User's Manual

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RL78/G1G Group

Renesas Starter Kit Code Generator Tutorial Manual For CS+

RENESAS MCU
RL78 Family / RL78/G1X 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 Code Generator for RL78 together with the CS+ 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 CS+, but does not intend to be a complete guide to software development on the RSK platform. Further details regarding operating the RL78/G1G 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 RL78/G1G 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.	RSKRL78G1G User's Manual	R20UT3022EG
Tutorial Manual	Provides a guide to setting up RSK environment, running sample code and debugging programs.	RSKRL78G1G Tutorial Manual	R20UT3019EG
Code Generator Tutorial	Provides a guide to code generation and importing into the CS+ IDE.	RSKRL78G1G Code Generator Tutorial Manual	R20UT3021EG
Quick Start Guide	Provides simple instructions to setup the RSK and run the first sample, on a single A4 sheet.	RSKRL78G1G Quick Start Guide	R20UT3020EG
Schematics	Full detail circuit schematics of the RSK.	RSKRL78G1G Schematics	R20UT3017EG
Hardware Manual	Provides technical details of the RL78/G1G microcontroller.	RL78/G1G Group, User's Manual: Hardware	R01UH0499EJ

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	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
Pmod™	This is a Digilent Pmod™ Compatible connector. Pmod™ is registered to Digilent Inc. Digilent-Pmod_Interface_Specification
PLL	Phase-locked Loop
RAM	Random Access Memory
ROM	Read Only Memory
RSK+	Renesas Starter Kit+
RTC	Realtime 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 CS+ IDE Code Generator plug in to create a working project for the RSK platform.

1.2 Features

This RSK tutorial guides the user through creating a project to evaluate the following features:

- Project creation with CS+,
- 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 RL78 family together with the CS+ IDE to create a working project for the RSK platform. The tutorials help explain the following:

- Project generation using the CS+,
- Detailed use of the Code Generator plug in for CS+,
- Integration with custom code,
- Building and running the project.

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

- ‘DefaultBuild’ is a project with debug support and optimisation level set to two.
- ‘Debug’ is a project built with the debugger support included. Optimisation is set to zero.
- ‘Release’ is a project with optimised compile options, producing code suitable for release in a product. Optimisation is set to two.

These tutorials are designed to show you how to use the RSK and are not intended as a comprehensive introduction to the CS+ debugger, compiler toolchains or the E1 emulator. Please refer to the relevant user manuals for more in-depth information.

3. Project Creation with CS+

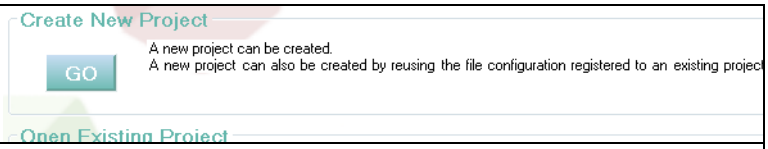
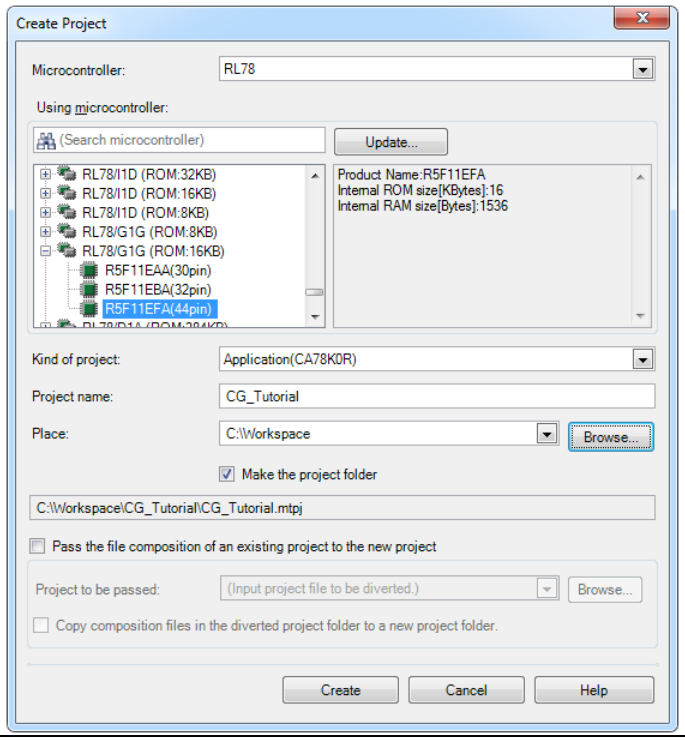
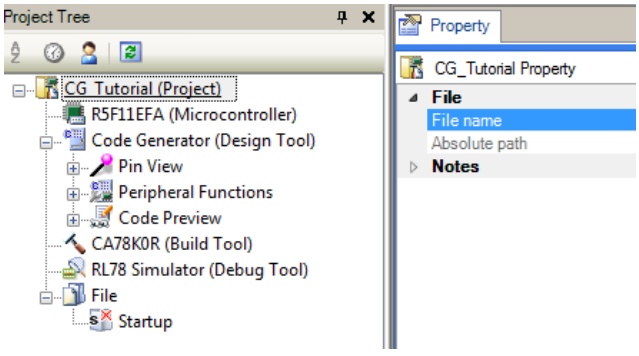
3.1 Introduction

In this section the user will be guided through the steps required to create a new 'C' project for the RL78/G1G microcontroller, 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

To use the program, start CS+:

Windows™ 7 & Vista: Start Menu (Start Menu > All Programs > Renesas Electronics CS+ > CS+ for CA, CX (78K,RL78,V850)
Windows™ 8: From Apps View, click 'CS+ for CA, CX (78K,RL78,V850)' icon

· CS+ will show the Start Page. Use the 'GO' button to Create a New Project.	
· In the 'Create Project' dialog, select 'RL78' from the 'Microcontroller' pull-down. · In the 'Using Microcontroller' list control, scroll down to 'RL78/G1G' and expand the tree control by clicking '+'. Select 'R5F11EFA (44pin)'. · Ensure that in the 'Kind of project' pull-down, 'Application(CA78K0R)' is selected. · Choose an appropriate name and location for the project, then click 'Create'. Note: this tutorial assumes the project is named and located at the place shown opposite. · If the folder entered cannot be found a 'Question' dialogue with be displayed; click 'Yes'.	
· CS+ will create the blank project with the standard project tree. A 'Code Generator' node may also be shown, if previously enabled.	

4. Code Generation Using the CS+ plug in

4.1 Introduction

Code Generator is an CS+ plug in GUI tool for generating template 'C' source code for the RL78/G1G. When using Code Generator, the user is able to configure various MCU features and operating parameters using intuitive GUI controls, bypassing the need, in most cases, to refer to sections of the Hardware Manual.

By following the steps detailed in this tutorial, the user will generate a CS+ project called CG_Tutorial. A fully completed Tutorial project is contained on the DVD and may be imported into CS+ 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 CS+.

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 free to add custom code to meet their specific requirement. Custom code should be added 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. Any code outside of these comment delimiters will be overwritten on subsequent code generation sessions.

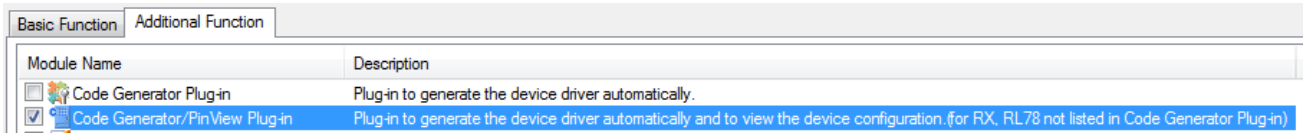
The CG_Tutorial project polls switch inputs and uses interrupts for the ADC module and the Serial Array Unit (SAU). These modules are used to perform A/D conversion and display the results via the UART in a terminal emulator running on the PC and also on the pmod LCD module connected to the CPU board. In addition a modulo 16 counter is maintained that counts the number of requested ADC conversions. The count results are displayed on the PC and they are also represented on LEDs 0 to 3.

Following a tour of the key user interface features of Code Generator in §4.3, the reader is guided through each of the peripheral function configuration dialogs in §4.4. In §6, the reader is familiarised with the structure of the template code, as well as how to add custom code in the areas provided by the Code Generator.

4.2 Enabling Code Generator

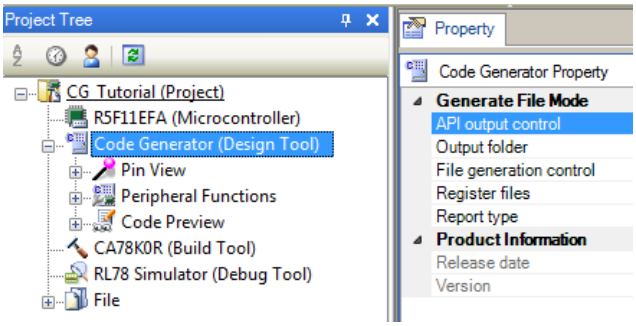
After installation of CS+, Code Generator must be enabled. This step is only required once, CS+ will remember this setting on subsequent launches.

From the 'Tool' pull-down menu select 'Plug-in Setting…'. On the 'Additional Function' tab, click the box next to the 'Code Generator/Pin View Plug-in' option and ensure it is ticked:



Click 'OK'. CS+ needs to restart to enable this selection, select 'Yes' from the Question dialogue box.

After restarting, 'Code Generator (Design Tool)' node will now be shown in the left-hand 'Project Tree' window pane.



4.3 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 (r20ut2663ej0100). Application Leading Tool is the stand-alone version of Code Generator and this manual is applicable to the Code Generator.

In the Project Tree pane, click on the ⊞ icon next to 'Code Generator' node to expand the list.
Expand the 'Peripheral Functions' node by clicking on the ⊞ next to it.
Open the 'Peripheral Functions' tab by double clicking on the 'Peripheral Functions' name.
The CS+ main window will now contain a 'Peripheral Functions' tab with the Initial View as show in Figure 4-1.

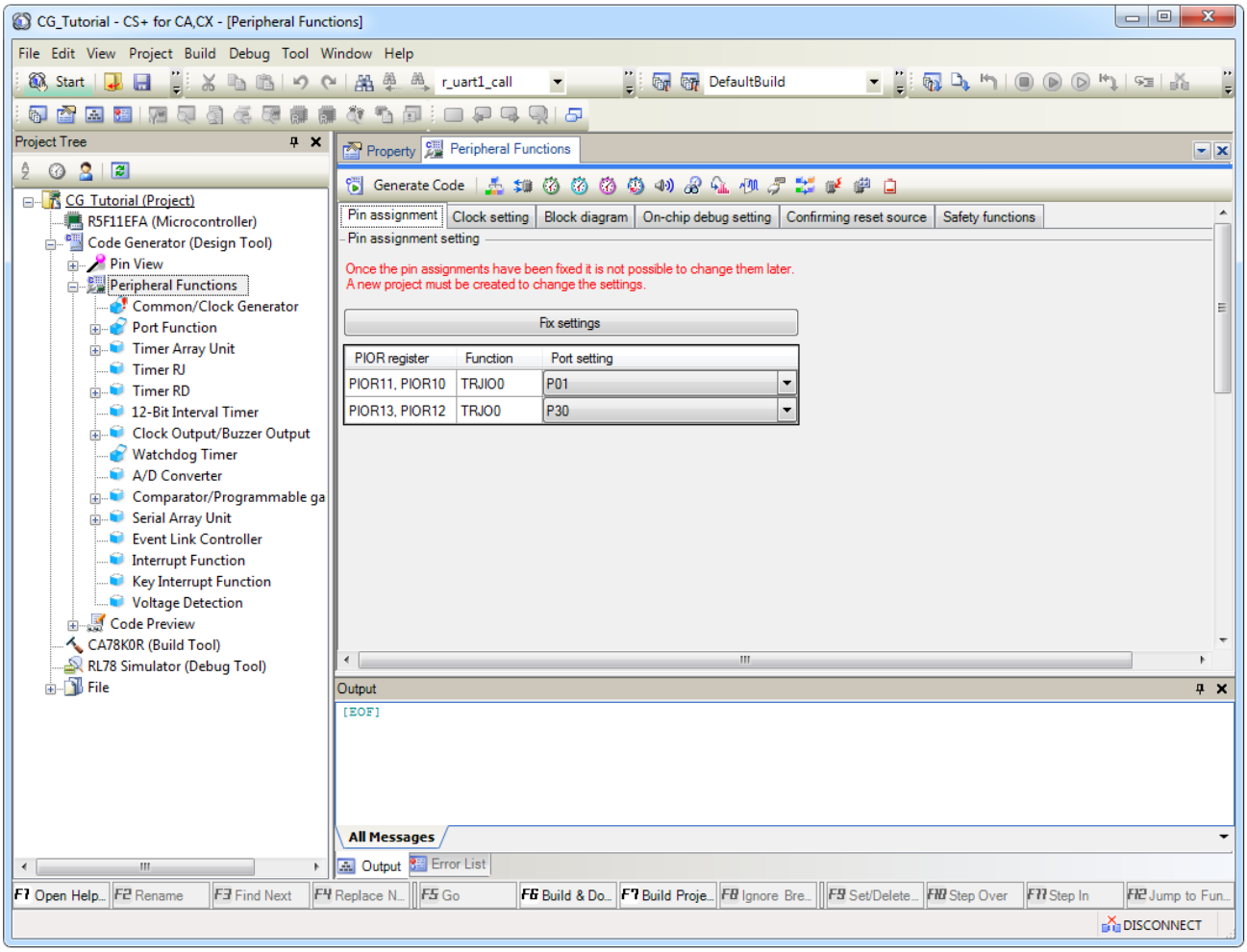


Figure 4-1 Initial View

Code Generator provides GUI features for configuration of MCU subsystems and peripherals. Once the user has configured all required MCU subsystems and peripherals, the user can click the 'Generate Code' button, resulting in a fully configured CS+ project.

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

4.4 Code Generation

In the following sections, the reader is guided through the steps to configure the MCU for a simple tutorial project containing ADC with external switch trigger, Serial Array Unit (SAU), Timer Array Unit (TAU) and LCD Output.

4.4.1 Clock Generator

Certain MCU pins in the RL78/G1G are configurable for different peripheral functions. In order to proceed to setting up the MCU peripheral functions, the user must first fix these pin assignments using the 'Fix settings' button (see Figure 4-1). Once fixed, these pin assignments may not be changed and it will be necessary to create a new project if different pin assignments are required. For this RSK the default settings are applicable, click 'Fix settings' and the button will then be greyed out.

Figure 4-2 shows a screenshot of Code Generator with the Common/Clock Generator function open.

In this tutorial we are using the High-speed system clock with a 20 MHz crystal oscillator for the main clock source. The 'Block diagram' tab shows how clocks are distributed throughout the system.

Double click on the 'Clock Generator' entry in the Code Generator -> Peripheral Functions list and then select the 'Clock setting' tab.
Configure the Clock Generator options as shown in Figure 4-2.

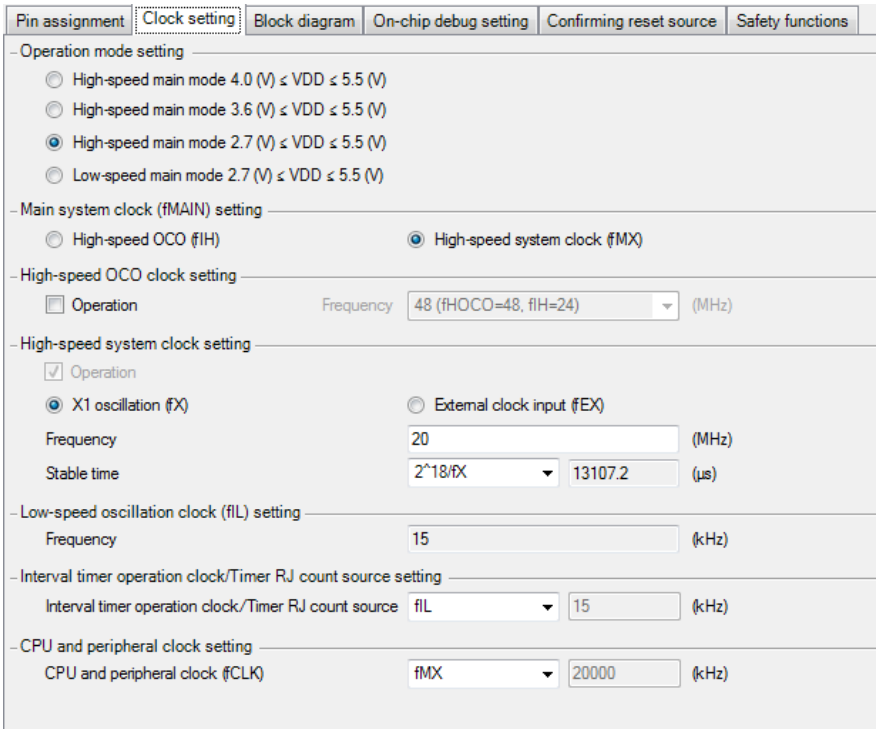


Figure 4-2 Clock setting tab

4.4.2 Port Function

This peripheral will be configured to assign output pins for user LEDs and input pins for user switches, with the exception of SW3 which is used as a trigger for the A/D Converter peripheral. Please refer to the RSK schematic for full details of the connectivity. A summary of those port settings is shown in Table 4-1

RSK component	Port	Configuration
SW1	P7.0	Input
SW2	P12.4	Input
SW3	P12.3	Input
LED0	P4.1	Output
LED1	P6.3	Output
LED2	P7.2	Output
LED3	P7.3	Output
PMOD	P6.1	Output
PMOD	P6.2	Output
PMOD	P7.1	Output

Table 4-1 RSK port configurations. The port number specifies a port and bit number of that port e.g. P7.0 indicates Port 7 bit 0.

Double click on the 'Port Function' entry in the Code Generator -> Peripheral Functions list, the initial view will be as shown in Figure 4-3.
All ports may be left with their default configurations except for ports 4, 6, 7 and 12. Select each of those port tabs and configure as shown in Figure 4-4 to Figure 4-7. Note that in order that the initial state of the LEDs is off (not illuminated) then the 'Output 1' tick box is selected for those ports connected to LEDs.

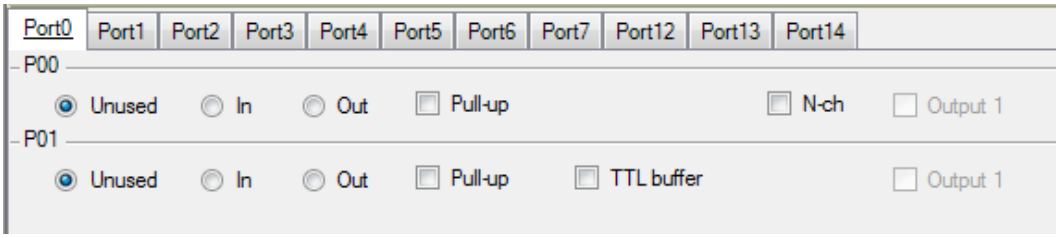


Figure 4-3 Initial Port view.

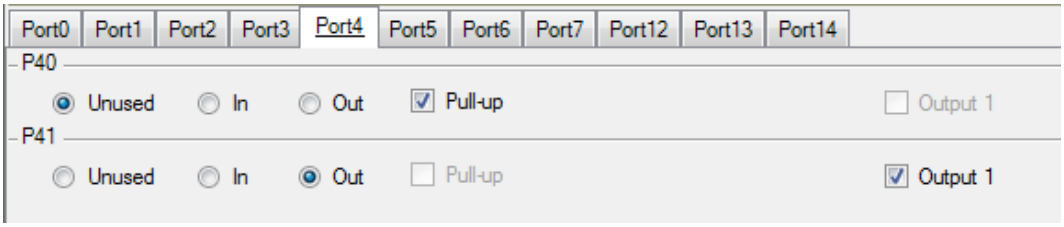


Figure 4-4 Port 4 Configuration.

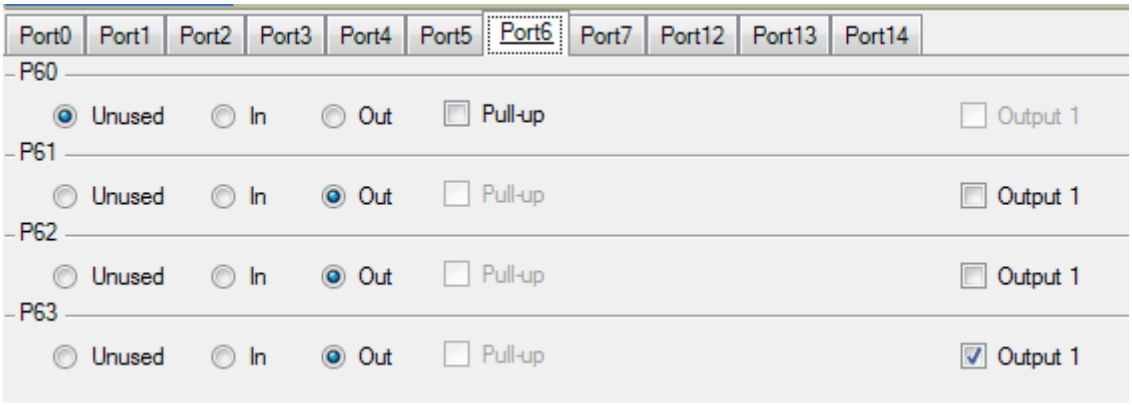


Figure 4-5 Port 6 Configuration.

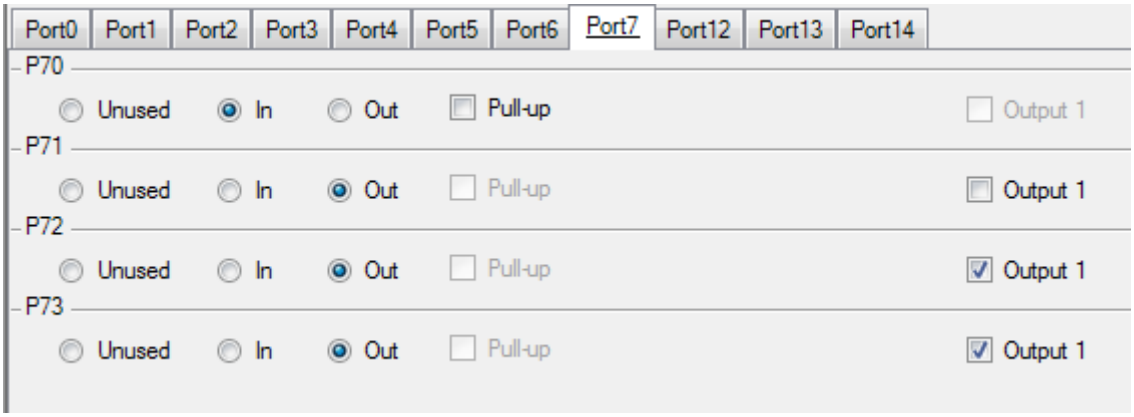


Figure 4-6 Port 7 Configuration.

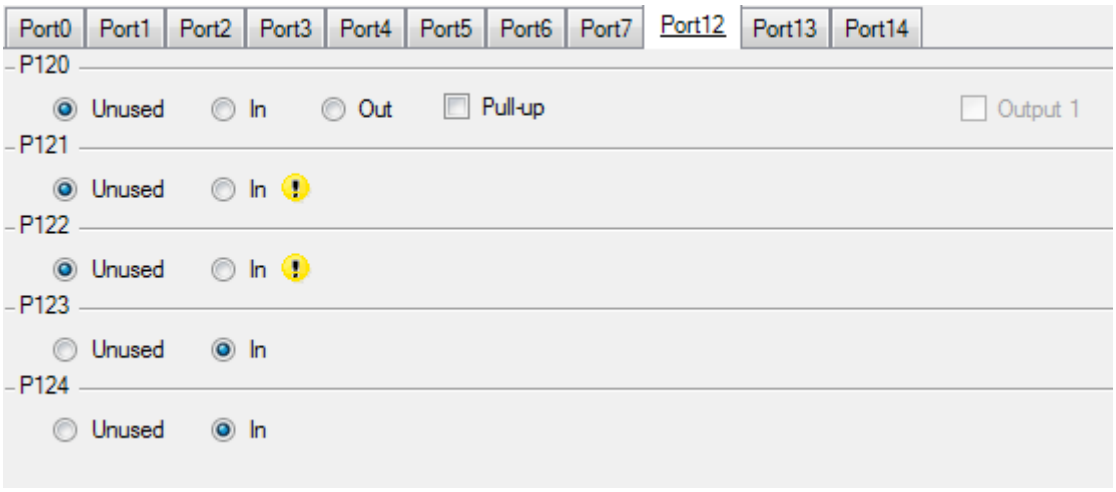


Figure 4-7 Port 12 Configuration. Note that Code Generator warns the user of any pin conflicts, all warnings may be ignored in this tutorial.

4.4.3 Timer Array Unit

For this tutorial Channel 0 and Channel 2 are set up as 1ms interval timers. Double click on the 'Timer Array Unit' entry in the Code Generator -> Peripheral Functions list and configure as shown in Figure 4-8

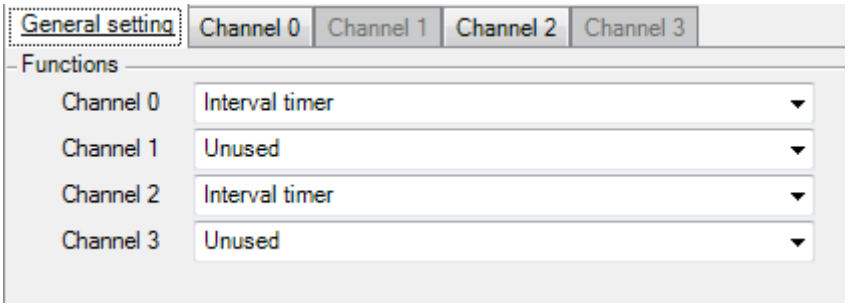


Figure 4-8 TAU channel 0 configured as a 1ms interval timer

Left click on the ‘Channel 0’ tab and configure as shown in Figure 4-9

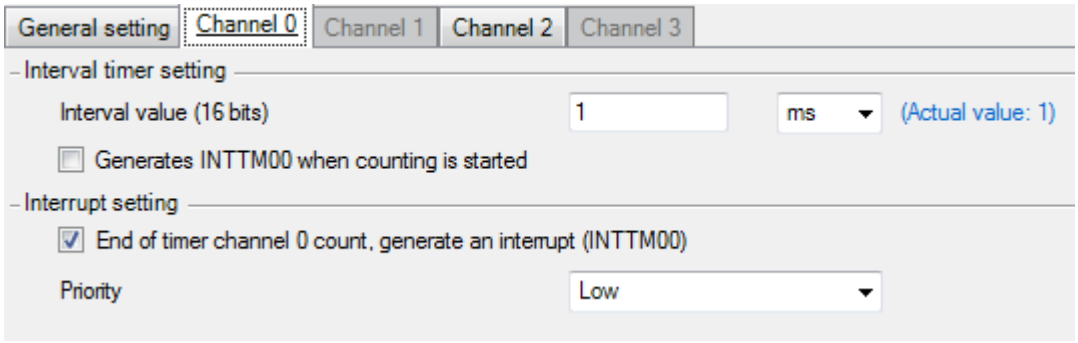


Figure 4-9 TAU Channel 0 Configuration

Left click on the ‘Channel 2’ tab and configure this in exactly the same way as Channel 0.

4.4.4 Watchdog Timer

The Watchdog Timer is enabled by default but it is not required in this project. Double click on ‘Watchdog Timer’ in the project tree and select ‘Unused’ for the Watchdog timer operation setting.

4.4.5 A/D Converter

For this tutorial the ADC is configured in 10-bit one shot mode on the ANI0 input, which is connected to the RV1 potentiometer output on the RSK.

Double click on the ’A/D Converter’ entry in the Code Generator -> Peripheral Functions list and configure as shown in Figure 4-10

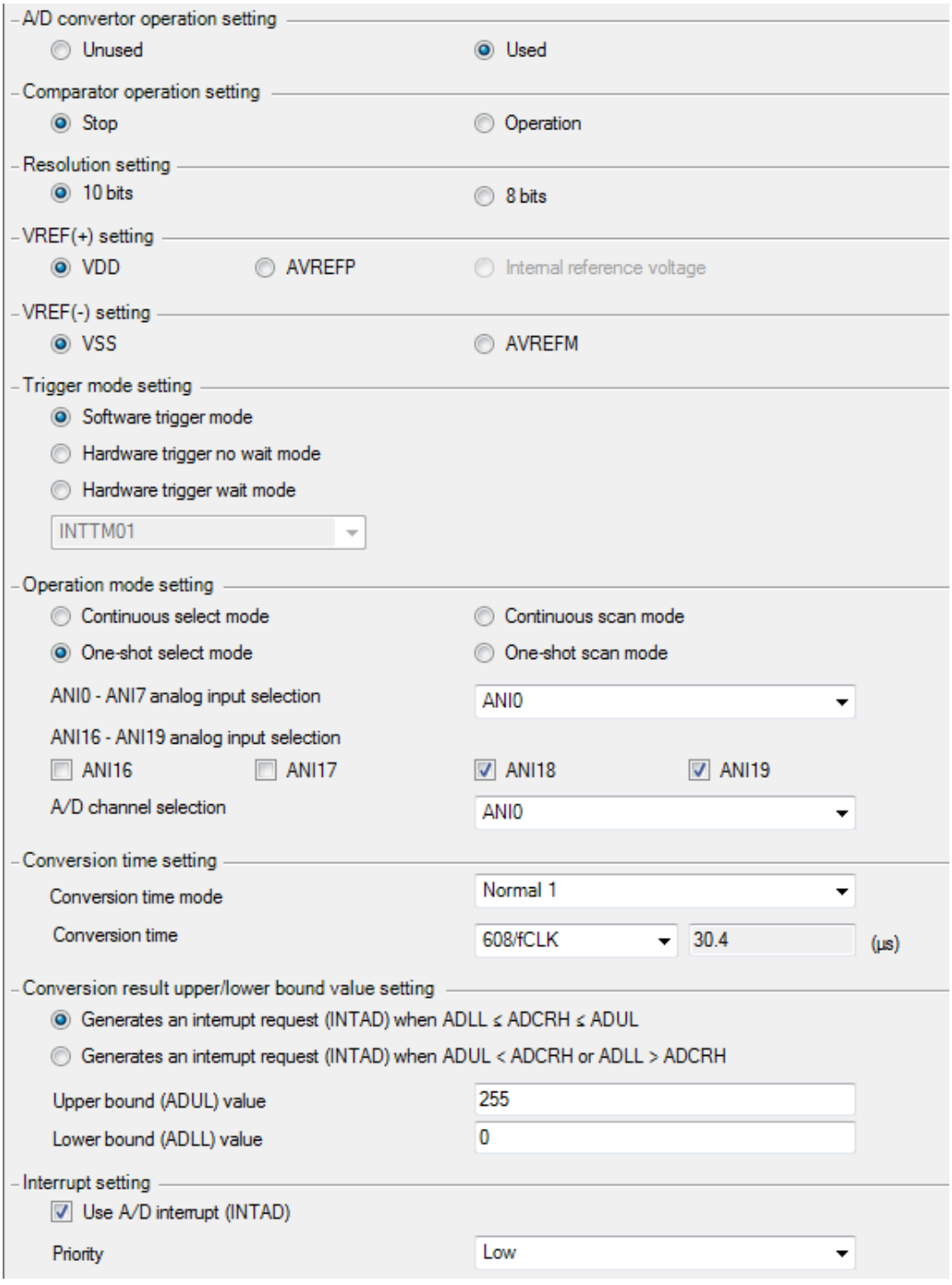


Figure 4-10 A/D Converter configuration

4.4.6 Serial Array Unit

The ‘Serial Array Unit’ (SAU) is used to communicate with both the pmod LCD module (via CSI00 on channel 0) and the PC (via UART1 on channel 2).

The UART1 lines TXD1 and RXD1 are connected to the RL78/G1C, which is pre-configured as a serial to USB converter.

Double click on ‘Serial Array Unit’ in the project tree and configure the SAU channels as shown in Figure 4-11.

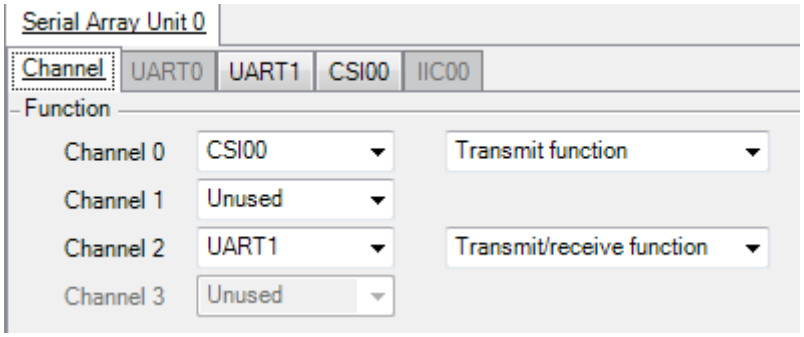


Figure 4-11 SAU channel configuration. Communications with the PMOD LCD module is via channel 0 (CSI00) and with the PC it is via channel 2 (UART1).

Left click on the CSI00 tab and configure as shown in Figure 4-12.

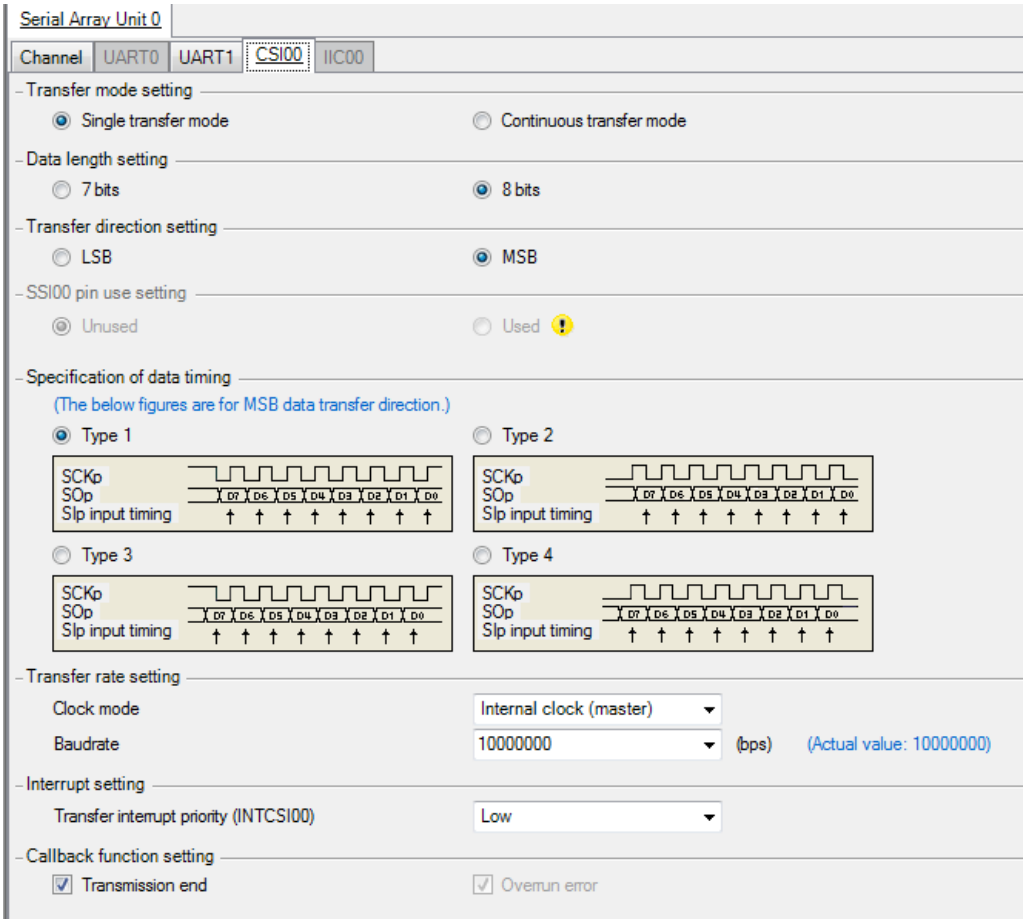


Figure 4-12 SAU CSI00 configuration.

Left click on the UART1 tab and configure as shown in Figure 4-13 and Figure 4-14.

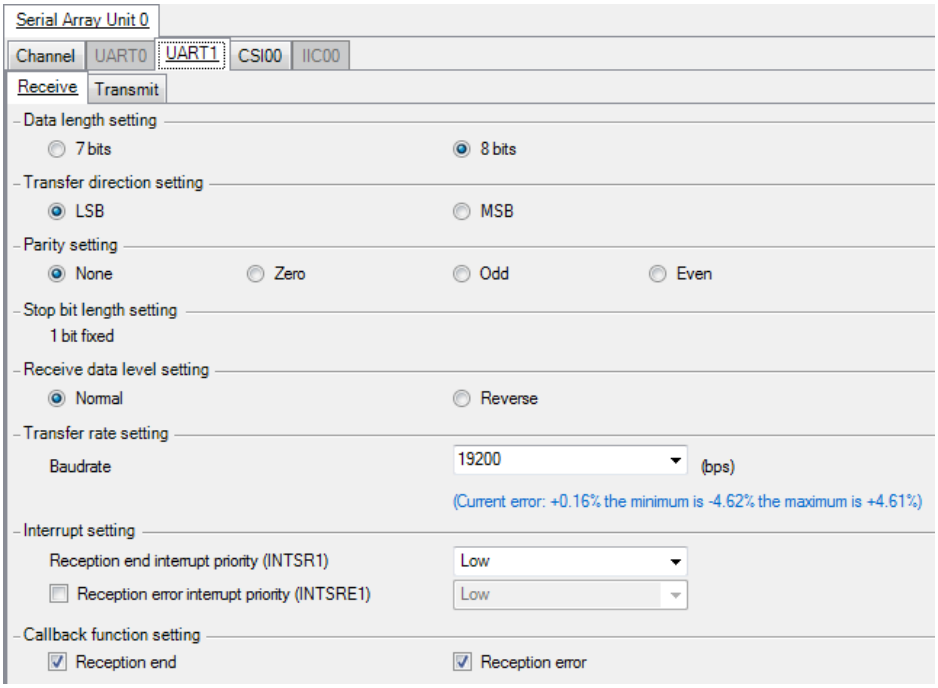


Figure 4-13 SAU UART1 Receive configuration (select Receive tab).

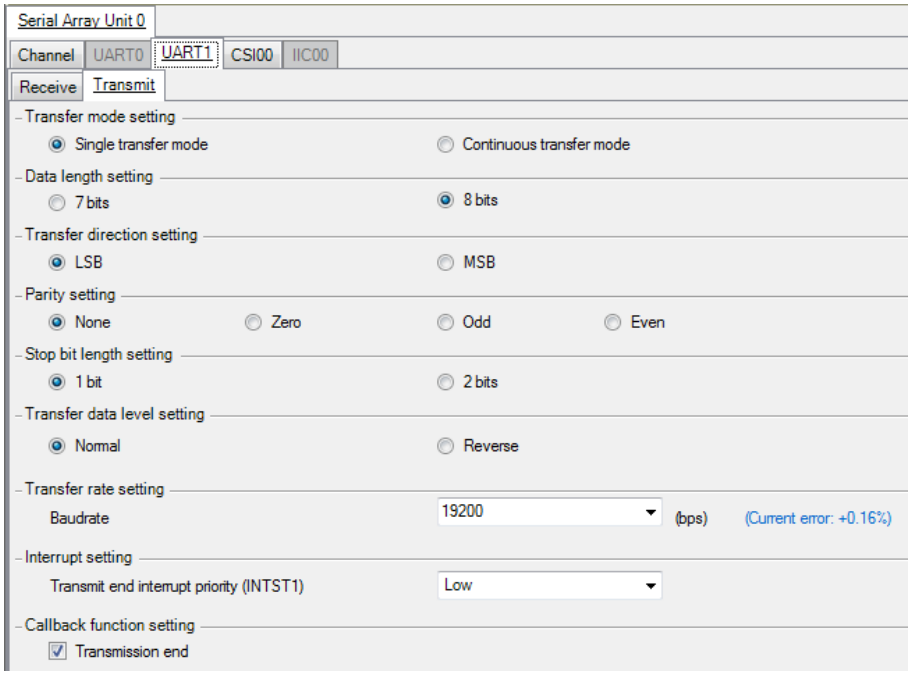


Figure 4-14 SAU UART1 Transmit configuration (select Transmit tab).

Code Generator configuration is now complete; save the configuration by selecting ‘Save All’ from the ‘File’ pull down menu. Proceed to the next section to generate the code.

4.4.7 Generating the code

Peripheral function configuration is now complete. Click ‘Generate Code’ button located below the Peripheral Functions tab. The Console pane should report ‘The operation of generating file was successful’, as shown in Figure 4-15 below.

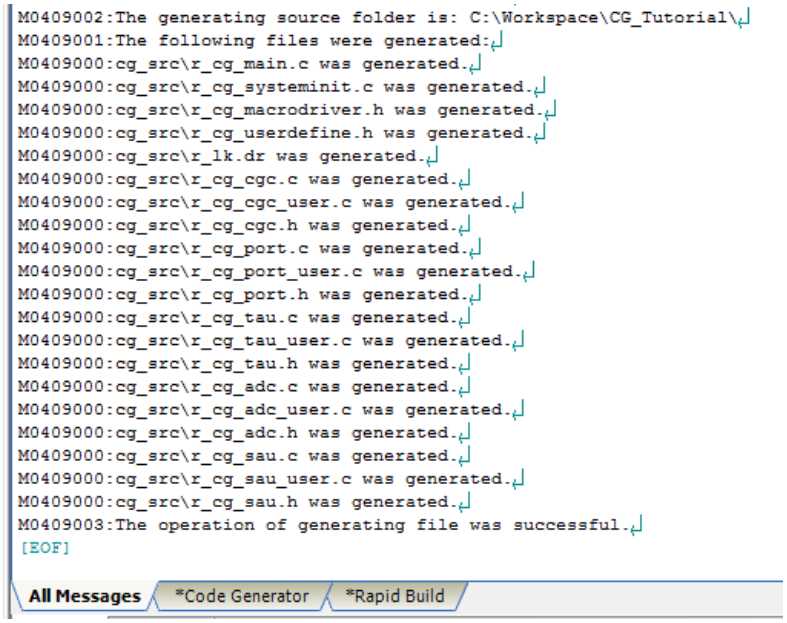


Figure 4-15 Code generator console

Figure 4-16 shows the Code Generator Files in the Project Tree pane. In the following sections the CG_Tutorial project will be completed by adding user code into these files and adding new source files to the project.

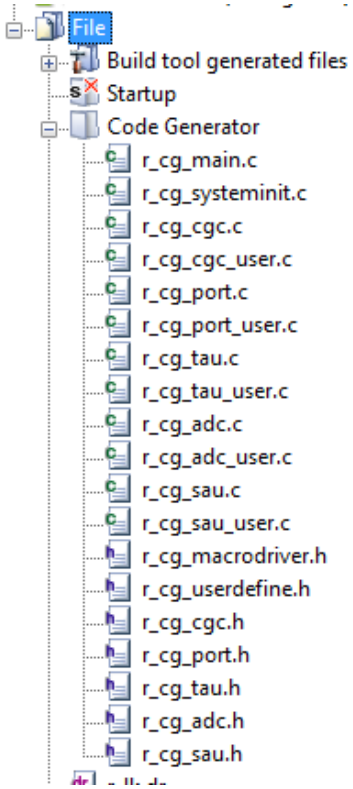
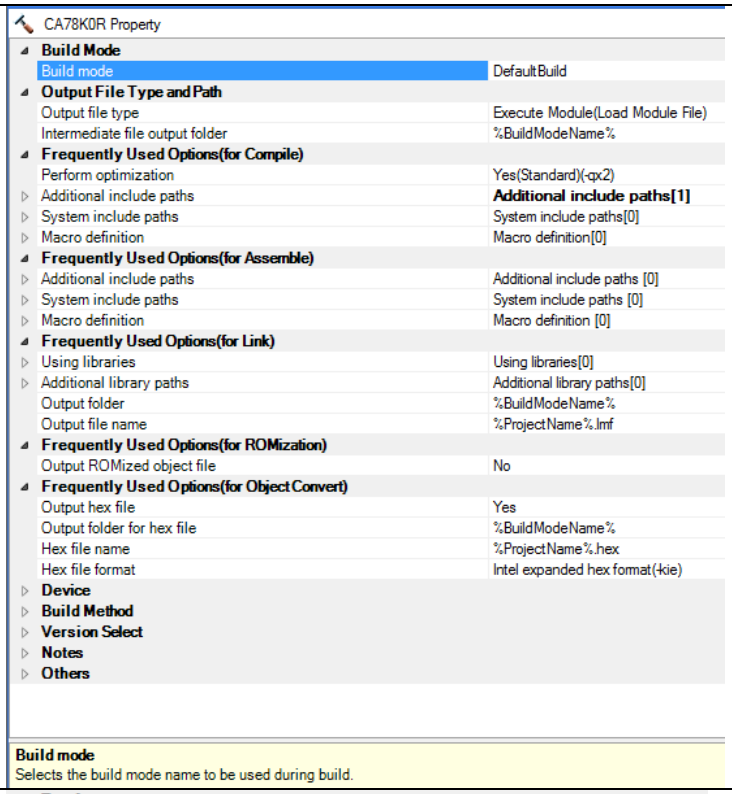


Figure 4-16 Generated Code in Project tree

5. Project Settings

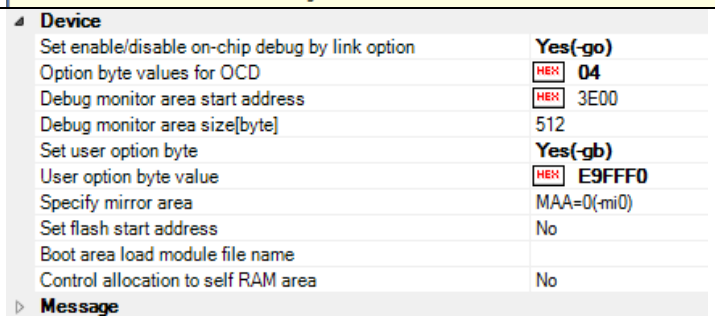
This section covers changes to the CS+ blank project to allow it to run on the RSK.

- In the ‘Project Tree’ pane, click on ‘CA78K0R (Build Tool)’. The build properties will appear in the main window.



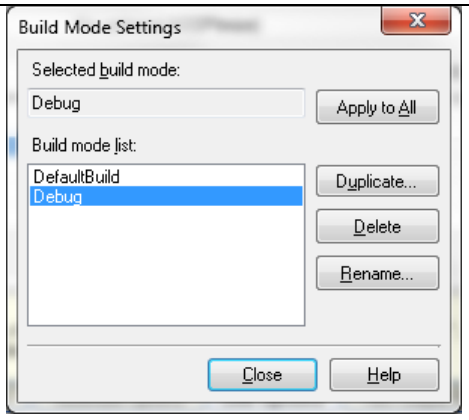
- CS+ creates a single build configuration called ‘Default Build’ for the project. This has standard code optimisation turned on by default (level 2).

- Note that when code generator is run it will configure some of the linker settings. Click on the ‘Link Options’ tab at the bottom of the Property pane and ensure the device settings are as shown. If they are not as shown then it is probably because code generator was not run while in the default Build configuration. It is important to do this at this stage before the Debug and Release configurations are created.

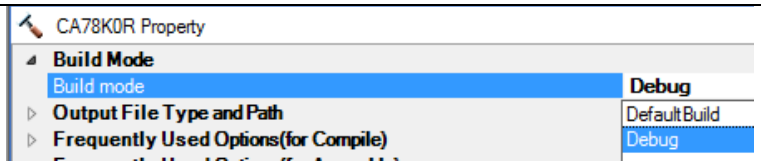


Build Mode Creation and Configuration - Debug

- From the ‘Build’ toolbar menu, select ‘Build Mode Settings…’.
- Click on ‘DefaultBuild’ entry in the Build mode list:
- Click ‘Duplicate’ and in the resulting ‘Character String Input’ dialog, enter ‘Debug’ for the name of the duplicate build mode.
- Click ‘Close’.

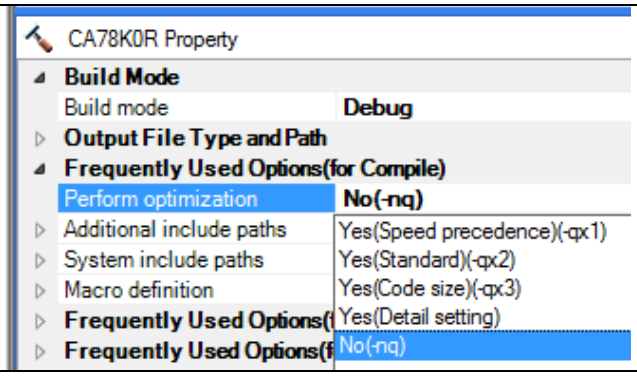


- In the main CA78K0R Property window, under the 'Common Options' tab, click on the line containing 'Build Mode', click the pull-down arrow and select 'Debug' from the pull-down'.



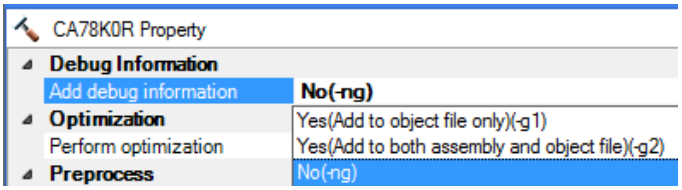
- In the 'Frequently Used Options (for Compile)' group, select the 'Optimization Level' option and select 'No(-nq)' from the pull-down.

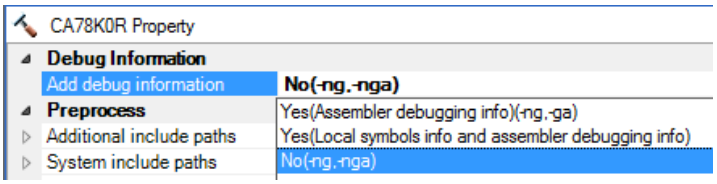
  This has now created a 'Debug' build mode, with no code optimisation. This Build Mode will be used throughout this tutorial to build and debug the project.

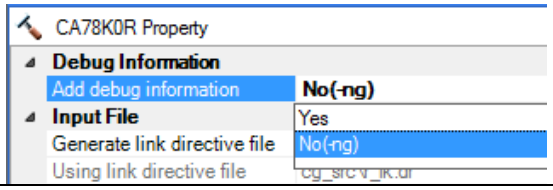


Build Mode Creation and Configuration - Release

- All of the sample code projects contained in this RSK are configured with three Build modes; 'DefaultBuild', 'Debug' and 'Release'.
- 'Release' is created in the same way as above; by duplicating 'Default Build'.
- 'Release' build mode leaves code optimisation turned on and removes debug information from the output file.
- To remove debug information from the 'Release' build mode, select the 'CA78K0R Property' window,
  - Select the 'Compile Options' tab at the bottom of the window pane. For the 'Add debug information' option, select 'No(-ng).
  - Select the 'Assemble Options' tab at the bottom of the window pane. For the 'Add debug information' option, select 'No(-ng. nga).
  - Select the 'Link Options' tab at the bottom of the window pane. For the 'Add debug information' option, select 'No(-ng).



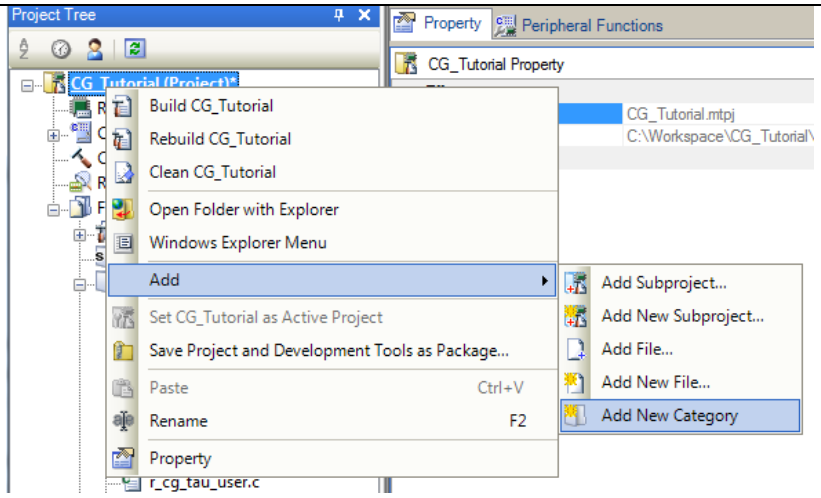
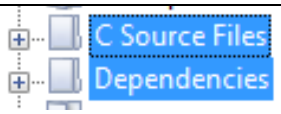




- The 'Debug' build will be used for the remainder of this tutorial:

  Reset the build mode back to 'Debug' using the 'Build Mode' pull-down control
- From the menu, select 'File -> Save All' to save all project settings.

5.1 Adding Project Folders

· Before new source files are added to the project, we will create two additional folders in the CS+ Project Tree. · In the Project Tree pane, right-click the CG_Tutorial project name and select 'Add -> Add New Category'.	
· Rename the newly-created 'New Category' folder to 'C Source Files'. · Repeat these steps to create a new category folder for 'Dependencies'	

6. User Code Integration

At this stage of a typical project development the user would expand on the generated code to create the application required. As a demonstration this tutorial will include code lines and files from the complete 'Tutorial' project, supplied on the RSK installation DVD.

When inserting code in Code Generator created files, it must be placed 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 refreshes the Code Generator-generated code.

6.1 Support file copying

RSK support and utility functions are provided in the following files:

r_ascii.c,
r_ascii.h,
r_lcd.c,
r_lcd.h,

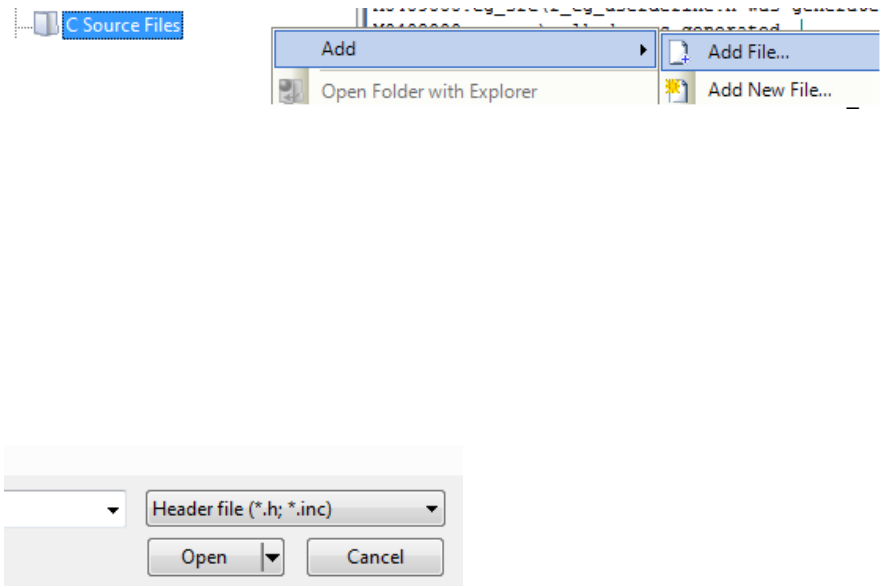
Using Windows™ Explorer, locate the 'Tutorial' project folder and copy the files above to the project folder created in section 3.2, this will be 'C:\Workspace\CG_Tutorial' if following the example screenshots.
The 'Tutorial' project is a standard RSK sample and can be obtained by following the steps shown in the Quick Start Guide.

6.2 Including files in the CS+ Project

- Right-click on 'C Source Files' in the Project Tree and select 'Add -> Add File…'.
- Browse to and select the following files copied in the section above and click 'Add':

  r_ascii.c
  r_lcd.c
- Right-click on 'Dependencies' in the Project Tree and select 'Add -> Add File…'.
- Change the file type to be searched to 'Header file (*.h; *.inc) and select the following files copied in the section above and click 'Add':

  r_ascii.h
  r_lcd.h



6.3 Adding Code to Generated Files

This section covers inserting code in to the newly created Code Generator files.

Each subsection is a Code Generated source file that needs to be opened by double clicking on the file name in the CS+ Project Tree window: ‘File -> Code Generator’.

The code from each section should be copied from this document and pasted in to the relevant file at the location indicated.

Note that only the code between the ‘start’ and ‘end’ comments needs to be added.

6.3.1 r_cg_main.c Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments as shown below in the file section designated Includes:

```
/* Start user code for include. Do not edit comment generated here */
#include <string.h>
#include "r_lcd.h"
/* End user code. Do not edit comment generated here */
```

Insert the following between the user code delimiter comments as shown below in the file section designated Global variables and functions.

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

/* Converts count to binary and displays on LEDs 0 to 3 */
static void led_display_count (const uint8_t count);

/* Read value from ADC. */
static uint16_t get_adc (void);

/* Read state of switches */
static void read_switch (volatile switch_t g_swn, uint8_t port_value);

/* Write to UART1 */
static void text_write (uint8_t * const msg_string);

/* Conversion to facilitate outputting to LCD module. */
static void uint16_to_string (uint8_t * const output_string, uint8_t pos, const uint16_t
input_number);

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

/* LCD module string buffer */
static uint8_t lcd_buf[10];

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

/* Character received from PC terminal */
extern volatile uint8_t g_rx_char;

/* Commands to clear terminal window and set cursor to start of window */
const uint8_t g_cmd_clr_scr[] =
{ 27, '[', '2', 'J', 0 };
const uint8_t g_cmd_cur_home[] =
{ 27, '[', 'H', 0 };

/* Variable to store the A/D conversion count for user display */
uint8_t adc_count = 0;
uint16_t adc_result;
uint8_t initial_adc_meas = TRUE;

/* Switch value (state of input port) */
uint8_t switch_value;
```

```
/* ADC rx complete interrupt flag */
extern volatile uint8_t g_adc_rx_int;

/* UART1 serial transmission in progress */
extern volatile uint8_t g_uart1_tx_busy;

/* Debounce state */
extern volatile uint8_t g_debounce_ongoing;

/* Switches */
extern volatile switch_t g_sw3;

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

In the main function replace this code:

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

With this code:

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

    /* Initialise the LCD display */
    init_lcd();

    /* Display test information */
    display_lcd(0, (uint8_t const *) "Renesas");
    display_lcd(1, (uint8_t const *) "RL78/G1G");
    display_lcd(3, (uint8_t const *) "Tutorial sample");
    display_lcd(4, (uint8_t const *) "Connect USB to PC");
    display_lcd(5, (uint8_t const *) "Serial configuration:");
    display_lcd(6, (uint8_t const *) "Baud Rate 19200");
    display_lcd(7, (uint8_t const *) "Data Bits 8");
    display_lcd(8, (uint8_t const *) "Stop Bits 1");
    display_lcd(9, (uint8_t const *) "Parity    None");
    display_lcd(10, (uint8_t const *) "Flow      None");

    /* Set up UART1 receive buffer and callback function */
    R_UART1_Receive((uint8_t * const) &g_rx_char, 1);

    /* Enable UART1 operations */
    R_UART1_Start();

    while (1U)
    {
        /* Read SW3. */
        switch_value = SW3_VALUE;
        read_switch(g_sw3, switch_value);

        /* If a new press of SW3 then request a new A/D conversion. */
        if (TRUE == g_sw3.switch_new_press)
        {
            g_sw3.switch_new_press = FALSE;

            /* set the flag indicating a user requested A/D conversion is required */
            g_adc_trigger = TRUE;
        }

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

            /* Display the result on the LCD */
            uint16_to_string(lcd_buf, (uint8_t) 0, adc_result);
            display_lcd(12, (uint8_t const *) lcd_buf);

            /* Increment the adc_count and display using the LEDs if not the initial reading. */
```

```
            if (FALSE == initial_adc_meas)
            {
                if (16 == (++adc_count))
                {
                    adc_count = 0;
                }
            }
            led_display_count(adc_count);

            /* Send count and ADC result to the UART */
            uart_display_adc(adc_count, adc_result);

            /* Reset the flag */
            g_adc_trigger = FALSE;

            initial_adc_meas = FALSE;
        }
    }
    /* End user code. Do not edit comment generated here */
```

Insert the following between the user code delimiter comments at the end of the file.

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

/***********************************************************************************************************
******************
 * Function Name : read_switch
 * Description   : If the switch state has changed then trigger the debounce timer, which will set
the debounced switch
 *                 state to pressed or released as appropriate. The calling program must set the new
press or new
 *                 released state to false once processed.
 * Argument      : none
 * Return value  : none

***********************************************************************************************************
******************/
static void read_switch (volatile switch_t g_sw, uint8_t port_value)
{
    /* Start TAU channel 0 timer (debounce timer) if switch state change detected. */
    if (((SWITCH_PRESSED == port_value) && (SWITCH_RELEASED == g_sw.current_switch_state))
            || ((SWITCH_RELEASED == port_value) && (SWITCH_PRESSED == g_sw.current_switch_state)))
    {
        /* TAU channel 0 only needs to be started if it has already been stopped */
        if (FALSE == g_debounce_ongoing)
        {
            g_debounce_ongoing = TRUE;

            /* Start TAU channel 0. which is configured as a periodic timer to aid switch debouncing.
*/
            R_TAU0_Channel0_Start();
        }
    }
}
/***********************************************************************************************************
******************
 * End of function read_switch

***********************************************************************************************************
******************/

/***********************************************************************************************************
******************
 * Function Name : get_adc
 * Description   : Reads the ADC result.
 * Argument      : none
 * Return value  : adc_result - Value of ADC conversion

***********************************************************************************************************
******************/
static uint16_t get_adc (void)
{
    uint16_t adc_result;

    /* Enable comparator operation */
    R_ADC_Set_OperationOn();
```

```
    /* Start a conversion */
    R_ADC_Start();

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

    R_ADC_Get_Result(&adc_result);

    /* stops comparator operation */
    R_ADC_Set_OperationOff();

    /* stops the AD converter */
    R_ADC_Stop();

    return adc_result;
}
/***********************************************************************************************************
******************
 * End of function get_adc

***********************************************************************************************************
*****************/

/***********************************************************************************************************
******************
 * Function Name : uart_display_adc
 * Description   : Converts adc result to a string and sends it to UART1.
 * Argument      : adc_count  - Number of ADC conversions (modulo 16)
 *                 adc result - Value of ADC conversion
 * Return value  : none

***********************************************************************************************************
*****************/
static void uart_display_adc (uint8_t adc_count, uint16_t adc_result)
{
    uint8_t str1[50];

    /* Clear terminal window and set cursor to start of window */
    text_write((uint8_t *) &g_cmd_clr_scr);
    text_write((uint8_t *) &g_cmd_cur_home);

    strcpy((char *) str1, "ADC value =       \r\n");
    uint16_to_string(str1, (uint8_t) 12, (uint16_t) adc_result);
    text_write(str1);

    strcpy((char *) str1, "Number of ADC conversions (modulo 16) =      \r\n");
    uint16_to_string(str1, (uint8_t) 40, (uint16_t) adc_count);
    text_write(str1);
}
/***********************************************************************************************************
******************
 * End of function uart_display_adc

***********************************************************************************************************
*****************/

/***********************************************************************************************************
******************
 * Function name : text_write
 * Description   : Transmits null-terminated string.
 * Argument      : msg_string - null terminated string
 * Argument      : None

***********************************************************************************************************
*****************/
static void text_write (uint8_t * const msg_string)
{
    uint16_t i;

    for (i = 0; msg_string[i]; i++)
    {
        /* Send one byte and set UART transmit busy flag */
```

```
        R_UART1_Send(&msg_string[i], 1);
        g_uart1_tx_busy = TRUE;

        /* Wait until UART transfer is complete*/
        while (TRUE == g_uart1_tx_busy)
        {
            /* Wait */
        }
    }
}
/***********************************************************************************************************
******************
 * End of Function text_write

***********************************************************************************************************
*****************/

/***********************************************************************************************************
******************
 * Function Name : led_display_count
 * Description   : Converts count to binary and displays on LEDs 0 to 3
 * Argument      : count - Number of ADC conversions (modulo 16)
 * Return value  : none
 ***********************************************************************************/
static void led_display_count (const uint8_t count)
{

    /* Set LEDs according to lower nibble of count parameter */
    LED0 = (count & 0x01) ? LED_ON : LED_OFF;
    LED1 = (count & 0x02) ? LED_ON : LED_OFF;
    LED2 = (count & 0x04) ? LED_ON : LED_OFF;
    LED3 = (count & 0x08) ? LED_ON : LED_OFF;
}
/***********************************************************************************************************
******************
 * End of function led_display_count

***********************************************************************************************************
*****************/

/***********************************************************************************************************
******************
 * Function Name: uint16_to_string
 * Description  : Function converts a 16 bit integer into a character string, inserts it into the
array via the pointer
 *                passed at execution.
 * Argument     :   output_string - Pointer to char array that will hold character string.
 *                          pos - uint8_t number, element number to begin inserting the character
string from (offset).
 *                 input_number - 16 bit integer to convert into a string.
 * Return value : none
 * Note         : No input validation is used, so output data can overflow the array passed.

***********************************************************************************************************
*****************/
static void uint16_to_string (uint8_t * const output_string, uint8_t pos, const uint16_t
input_number)
{

    /* Declare 16bit mask variable */
    uint16_t mask = 0xF000;

    /* Declare temporary character storage variable, and bit_shift variable */
    uint8_t a = 0x00;
    uint8_t bit_shift = 12u;

    /* Loop through until each hex digit is converted to an ASCII character */
    while (bit_shift < 30u)
    {
        /* Mask and shift the hex digit, and store in temporary variable, a */
        a = (uint8_t) ((input_number & mask) >> bit_shift);

        /* Convert the hex digit into an ASCII character, and store in output
         string */
        output_string[pos] = (uint8_t) ((a < 0x0A) ? (a + 0x30) : (a + 0x37));

        /* Shift the bit mask 4 bits to the right, to convert the next digit */
```

```
        mask = (uint16_t) (mask >> 4u);

        /* Decrement the bit_shift counter by 4 (bits in a each digit) */
        bit_shift = (uint8_t) (bit_shift - 4u);

        /* Increment the output string location */
        pos++;
    }
}
/***********************************************************************************************
******************
 * End of function uint16_to_string

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

6.3.2 r_cg_adc_user.c Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments as shown below in the file section designated Global variables and functions.

```
/* Start user code for global. Do not edit comment generated here */
volatile uint8_t g_adc_rx_int = FALSE;
/* End user code. Do not edit comment generated here */
```

Insert the following in to the function r_adc_interrupt.

```
    /* Start user code. Do not edit comment generated here */
    g_adc_rx_int = TRUE;

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

6.3.3 r_cg_sau.h Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments at the end of the file.

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

void send_csi0 (uint8_t * const tx_buf, uint16_t const tx_num);
uint8_t csi0_tx_is_busy (void);

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

6.3.4 r_cg_sau.c Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments as shown below in the file section designated Global variables and functions.

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

volatile uint8_t g_csi0_tx_in_process = FALSE;

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

Insert the following between the user code delimiter comments at the end of the file.

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

/***********************************************************************************************
******************
 * Function Name: send_csi0
 * Description  : This function sends CSI0 data to slave device. Adds flagging around R_CSI00_Send
```

```
 * Arguments    : tx_buf -
 *                    transfer buffer pointer (Not used when transmit data handled by DTC)
 *                tx_num -
 *                    buffer size
 * Return Value : status -
 *                    MD_OK or MD_ARGERROR

*******************************************************************************************************
*****************/
void send_csi0 (uint8_t * const tx_buf, uint16_t const tx_num)
{
    g_csi0_tx_in_process = TRUE;
    R_CSI00_Send(tx_buf, tx_num);
}
/*******************************************************************************
 * End of function send_csi0
 *******************************************************************************/

/*******************************************************************************
 * Function Name : csi0_tx_is_busy
 * Description   : reports if CSI00 is transmitting
 * Argument      : none
 * Return value  : None
 *******************************************************************************/
uint8_t csi0_tx_is_busy (void)
{
    return (g_csi0_tx_in_process);
}
/*******************************************************************************
 * End of function csi0_tx_is_busy
 *******************************************************************************/
/* End user code. Do not edit comment generated here */
```

6.3.5 r_cg_sau_user.c Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments as shown below in the file section designated Global variables and functions.

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

extern volatile uint8_t g_csi0_tx_in_process;
extern volatile uint8_t g_adc_trigger;

/* UART1 serial transmission in progress */
volatile uint8_t g_uart1_tx_busy = FALSE;

/* Character received from PC terminal */
volatile uint8_t g_rx_char;

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

Insert the following in to the function r_uart1_callback_receiveend.

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

    /* Check the character received from the PC */
    if (('c' == g_rx_char) || ('C' == g_rx_char))
    {
        g_adc_trigger = TRUE;
    }

    /* Set up UART1 receive buffer and callback function again */
    R_UART1_Receive((uint8_t * const) &g_rx_char, 1);

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

Insert the following in to the function r_uart1_callback_sendend.

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

    /* UART1 serial transmission finished */
```

```
    g_uart1_tx_busy = FALSE;

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

Insert the following in to the function r_csi00_callback_sendend.

```
    /* Start user code. Do not edit comment generated here */
    g_csi0_tx_in_process = FALSE;

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

6.3.6 r_cg_userdefine.h Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments as shown below in the file section designated User definitions.

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

/* Switch port settings */
#define SW1             (1)
#define SW2             (2)
#define SW3             (3)
#define SW1_VALUE       (P7.0)
#define SW2_VALUE       (P12.4)
#define SW3_VALUE       (P12.3)
#define SWITCH_PRESSED  (0)
#define SWITCH_RELEASED (1)

/* Switch debounce settings */
#define PRESSED_DEBOUNCE_COUNT  (10)
#define RELEASED_DEBOUNCE_COUNT (20)

/* LED port settings */
#define LED0            (P4.1)
#define LED1            (P6.3)
#define LED2            (P7.2)
#define LED3            (P7.3)
/* LED lights.  */
#define LED_ON          (0)
#define LED_OFF         (1)

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

/* Switches */
typedef struct
{
    uint8_t current_switch_state;
    uint8_t switch_new_press;
    uint8_t switch_new_release;
    uint8_t debounce_counter;
} switch_t;

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

6.3.7 r_cg_tau_user.c Code Insertion

Open this file by double clicking on the file name in the CS+ Project Tree window.

Insert the following between the user code delimiter comments as shown below in the file section designated Global variables and functions.

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

/* TAU0 channel2 interrupt count */
volatile uint16_t g_tau_ch2_cnt = 0;

/* Switches */
```

```
volatile switch_t g_sw1 =
{ SWITCH_RELEASED, FALSE, FALSE, 0 };
volatile switch_t g_sw2 =
{ SWITCH_RELEASED, FALSE, FALSE, 0 };
volatile switch_t g_sw3 =
{ SWITCH_RELEASED, FALSE, FALSE, 0 };

/* Debounce state */
volatile uint8_t g_debounce_ongoing = FALSE;

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

Insert the following in to the function r_tau0_channel0_interrupt.

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

    /* This ISR will debounce switches SW1, SW2 and SW3. The debounce algorithm will check that the
switch state (either
     * pressed or released is stable over a defined period, which can be modified at compile time.
The debounce time
     * for pressing and releasing can be independently configured. Once a switch is pressed or
released then the state
     * of the switch is sampled over the predefined time; a counter is incremented every time the
sampled signal is the
     * same as the previous state. On reaching the end of the debounce period, if it has been stable
for the whole
     * period then the change in switch state is deemed to be valid (debounced) and the new state is
updated. If the
     * sampled switch state is not the same as the previous one then the counter is reset and
counting recommences.
     * This timer will start when any of the switches have been pressed or released and will stop
only after all
     * switches have been debounced. */

    /* Check the last current stable state of SW1. */
    if (SWITCH_RELEASED == g_sw1.current_switch_state)
    {
        /* Switch is in the RELEASED state so it must have been pressed. Read switch input value,
clear debounce counter
         * if switch has bounced back to the release position (open), else increment debounce counter
and confirm new
         * state and new switch pressed once debounce count is reached. */
        if (SWITCH_RELEASED == SW1_VALUE)
        {
            g_sw1.debounce_counter = 0;
        }
        else
        {
            g_sw1.debounce_counter++;

            /* If at the end of the debounce period, then update the current state and indicate that
a new press has
             * been detected. */
            if (PRESSED_DEBOUNCE_COUNT == g_sw1.debounce_counter)
            {
                g_sw1.current_switch_state = SWITCH_PRESSED;
                g_sw1.switch_new_press = TRUE;
            }
        }
    }
    else
    {
        if (SWITCH_PRESSED == g_sw1.current_switch_state)
        {
            /* Switch is in the PRESSED state so it must have been released. Read switch input value,
clear debounce
             * counter if switch has bounced back to the pressed position (closed), else increment
debounce counter and
             * confirm new state and new switch released once debounce count is reached. */
            if (SWITCH_PRESSED == SW1_VALUE)
            {
                g_sw1.debounce_counter = 0;
            }
            else
            {
                g_sw1.debounce_counter++;
```

```
                /* If at the end of the debounce period, then update the current state and indicate
that a new release
                 * has been detected. */
                if (RELEASED_DEBOUNCE_COUNT == g_sw1.debounce_counter)
                {
                    g_sw1.current_switch_state = SWITCH_RELEASED;
                    g_sw1.switch_new_release = TRUE;
                }
            }
        }
    }

    /* Check the last current stable state of SW2. */
    if (SWITCH_RELEASED == g_sw2.current_switch_state)
    {
        /* Switch is in the RELEASED state so it must have been pressed. Read switch input value,
clear debounce counter
         * if switch has bounced back to the release position (open), else increment debounce counter
and confirm new
         * state and new switch pressed once debounce count is reached. */
        if (SWITCH_RELEASED == SW2_VALUE)
        {
            g_sw2.debounce_counter = 0;
        }
        else
        {
            g_sw2.debounce_counter++;

            /* If at the end of the debounce period, then update the current state and indicate that
a new press has
             * been detected. */
            if (PRESSED_DEBOUNCE_COUNT == g_sw2.debounce_counter)
            {
                g_sw2.current_switch_state = SWITCH_PRESSED;
                g_sw2.switch_new_press = TRUE;
            }
        }
    }
    else
    {
        if (SWITCH_PRESSED == g_sw2.current_switch_state)
        {
            /* Switch is in the PRESSED state so it must have been released. Read switch input value,
clear debounce
             * counter if switch has bounced back to the pressed position (closed), else increment
debounce counter and
             * confirm new state and new switch released once debounce count is reached. */
            if (SWITCH_PRESSED == SW2_VALUE)
            {
                g_sw2.debounce_counter = 0;
            }
            else
            {
                g_sw2.debounce_counter++;

                /* If at the end of the debounce period, then update the current state and indicate
that a new release
                 * has been detected. */
                if (RELEASED_DEBOUNCE_COUNT == g_sw2.debounce_counter)
                {
                    g_sw2.current_switch_state = SWITCH_RELEASED;
                    g_sw2.switch_new_release = TRUE;
                }
            }
        }
    }

    /* Check the last current stable state of SW3. */
    if (SWITCH_RELEASED == g_sw3.current_switch_state)
    {
        /* Switch is in the RELEASED state so it must have been pressed. Read switch input value,
clear debounce counter
         * if switch has bounced back to the release position (open), else increment debounce counter
and confirm new
         * state and new switch pressed once debounce count is reached. */
        if (SWITCH_RELEASED == SW3_VALUE)
        {
```

```
            g_sw3.debounce_counter = 0;
        }
        else
        {
            g_sw3.debounce_counter++;

            /* If at the end of the debounce period, then update the current state and indicate that
a new press has
             * been detected. */
            if (PRESSED_DEBOUNCE_COUNT == g_sw3.debounce_counter)
            {
                g_sw3.current_switch_state = SWITCH_PRESSED;
                g_sw3.switch_new_press = TRUE;
            }
        }
    }
    else
    {
        if (SWITCH_PRESSED == g_sw3.current_switch_state)
        {
            /* Switch is in the PRESSED state so it must have been released. Read switch input value,
clear debounce
             * counter if switch has bounced back to the pressed position (closed), else increment
debounce counter and
             * confirm new state and new switch released once debounce count is reached. */
            if (SWITCH_PRESSED == SW3_VALUE)
            {
                g_sw3.debounce_counter = 0;
            }
            else
            {

                g_sw3.debounce_counter++;

                /* If at the end of the debounce period, then update the current state and indicate
that a new release
                 * has been detected. */
                if (RELEASED_DEBOUNCE_COUNT == g_sw3.debounce_counter)
                {
                    g_sw3.current_switch_state = SWITCH_RELEASED;
                    g_sw3.switch_new_release = TRUE;
                }
            }
        }
    }

    /* Stop TAU channel 0 timer if no switches are in the process of being debounced */
    if (((0 == g_sw1.debounce_counter) && (0 == g_sw2.debounce_counter)) && (0 ==
g_sw3.debounce_counter))
    {
        g_debounce_ongoing = FALSE;
        R_TAU0_Channel0_Stop();
    }

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

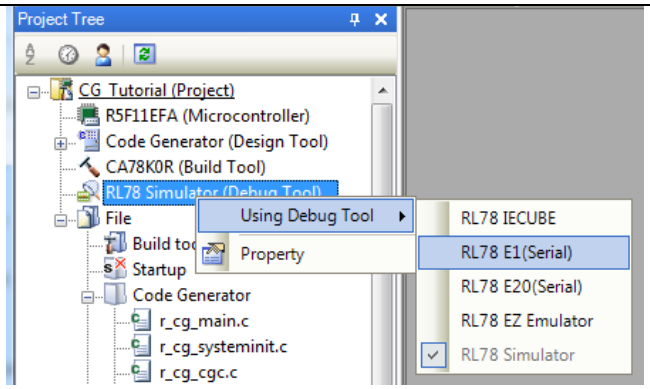
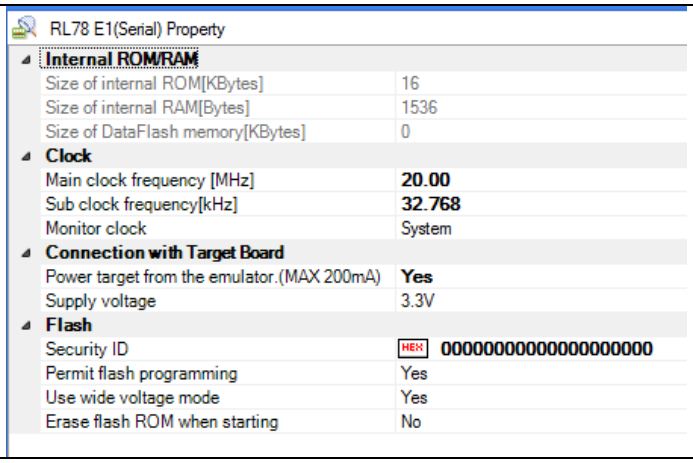
Insert the following in to the function r_tau0_channel2_interrupt.

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

    /* TAU0 channel2 interrupt count */
    g_tau_ch2_cnt++;

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

7.Project Build and Debugger Configuration

Select ‘Build Project’ from the ‘Build’ menu, or press F7. CS+ will build the project with no errors.

Configure the E1 debugger and board as follows.

· In the ‘Project Tree’ pane, right-click the ‘RL78 Simulator (Debug Tool)’. Select: ‘Using Debug Tool -> RL78 E1(Serial)’.	
· Double-click ‘RL78 E1(Serial) (Debug Tool)’ to display the debugger tool properties. · Under ‘Clock’, change the ‘Main clock frequency(MHz) to 20.00 MHz. · Under ‘Connection with Target Board’, change ‘Power target from the emulator.(MAX 200mA) to ‘Yes’ · All other settings can remain at their defaults.	
· Connect the E1 to the PC and the RSK E1 connector. · Ensure the LCD module is connected to PMOD1.	

7.1 Running the Tutorial

Before launching the tutorial connect the RSK RL78G1C-USB 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 emulation program, such as HyperTerminal, connecting to COMx with the settings 19200 baud, 8 data bits, No parity, 1 stop bit.

From the CS+ ‘Debug’ menu select ‘Download’ to start the debug session and download code to the target.	
Once the program has been downloaded onto the RSK device, the program can be executed. Click the ‘Go’ button or press F5 to begin the program from the current program counter position.	

The program will display the following on the pmod display:

Renesas
RL78/G1G

Tutorial sample
Connect USB to PC
Serial configuration:
Baud Rate 19200
Data Bits 8
Stop Bits 1
Parity None
Flow None

Pressing SW3 or entering the character ‘C’ or ‘c’ in the serial terminal window will trigger an ADC conversion and display the resulting value on the terminal window and the LCD. In addition a modulo 16 counter is maintained that counts the number of requested ADC conversions. The count results are displayed on the PC and they are also represented on LEDs 0 to 3.

8. Additional Information

Technical Support
For details on how to use CS+, refer to the manual available on the DVD or from the web site.

Online technical support and information is available at: http://www.renesas.com/rskrl78g1g

For information about the RL78/G1G Group microcontrollers refer to the RL78/G1G Group Hardware Manual.

For information about the RL78 assembly language, refer to the RL78 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:
http://www.renesas.com/

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Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
2801 Scott Boulevard Santa Clara, CA 95050-2549, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130
Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004
Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-585-100, Fax: +44-1628-585-900
Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327
Renesas Electronics (China) Co., Ltd.
Room 1709, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100191, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679
Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, P. R. China 200333
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999
Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022
Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670
Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300
Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510
Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HALII Stage, Indiranagar, Bangalore, India
Tel: +91-80-67208700, Fax: +91-80-67208777
Renesas Electronics Korea Co., Ltd.
12F., 234 Teheran-ro, Gangnam-Gu, Seoul, 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141

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