S12AD0_SWTriggerStart
*******************************************************************************/
```

```
/*******************************************************************************
* Function Name: R_S12AD0_SWTriggerStop
* Description  : This function stops the AD converter.
* Arguments    : None
* Return Value : None
*******************************************************************************/
void R_S12AD0_SWTriggerStop(void)
{
    S12AD.ADCSR.BIT.ADST = 0U;
    IEN(S12AD, S12ADI) = 0U;
    IR(S12AD, S12ADI) = 0U;
}
/*******************************************************************************
End of function R_S12AD0_SWTriggerStop
*******************************************************************************/

/* End user code. Do not edit comment generated here */
```

Open the file r_cg_s12ad_user.c and insert the following code in the user code area for global, resulting in the code shown below:

```
/* Start user code for global. Do not edit comment generated here */

/* Flag indicates when A/D conversion is complete */
volatile uint8_t g_adc_complete;

/* End user code. Do not edit comment generated here */
```

Insert the following code in the user code area of the r_s12ad0_interrupt function, resulting in the code shown below:

```
static void r_s12ad0_interrupt(void)
{
    /* Start user code. Do not edit comment generated here */

    g_adc_complete = TRUE;

    /* End user code. Do not edit comment generated here */
}
```

Select 'Build Project' from the 'Project' menu, or use the  button. e² studio will build the project with no errors.

The project may now be run using the debugger as described in §6. When any switch is pressed, the program will perform an A/D conversion of the voltage level on the ADPOT line and display the result on the LCD panel. Return to this point in the Tutorial to add the UART user code.

5.4 Debug Code Integration

API functions for trace debugging via the RSK serial port are provided with the RSK. Locate the files r_rsk_debug.h and r_rsk_debug.c on the RSK Web Installer. These files can be found in the RSKRX24U_Tutorial project for e² studio. Copy these files into the C:\Workspace\CG_Tutorial\src directory. Import these two files into the project in the same way as the LCD files.

In the r_rsk_debug.h file, ensure the following macro definition is included:

```
/* Macro for definition of serial debug transmit function - user edits this */
#define SERIAL_DEBUG_WRITE (R_SCI1_AsyncTransmit)
```

This macro is referenced in the r_rsk_debug.c file and allows easy re-direction of debug output if a different debug interface is used.

5.5 UART Code Integration

5.5.1 SCI Code

In the e² studio Project Tree, expand the 'src/cg_src' folder and open the file 'r_cg_sci.h' by double-clicking on it. Insert the following code in the user code area at the end of the file:

```
/* Start user code for function. Do not edit comment generated here */

/* Exported functions used to transmit a number of bytes and wait for completion */
MD_STATUS R_SCI9_SPIMasterTransmit(uint8_t * const tx_buf, const uint16_t tx_num);
MD_STATUS R_SCI1_AsyncTransmit(uint8_t * const tx_buf, const uint16_t tx_num);

/* Character is used to receive key presses from PC terminal */
extern uint8_t g_rx_char;

/* Flag used to control transmission to PC terminal */
extern volatile uint8_t g_tx_flag;

/* End user code. Do not edit comment generated here */
```

Open the file 'r_cg_sci_user.c. Insert the following code in the user area for global near the beginning of the file:

```
/* Start user code for global. Do not edit comment generated here */

/* Global used to receive a character from the PC terminal */
uint8_t g_rx_char;

/* Flag used to control transmission to PC terminal */
volatile uint8_t g_tx_flag = FALSE;

/* Flag used locally to detect transmission complete */
static volatile uint8_t sci9_txdone;
static volatile uint8_t sci1_txdone;

/* End user code. Do not edit comment generated here */
```

In the same file, insert the following code in the user code area inside the r_sci1_callback_transmitend function:

```
static void r_sci1_callback_transmitend(void)
{
    /* Start user code. Do not edit comment generated here */
    sci1_txdone = TRUE;

    /* End user code. Do not edit comment generated here */
}
```

In the same file, insert the following code in the user code area inside the r_sci1_callback_receiveend function:

```
void r_sci1_callback_receiveend(void)
{
    /* Start user code. Do not edit comment generated here */

    /* Check the contents of g_rx_char */
    if (('c' == g_rx_char) || ('C' == g_rx_char))
    {
        g_adc_trigger = TRUE;
    }

    /* Set up SCI1 receive buffer and callback function again */
    R_SCI1_Serial_Receive((uint8_t *)&g_rx_char, 1);

    /* End user code. Do not edit comment generated here */
}
```

At the end of the file, in the user code area for adding, add the following function definition:

```
/*******************************************************************************
* Function Name: R_SCI1_AsyncTransmit
* Description  : This function sends SCI1 data and waits for the transmit end flag.
* Arguments    : tx_buf -
*                    transfer buffer pointer
*                tx_num -
*                    buffer size
* Return Value : status -
*                    MD_OK or MD_ARGERROR
*******************************************************************************/
MD_STATUS R_SCI1_AsyncTransmit (uint8_t * const tx_buf, const uint16_t tx_num)
{
    MD_STATUS status = MD_OK;

    /* clear the flag before initiating a new transmission */
    sci1_txdone = FALSE;

    /* Send the data using the API */
    status = R_SCI1_Serial_Send(tx_buf, tx_num);

    /* Wait for the transmit end flag */
    while (FALSE == sci1_txdone)
    {
        /* Wait */
    }
    return (status);
}

/*******************************************************************************
* End of function R_SCI1_AsyncTransmit
*******************************************************************************/
```

5.5.2 Main UART code

Open the file ‘r_cg_main.c’. Add the following declaration to the user code area for include near the top of the file:

```
/* Start user code for include. Do not edit comment generated here */

#include "r_okaya_lcd.h"
#include "r_rsk_switch.h"
#include "r_rsk_debug.h"

/* End user code. Do not edit comment generated here */
```

Add the following declaration to the user code area for global near the top of the file:

```
/* Start user code for global. Do not edit comment generated here */
/* Variable for flagging user requested ADC conversion */
volatile uint8_t g_adc_trigger = FALSE;

/* Prototype declaration for cb_switch_press */
static void cb_switch_press (void);

/* Prototype declaration for get_adc */
static uint16_t get_adc(void);

/* Prototype declaration for lcd_display_adc */
static void lcd_display_adc (const uint16_t adc_result);

/* Prototype declaration for uart_display_adc */
static void uart_display_adc(const uint8_t adc_count, const uint16_t adc_result);

/* Variable to store the A/D conversion count for user display */
static uint8_t adc_count = 0;

/* End user code. Do not edit comment generated here */
```

Add the following highlighted code to the user code area in the main function:

```
void main(void)
{
    R_MAIN_UserInit();
    /* Start user code. Do not edit comment generated here */

    /* Initialize the switch module */
    R_SWITCH_Init();

    /* Set the call back function when SW1 or SW2 is pressed */
    R_SWITCH_SetPressCallback(cb_switch_press);

    /* Initialize the debug LCD */
    R_LCD_Init();

    /* Displays the application name on the debug LCD */
    R_LCD_Display(0, (uint8_t *)" RSKRX24U ");
    R_LCD_Display(1, (uint8_t *)" Tutorial ");
    R_LCD_Display(2, (uint8_t *)" Press Any Switch ");

    /* Start the A/D converter */
    R_S12AD0_Start();

    /* Set up SCI1 receive buffer and callback function */
    R_SCI1_Serial_Receive((uint8_t *)&g_rx_char, 1);

    /* Enable SCI1 operations */
    R_SCI1_Start();

    while (1U)
    {
        uint16_t adc_result;

        /* Wait for user requested A/D conversion flag to be set (SW1 or SW2) */
        if (TRUE == g_adc_trigger)
        {
            /* Call the function to perform an A/D conversion */
            adc_result = get_adc();

            /* Display the result on the LCD */
            lcd_display_adc(adc_result);

            /* Increment the adc_count */
            if (16 == (++adc_count))
            {
                adc_count = 0;
            }

            /* Send the result to the UART */
            uart_display_adc(adc_count, adc_result);
            /* Reset the flag */
            g_adc_trigger = FALSE;
        }

        /* SW3 is directly wired into the ADTRG0n pin so will
           cause the interrupt to fire */
        else if (TRUE == g_adc_complete)
        {
            /* Get the result of the A/D conversion */
            R_S12AD0_Get_ValueResult(ADCHANNEL0, &adc_result);

            /* Display the result on the LCD */
            lcd_display_adc(adc_result);

            /* Increment the adc_count */
            if (16 == (++adc_count))
            {
                adc_count = 0;
            }

            /* Send the result to the UART */
            uart_display_adc(adc_count, adc_result);
            /* Reset the flag */
            g_adc_complete = FALSE;
        }
        else
        {
            /* do nothing */
        }
    }
    /* End user code. Do not edit comment generated here */
}
```

Then, add the following function definition in the user code area at the end of the file:

```
/*******************************************************************************
* Function Name : uart_display_adc
* Description   : Converts adc result to a string and sends it to the UART1.
* Argument      : uint8_t : adc_count
*                 uint16_t: adc result
* Return value  : none
*******************************************************************************/
static void uart_display_adc (const uint8_t adc_count, const uint16_t adc_result)
{
    /* Declare a temporary variable */
    char a;

    /* Declare temporary character string */
    static char uart_buffer[] = "ADC xH Value: xxxH\r\n";

    /* Convert ADC result into a character string, and store in the local.
       Casting to ensure use of correct data type. */
    a = (char)(adc_count & 0x000F);
    uart_buffer[4] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));
    a = (char)((adc_result & 0x0F00) >> 8);
    uart_buffer[14] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));
    a = (char)((adc_result & 0x00F0) >> 4);
    uart_buffer[15] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));
    a = (char)(adc_result & 0x000F);
    uart_buffer[16] = (char)((a < 0x0A) ? (a + 0x30) : (a + 0x37));

    /* Send the string to the UART */
    R_DEBUG_Print(uart_buffer);

}

/*******************************************************************************
* End of function uart_display_adc
*******************************************************************************/
```

Select 'Build Project' from the 'Build' menu. e^2 studio will build the project with no errors.

The project may now be run using the debugger as described in §6. Connect the RSK G1CUSB0 port to a USB port on a PC. If this is the first time the RSK has been connected to the PC then a device driver will be installed automatically. Open Device Manager, the virtual COM port will now appear under 'Port (COM & LPT)' as 'RSK USB Serial Port (COMx)', where x is a number.

Open a terminal program, such as HyperTerminal, on the PC with the same settings as for SCI1 (see §4.3.5). When any switch is pressed, or when 'c' is sent via the COM port, the program will perform an A/D conversion of the voltage level on the ADPOT line and display the result on the LCD panel and send the result to the PC terminal program via the SCI1. Return to this point in the Tutorial to add the LED user code.

5.6 LED Code Integration

Open the file 'r_cg_main.c'. Add the following declaration to the user code area for include near the top of the file:

```
/* Start user code for include. Do not edit comment generated here */

#include "r_okaya_lcd.h"
#include "r_rsk_switch.h"
#include "r_rsk_debug.h"
#include "rskrx24udef.h"

/* End user code. Do not edit comment generated here */
```

Add the following declaration to the user code area for global near the top of the file:

```
/* Start user code for global. Do not edit comment generated here */
/* Variable for flagging user requested ADC conversion */
volatile uint8_t g_adc_trigger = FALSE;

/* Prototype declaration for cb_switch_press */
static void cb_switch_press (void);

/* Prototype declaration for get_adc */
static uint16_t get_adc(void);

/* Prototype declaration for lcd_display_adc */
static void lcd_display_adc (const uint16_t adc_result);

/* Prototype declaration for uart_display_adc */
static void uart_display_adc(const uint8_t adc_count, const uint16_t adc_result);

/* Variable to store the A/D conversion count for user display */
static uint8_t adc_count = 0;

/* Prototype declaration for led_display_count */
static void led_display_count(const uint8_t count);

/* End user code. Do not edit comment generated here */
```

Add the following highlighted code to the user code area in the main function:

```
void main(void)
{
    R_MAIN_UserInit();
    /* Start user code. Do not edit comment generated here */
    /* Initialize the switch module */
    R_SWITCH_Init();

    /* Set the call back function when SW1 or SW2 is pressed */
    R_SWITCH_SetPressCallback(cb_switch_press);
    /* Initialize the debug LCD */
    R_LCD_Init();
    /* Displays the application name on the debug LCD */
    R_LCD_Display(0, (uint8_t *)" RSKRX24U ");
    R_LCD_Display(1, (uint8_t *)" Tutorial ");
    R_LCD_Display(2, (uint8_t *)" Press Any Switch ");
    /* Start the A/D converter */
    R_S12AD0_Start();
    /* Set up SCI1 receive buffer and callback function */
    R_SCI1_Serial_Receive((uint8_t *)&g_rx_char, 1);
    /* Enable SCI1 operations */
    R_SCI1_Start();
    while (1U)
    {
        uint16_t adc_result;
        /* Wait for user requested A/D conversion flag to be set (SW1 or SW2) */
        if (TRUE == g_adc_trigger)
        {
            /* Call the function to perform an A/D conversion */
            adc_result = get_adc();
            /* Display the result on the LCD */
            lcd_display_adc(adc_result);
            /* Increment the adc_count and display using the LEDs */
            if (16 == (++adc_count))
            {
                adc_count = 0;
            }
            led_display_count(adc_count);
            /* Send the result to the UART */
            uart_display_adc(adc_count, adc_result);
            /* Reset the flag */
            g_adc_trigger = FALSE;
        }

        /* SW3 is directly wired into the ADTRG0n pin so will
           cause the interrupt to fire */
        else if (TRUE == g_adc_complete)
        {
            /* Get the result of the A/D conversion */
            R_S12AD0_Get_ValueResult(ADCHANNEL0, &adc_result);

            /* Display the result on the LCD */
            lcd_display_adc(adc_result);
            /* Increment the adc_count and display using the LEDs */
            if (16 == (++adc_count))
            {
                adc_count = 0;
            }
            led_display_count(adc_count);
            /* Send the result to the UART */
            uart_display_adc(adc_count, adc_result);
            /* Reset the flag */
            g_adc_complete = FALSE;
        }
        else
        {
            /* do nothing */
        }
    }

    /* End user code. Do not edit comment generated here */
}
```

Then, add the following function definition in the user code area at the end of the file:

```
/******************************************************************************
* Function Name : led_display_count
* Description   : Converts count to binary and displays on 4 LEDS0-3
* Argument      : uint8_t count
* Return value  : none
******************************************************************************/
static void led_display_count (const uint8_t count)
{
    /* Set LEDs according to lower nibble of count parameter */
    LED0 = (uint8_t)((count & 0x01) ? LED_ON : LED_OFF);
    LED1 = (uint8_t)((count & 0x02) ? LED_ON : LED_OFF);
    LED2 = (uint8_t)((count & 0x04) ? LED_ON : LED_OFF);
    LED3 = (uint8_t)((count & 0x08) ? LED_ON : LED_OFF);
}
/******************************************************************************
* End of function led_display_count
******************************************************************************/
```

```
/* End user code. Do not edit comment generated here */
```

Select 'Build Project' from the 'Build' menu, or use the  button. e^2 studio will build the project with no errors.

The project may now be run using the debugger as described in §6. The code will perform the same but now the LEDs will display the adc_count in binary form.

6. Debugging the Project

In the Project Explorer pane, ensure that the 'CG_Tutorial' project is selected. To enter the debug configurations, click upon the arrow next to the debug button and select 'Debug Configuration'. In order to run the project there are two setting under 'Renesas GDB Hardware Debugging' -> 'Debugger' -> 'Connection Settings' that need modifying.
Ensure that in debug configuration that the 'Power Target From The Emulator(MAX 200mA)' is set to Yes , and the 'Extal Frequency' is set to the correct frequency, this can be found from the device schematics (in the case of RSKRX24U the setting should be 20.0000).
For more information on powering the RSKRX24U please refer to the Usermanual.

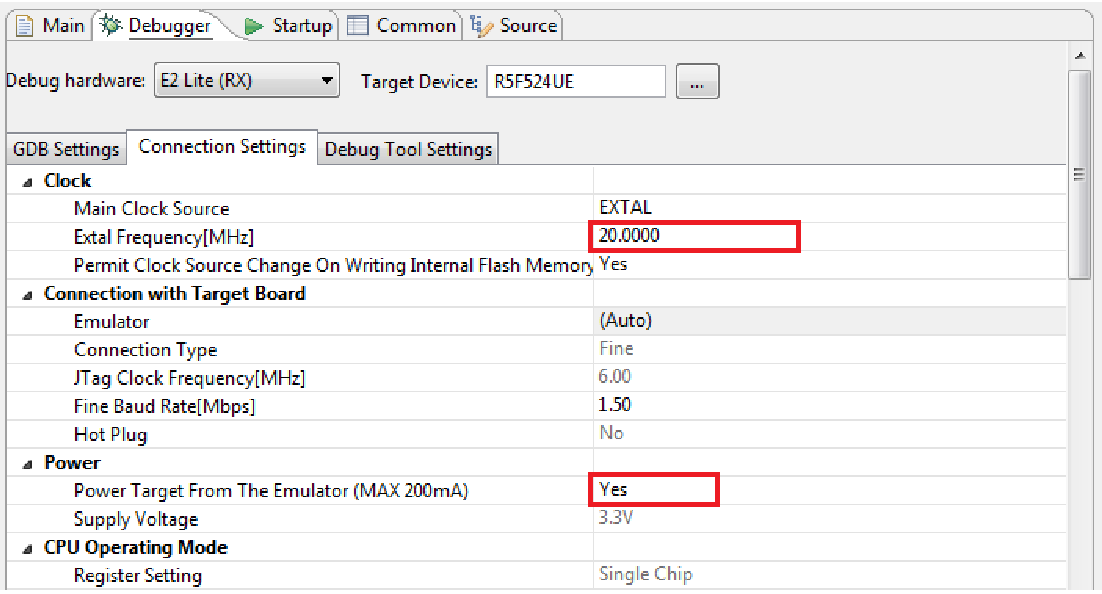


Figure 6-1 Debug Configurations

Connect the E2 Lite to the PC and the RSK E1 connector. Connect the Pmod LCD to the PMOD1 connector. In the Project Explorer pane, ensure that the 'CG_Tutorial' project is selected. To debug the project, click the button. The dialog shown in **Figure 6-2** will be displayed.

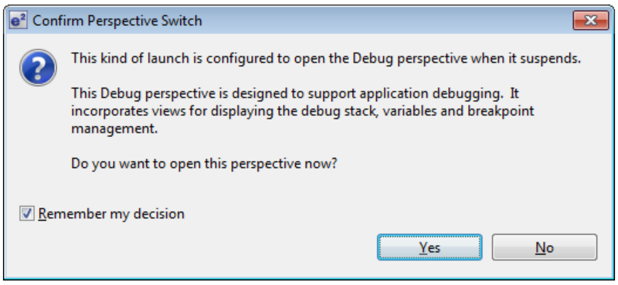


Figure 6-2 Perspective Switch Dialog

Click Remember my decision to skip this dialog later. Click 'YES' to confirm that the debug window perspective will be used. The debugger will start up and the code will stop at the Code Generator function 'PowerOn_Reset_PC' as shown in **Figure 6-3**.

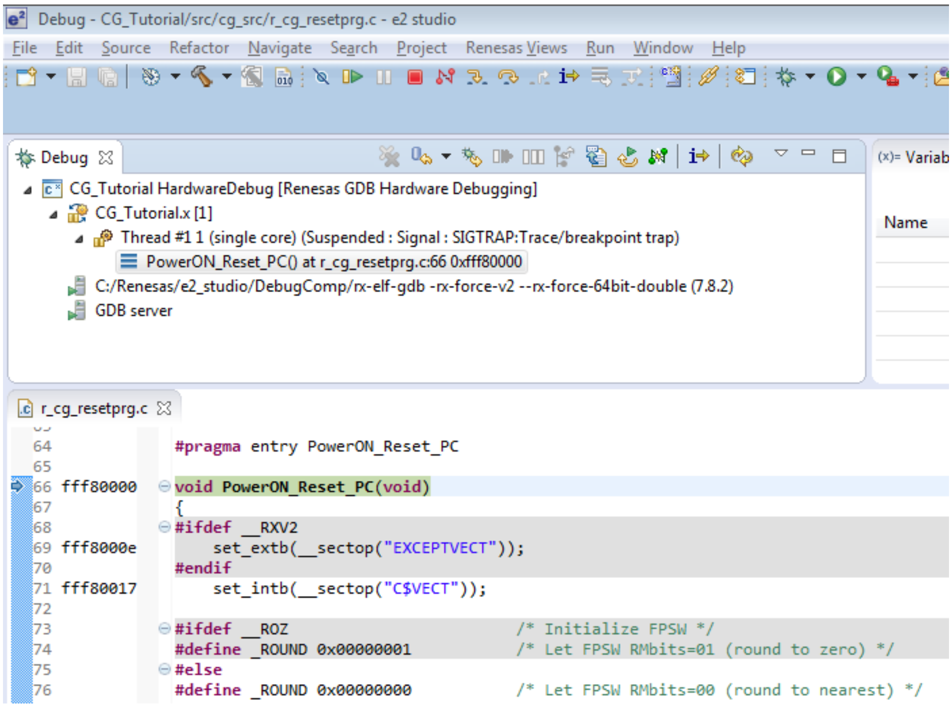


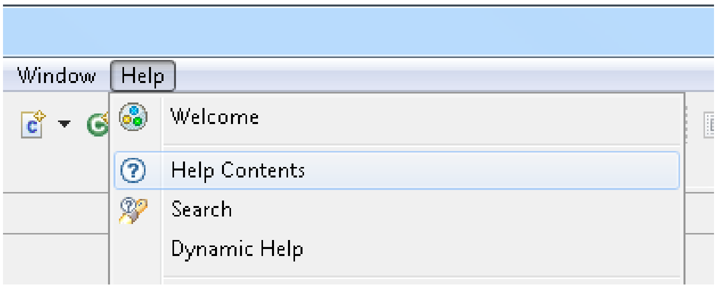
Figure 6-3 Debugger start up screen

For more information on the e² studio debugger refer to the Tutorial manual. To run the code click the button. The debugger will stop again at the beginning of the main function. Press again to run the code.

7. Additional Information

Technical Support

For details on how to use e[2] studio, refer to the help file by opening e[2] studio, then selecting Help > Help Contents from the menu bar.



For information about the RX24U group microcontroller refer to the RX24U Group Hardware Manual.

For information about the RX assembly language, refer to the RX Family Software Manual.

Technical Contact Details

Please refer to the contact details listed in section 8 of the "Quick Start Guide".

General information on Renesas microcontrollers can be found on the Renesas website at:
https://www.renesas.com/

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