User's Manual

32

RX231 Group

Hear-it! Solution Kit User's Manual

For e^2 studio

RENESAS MCU

RX200 Series

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Disclaimer

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The Solution Kit is not guaranteed to be error free, and the entire risk as to the results and performance of the Solution Kit is assumed by the User. The Solution Kit is provided by Renesas on an "as is" basis without warranty of any kind whether express or implied, including but not limited to the implied warranties of satisfactory quality, fitness for a particular purpose, title and non-infringement of intellectual property rights with regard to the Solution Kit. Renesas expressly disclaims all such warranties. Renesas or its affiliates shall in no event be liable for any loss of profit, loss of data, loss of contract, loss of business, damage to reputation or goodwill, any economic loss, any reprogramming or recall costs (whether the foregoing losses are direct or indirect) nor shall Renesas or its affiliates be liable for any other direct or indirect special, incidental or consequential damages arising out of or in relation to the use of this Solution Kit, even if Renesas or its affiliates have been advised of the possibility of such damages.

Precautions

The following precautions should be observed when operating any Solution Kit product:

This Solution 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 Solution 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 the demonstration application, how to use e^2 studio IDE to develop and debug software for the Hear-it! Solution Kit. It is intended for users designing code on the Hear-it! Solution Kit, using the many different incorporated peripheral devices.

The manual comprises of step-by-step instructions to load and debug a project in e^2 studio, but does not intend to be a complete guide to software development on the Hear-it! Solution Kit. Further details of the RX231 microcontroller may be found in the RX231 Group Hardware Manual and within the provided demonstration 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 Hear-it! Solution Kit. 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.
Quick Start Guide	Provides simple instruction to setup the solution kit and run the first sample.	Quick Start Guide	R12QS0007EG
Schematics	Full detail circuit schematics of Hear-it!	Hear-it! Solution Kit Schematics	R01UH0692EG
Hardware Manual	Provides technical details of the RX231 MCU.	RX230 Group, RX231 Group User's Manual: Hardware	R01UH0496EJ
BSP FIT application note	Provides technical details of how to integrate and use the BSP FIT module.	Board Support Package Module Using Firmware Integration Technology	R01AN1685EJ
DMACA FIT application note	Provides technical details of how to integrate and use the DMACA FIT module.	DMA Controller DMACA Control Module Using Firmware Integration Technology	R01AN2063EJ
CMT FIT application note	Provides technical details of how to integrate and use the CMT FIT module.	CMT Module Using Firmware Integration Technology	R01AN1856EU

RSPI FIT application note	Provides technical details of how to integrate and use the RSPI FIT module.	RSPI Clock synchronous Single Master Control Module Firmware Integration Technology	R01AN1914EJ
SSI FIT application note	Provides technical details of how to integrate and use the SSI FIT module.	SSI Module Using Firmware Integration Technology	R01AN2150EJ
USB host peripheral driver FIT application note	Provides technical details of how to integrate and use the USB peripheral driver FIT module.	USB Basic Mini Host and Peripheral Driver (USB Mini Firmware) Using Firmware Integration Technology	R01AN2166EJ
USB host CDC FIT application note	Provides technical details of how to integrate and use the USB host CDC FIT module.	USB Host Communication Device Class Driver for USB Mini Firmware Using Firmware Integration Technology	R01AN2167EJ
USB host mass storage class driver FIT application note	Provides technical details of how to integrate and use the USB host mass storage class driver FIT module.	USB Host Mass Storage Class Driver for USB Mini Firmware Using Firmware Integration Technology	R01AN2169EJ
Open source FAT file system FIT application note	Provides technical details of how to integrate and use the M3S-TFAT-Tiny FIT module.	Open Source FAT file System [M3S-TFAT-Tiny] Module Firmware Integration Technology	R20AN0038EJ

2. List of Abbreviations and Acronyms

Abbreviation	Full Form
ADC	Analog-to-Digital Converter
BTL	Bridge-Tied Load
BPF	Band-Pass Filter
CAN	Controller Area Network
CDC	Communication Device Class
CMT	Compare Match Timer
CODEC	Coder-decoder
DAC	Digital-to-Analog Converter
DMA	Direct Memory Access
DMAC	Direct Memory Access Controller
DSP	Digital Signal Processor
FAT	File Allocation Table
FIR	Finite Impulse Response
FIT	Firmware Integration Technology
HPF	High-Pass Filter
I^2S	Inter-IC Sound
ISR	Interrupt Service Routine
LPF	Low-Pass Filter
MCU	Microcontroller Unit
MTU	Multi-Function Timer Pulse Unit
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PGA	Programmable Gain Amplifier
PMOD™	Peripheral Module
RAM	Random Access Memory
RFP	Renesas Flash Programmer
ROM	Read Only Memory
RSPI	Renesas Serial Peripheral Interface
RTC	Real Time Clock
SCI	Serial Communications Interface
SPI	Serial Peripheral Interface
SSI	Serial Sound Interface
USB	Universal Serial Bus
WAV	Waveform Audio File Format

Table of Contents

1. Overview....10
1.1 Purpose....10
2. Introduction....11
2.1 Target Device....11
3. Description of Application Firmware....12
3.1 USB Playback Sample....12
3.2 Audio Streaming Sample....13
4. Hardware Design....14
4.1 Operating Check Conditions....14
4.2 Hardware Configuration....15
4.2.1 RX231 Microcontroller....15
4.2.2 Programmer/Debugger Connections....15
4.2.3 User Controls....15
4.2.4 USB Host Connection....15
4.2.5 PMOD™ Connectivity....16
4.2.6 WM8983 CODEC....16
4.2.7 Power Supply....16
5. Embedded Firmware Application Samples....17
5.1 Hardware Configuration....17
5.1.1 Switch Settings for Embedded E2-Lite Programmer/Debugger....17
5.1.2 Jumper Settings....17
5.1.3 Resistor Modifications....17
5.2 Starting e² studio and Importing Sample Code....18
5.3 Software Configurations....20
5.3.1 Streaming Sample Application....20
5.3.2 USB Playback Application....21
5.4 Build Configuration....22
5.5 Running in Debug Mode....23
5.6 Running the Hear-it! Application Code....23
6. Description of Software....24
6.1 USB Playback Sample....24
6.1.1 Operation....24
6.1.2 PCM Data Transfer....24

6.1.3 Volume Control 25

6.1.4 USB Device File Searching 26

6.2 Audio Streaming Sample 27

6.2.1 Operation 27

6.2.2 PCM Data Transfer – Audio Streaming Sample 27

6.2.3 DSP FIR Filter 28

6.2.4 Volume Control 29

7. Additional Information 30

1. Overview

1.1 Purpose

This Solution Kit is an evaluation tool for Renesas microcontrollers.

This manual describes the Hear-it! Solution Kit hardware and demonstration application

2. Introduction

The Hear-it! Solution Kit is designed to demonstrate the capability of the Renesas RX231 microcontroller in low cost audio processing applications. Digital filtering can be applied to an audio input source (3.5mm line-in or optionally a Mic input) and the result output to 3.5mm speaker or line-out connection. A demonstration of audio playback from a USB mass storage device connected to the USB Host connector is also provided. The single-board PCB also incorporates an integrated E2-Lite debugger/programmer, a PMOD^{TM} interface for connection of a display (supplied) and provides a flexible hardware and software platform to be used as a basis for further developments.

This user manual has been written to help the user understand the sample code provided with the Hear-it! Kit. It is intended to be read by those using the Hear-it! as a guide or starting point for their own applications.

Renesas Firmware Integration Technology (FIT) is used to initialise and drive hardware modules that are needed for this sample. Using FIT ensures the portability of this sample between different microcontrollers in the RX family.

2.1 Target Device

RX231 100pin LFQFP package, 512K/64K ROM/RAM, Part number R5F52318ADFP

3. Description of Application Firmware

The Hear-it! Solution Kit is supplied with 2 sample applications. One sample, rx231_usb_playback_demo, plays audio files in wav format from a USB mass storage device connected to the USB Host connector, CN9. The second sample, rx231_dsp_demo, demonstrates the application of digital FIR filtering to an audio stream.

3.1 USB Playback Sample

This sample implements an audio player capable of rendering 48 kHz 16-bit WAV- PCM format file stored on a USB device. A USB device can be attached to CN9 with a maximum of sixteen .wav files. Further details of the configuration of the USB is detailed in section 4.2.4.

The .wav files will be displayed on the PMOD™ display and can be highlighted and selected for audio playback using the on-board switch (SW3) and potentiometer (R43).

Audio information from the USB is sent by DMA transfer in I^2S format to the audio codec via the SSI interface for digital to analogue conversion and output to speaker and/or headphone. Once a .wav file is selected and has started playing, the on-board potentiometer can be used to control the output volume. This volume control is implemented with an attenuation function in the sample application software, or optionally by configuring the volume on the WM8983 CODEC IC. Figure 3-1 gives a holistic outline the USB audio playback.

Caution:
Headphones should be connected to the 3.5mm line-out connector CN5. Connector CN6 is designed to connect to a speaker only. It is not recommended to attach headphones to speaker connection CN6, as damage to the headphones may occur. Refer to section 4.2.6 for further information.

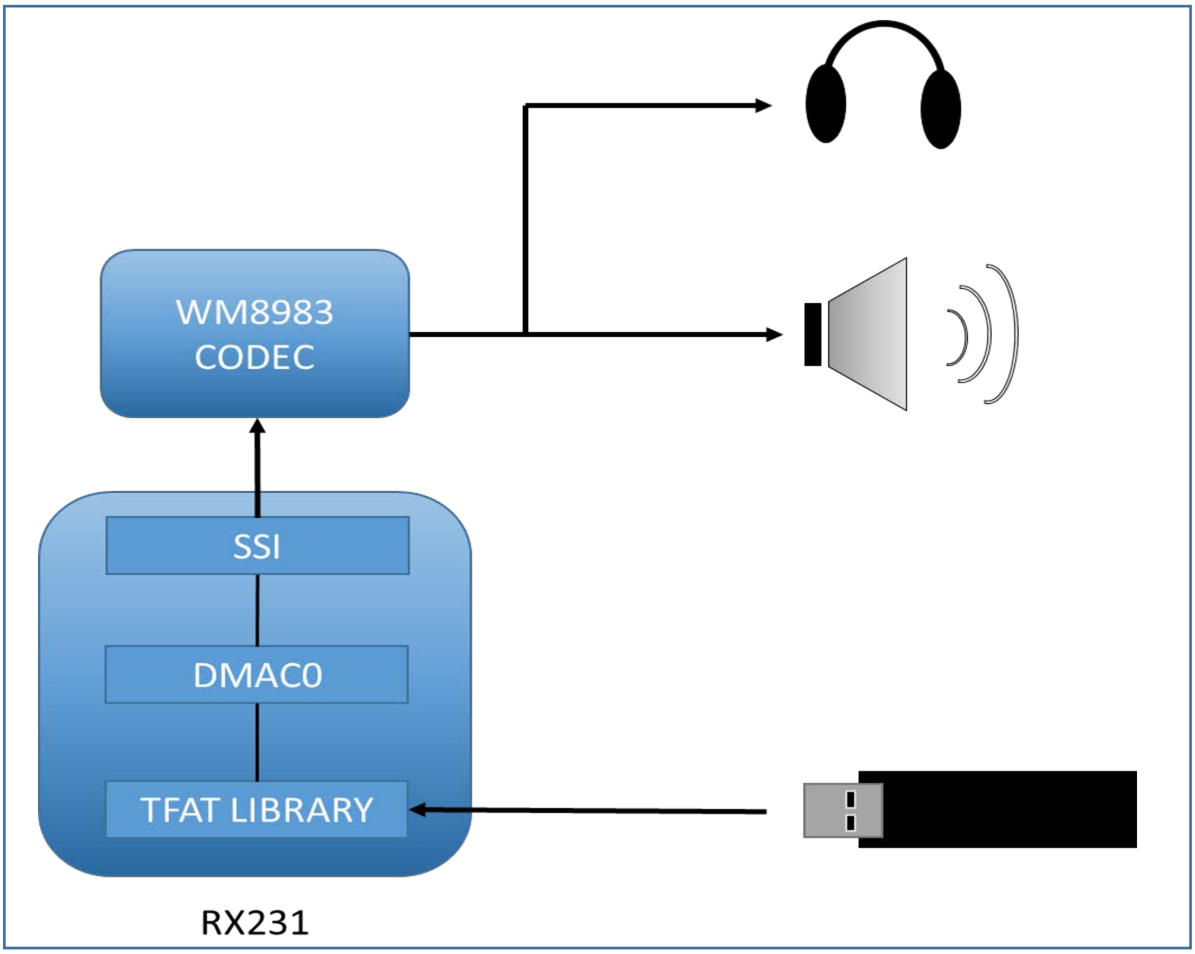


Figure 3-1 : USB Audio Playback

3.2 Audio Streaming Sample

The second sample, rx231_dsp_demo, demonstrates the application of a DSP FIR filter on the left or right channel of an incoming audio signal from the line-in or microphone inputs. The modified audio stream is then transmitted to the audio codec via DMA and the SSI peripheral and then out to the speaker and/or headphones. Figure 3-2 shows a holistic outline of the audio streaming. As with the USB playback demonstration, the volume control is implemented with a software attenuation function, with an option in the source code for control via the codec directly. There further configuration available in the source code to select the left or right channel as the input source, and the left, right or both channels as output source.

The output volume can be controlled by adjusting the potentiometer, R43. Switch SW3 cycles between the different FIR filter profiles; Flat, High Pass, Low Pass, Band Pass where the audio is playing.

Caution:
Headphones should be connected to the 3.5mm line-out connector CN5. Connector CN6 is designed to connect to a speaker only. It is not recommended to attach headphones to speaker connection CN6, as damage to the headphones may occur. Refer to section 4.2.6 for further information.

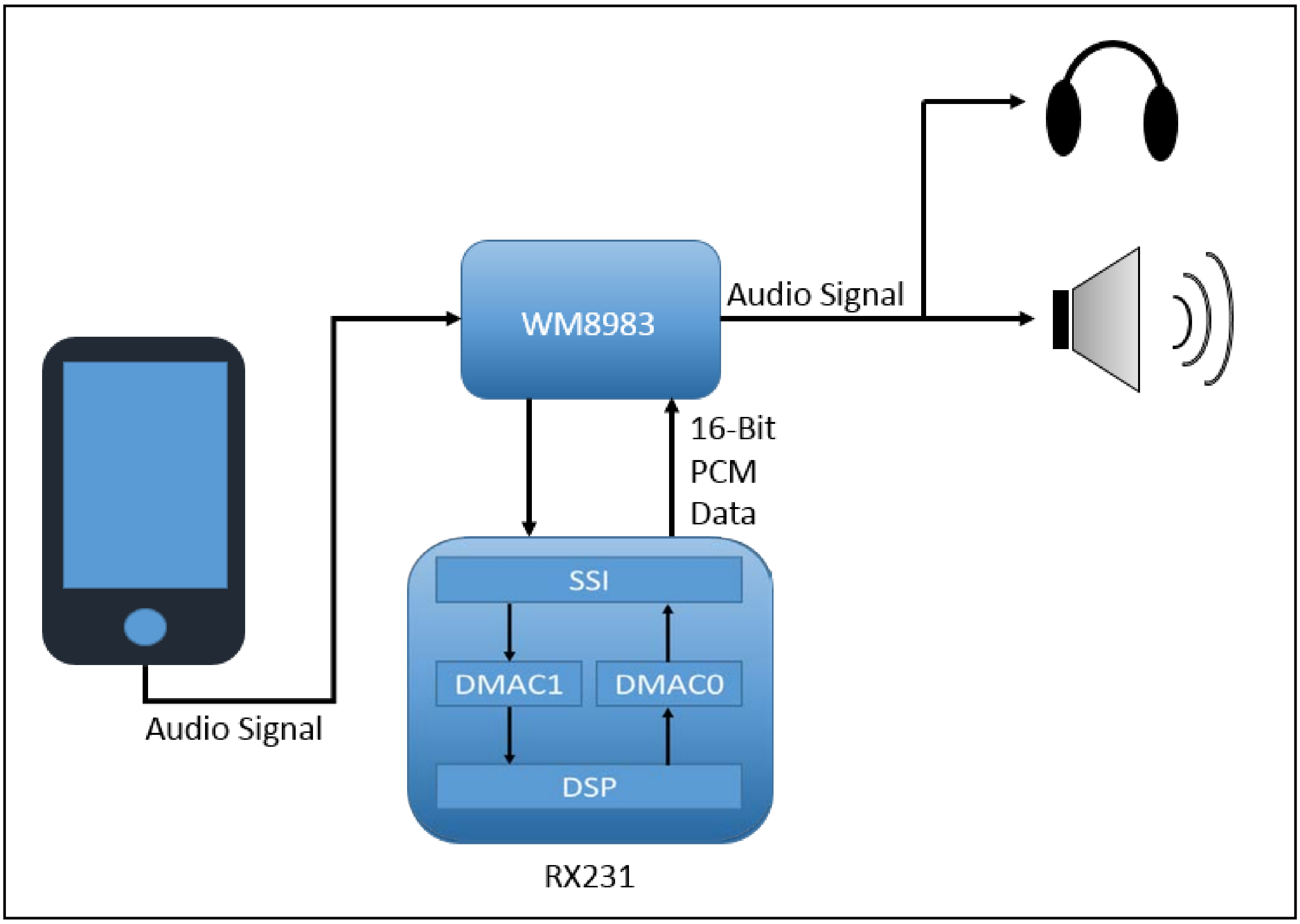


Figure 3-2 : Audio Streaming Mode

4. Hardware Design

- Hear-it! Solution Kit.
- 3.5mm line-in input audio jack (CN7).
- 3.5mm line-out output audio jack for headphones (CN5).
- 3.5mm audio jack for speaker connection (CN6). The output is set to drive a mono speaker in BTL configuration. See Figure 4-1.

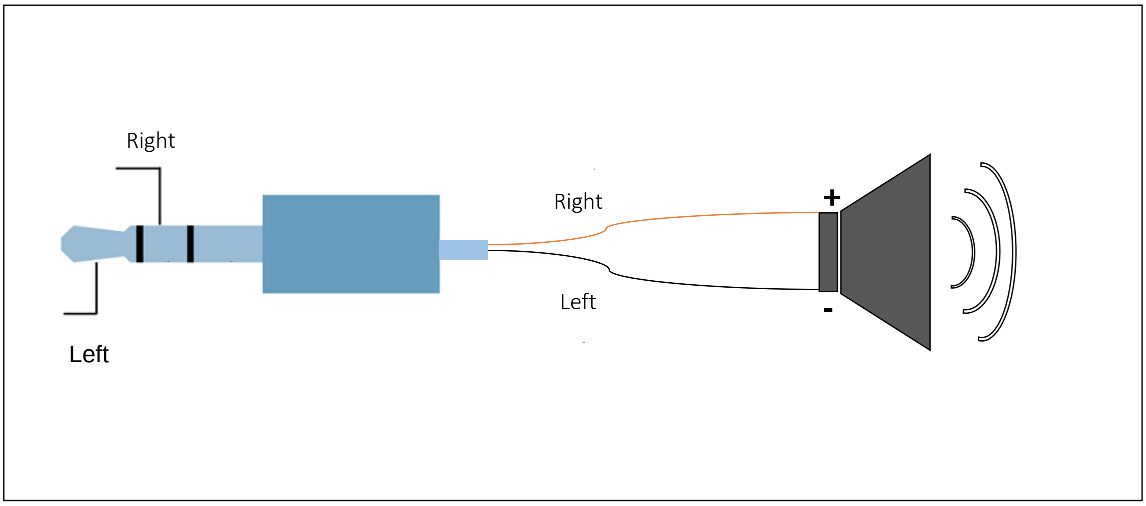


Figure 4-1 : BTL Speaker Configuration

4.1 Operating Check Conditions

The sample code described in this user manual has been checked under the conditions listed in Table 4-1.

Item	Description
Microcontroller used	RX231 (R5F52318ADFP)
Operating frequency	Maximum operating frequency – 54 MHz PCLKA : 54 MHz PCLKD : 54 MHz BCLK : 32 MHz FCLK : 32 MHz
Power Supply Operating Voltage	5.0Vdc
Integrated development environment	e^2 studio version 5.3
Toolchain	Renesas RXC Toolchain v2.06
Board used	Hear-it! Solution Kit

Table 4-1 : Operating Conditions

4.2 Hardware Configuration

The Hear-it! Solution Kit hardware consists of the RX231 microcontroller and associated circuitry, a WM8983 CODEC IC, a USB Host connector, embedded E2-Lite programmer/debugger, PMOD^{TM} connector and power supply.

4.2.1 RX231 Microcontroller

The RX231 fitted to the Hear-it! PCB has the Renesas part number R5F52318ADFP. It is a 100pin LFQFP package with 512kB Flash ROM, 64kB RAM and 8kB DataFlash. The 32-bit CPU can be clocked at up to 54MHz and supports single precision floating point operations. The RX231 microcontroller incorporates extensive supporting peripherals such as DMA, multiple timers, multiple communications functions such as SSI, SCI, I^{2}C, SPI, CAN, 12-bit ADC and DAC, capacitive touch-sensing.

The circuitry supporting the RX231 microcontroller consists of an 8MHz main oscillator, Real-Time-Clock oscillator (RTC) (not fitted as standard), programmer/debugger connections and a potentiometer and switch for user input.

4.2.2 Programmer/Debugger Connections

By default the Hear-it! board uses the embedded E2-Lite programmer/debugger to access the RX231 microcontroller. There is provision to fit a 14-way connector (Samtec part number SAM_HTST-107-01-X-DV) to support connection of an external E1 or E2-Lite programmer/debugger if required. If an external debugger is used, the embedded E2-Lite debugger must be deactivated by setting it to 'standalone' mode, achieved by setting both switches in the switch block SW1 to the 'OFF' position, see Figure 4-2.

Figure 4-2 : Debugger Isolating Switch SW1 in "Off" Position

4.2.3 User Controls

Inputs from the user are taken from the potentiometer R43, for up and down menu control and switch SW3, for user selection. The potentiometer is read on the MCU's ADC channel 0 (P4-0, pin 95). The reading, as a percentage of the full scale, is used to determine which menu item is currently highlighted by the user.

The momentary action switch, SW3 is connected to a hardware interrupt line IRQ1, (P3-1, pin 19). This provides an interrupt to handle switch presses with a minimum of CPU intervention. The switch is used to determine the user's selection in the current menu.

4.2.4 USB Host Connection

A USB Host connection is provided, for connection of a USB mass storage device on connector CN9. It is not intended that this is used to supply significant power to any connected devices. It is recommended to keep the current drawn to below 200mA.

4.2.5 PMOD™ Connectivity

The Hear-it! Solution kit is distributed with a 128x128 colour display, driven from the PMOD™ connector on CN2. Communications between the MCU (IC7) and the PMOD™ display are made by the on-board SCI9 peripheral, in SPI transmit only mode, plus various other signals to manage device select, reset and backlight control.
The connection of the display to the microcontroller is shown in Figure 4-3 and Table 4-2. Note that the pinout for the PMOD™ connector is not made in the standard fashion of left to right ascending, but ascending on the left then on the right, as per the PMOD™ standard.

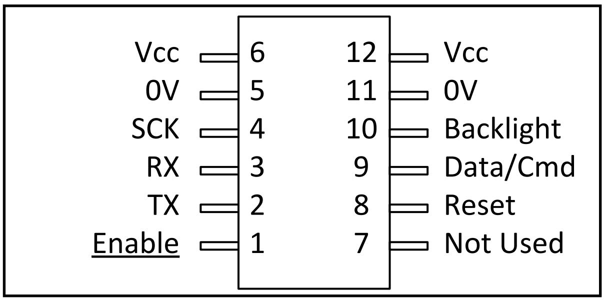


Figure 4-3 : Connection Diagram for PMOD™ display on CN2

CN2 PMOD™ Pin	Function	IC7 MCU Pin	IC7 MCU Port/Pin, function	Schematic Signal
1	Enable (Chip Select) (Active Low)	17	P33, I/O	PMOD_CS
2	TX	53	PB7, SCI9 TX	TXD9
3	RX (Not used on display)	54	PB6, Not Used	RXD9
4	SCK	55	PB5, SCI9 SCK	SCK9
7	Not used on display	72	PE6, Not Used	IRQ6
8	Reset	71	PE7, I/O	IRQ7
9	Data/Cmd	75	PE3, I/O	PE3
10	Backlight	74	PE4, I/O	PE4

Table 4-2 : Connection Details for PMOD™ Display on CN5

4.2.6 WM8983 CODEC

The Hear-it! Solution Kit board incorporates a Cirrus Logic WM8983 Stereo CODEC with speaker driver. This provides Line-In and MIC inputs and outputs for a headphone and speaker (up to 1W). The MIC input connector CN8 is not fitted by default on the PCB. If it is required then the recommended part is SJ-3506-SMT-TR from CUI. Audio data is transferred to and received from the RX231 MCU by SSI interface, and a separate SPI connection is used to configure the CODEC, on SCI8 of the RX231 MCU.

The audio clock for the CODEC is a 12.288MHz oscillator, OSC1, which is also fed to the RX231 MCU on pin 16, P34 for the SSI interface.

Caution:
Headphones should be connected to the 3.5mm line-out connector CN5. Connector CN6 is designed to connect to a speaker only. It is not recommended to attach headphones to speaker connection CN6, as damage to the headphones may occur.

4.2.7 Power Supply

The Hear-it! Solution Kit can be powered either from the embedded programmer/debugger USB-mini function connector CN4, or by a 5V supply connected to CN1, with a standard centre-positive barrel connector. The connection from CN1 is intended to provide the lowest noise solution. No modification or configuration is required to use either source. A 3.3V supply for the MCU, PMOD™ and CODEC is provided by regulator IC1. The RX231 MCU is supplied through header JP1/R12, to allow the current consumption of the RX231 MCU to be evaluated.

5. Embedded Firmware Application Samples

The Hear-it! Solution Kit is shipped with the application firmware pre-programmed to run the 'streaming' demonstration configured to use the left channel. The application firmware can be programmed or run in debug mode via the embedded E2-Lite programmer/debugger and the e^2 studio IDE or programmed by the Renesas Flash Programmer (RFP) on the PC.

- Fit the PMOD™ display to the board on connector CN2.
- In order to run standalone, ensure that switch SW1 is configured for standalone mode. Refer to Table 5-2 for the correct settings. Make the audio connections as required and then apply power by connecting the mini-USB function connector CN4 to the PC or by connecting a 5V supply to the centre-positive barrel connector CN1 if desired.
- For debug or programming, refer to Table 5-1 for the correct settings for switch SW1. Make the required audio connections. Connect the mini-USB function connector CN4 to the host PC using the supplied cable. The Hear-it! Solution kit is now ready for programming/debug operations

When running the 'streaming' demo, ensure potentiometer R43 is turned fully anti-clockwise before operating the demonstration. This potentiometer controls the volume. When playing audio through the device slowly turn clockwise to listen to the audio at the appropriate volume.

5.1 Hardware Configuration

5.1.1 Switch Settings for Embedded E2-Lite Programmer/Debugger

For standalone operation or if using external E1 debugger, ensure that SW1 has the settings shown in Table 5-2. For programming or debugging, the SW1 should be set as described in Table 5-1.

	SW1-1	SW1-2	
State	ON	ON	

Table 5-1 : SW1 Configuration for Programming/Debug Operation

	SW1-1	SW1-2	
State	OFF	OFF	

Table 5-2 : SW1 Configuration for Standalone Operation

5.1.2 Jumper Settings

Ensure that the following jumpers are **NOT** connected.

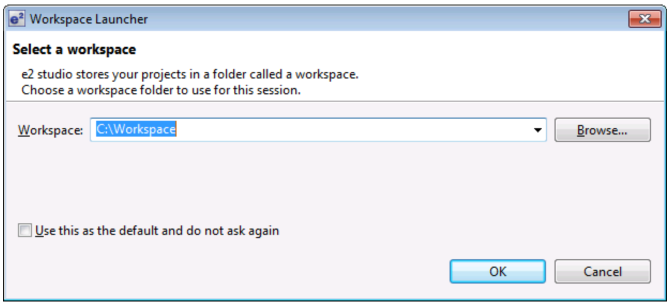
- JP1
- JP2

5.1.3 Resistor Modifications

No resistor modification to the default Hear-it! Solution Kit is required.

5.2 Starting e² studio and Importing Sample Code

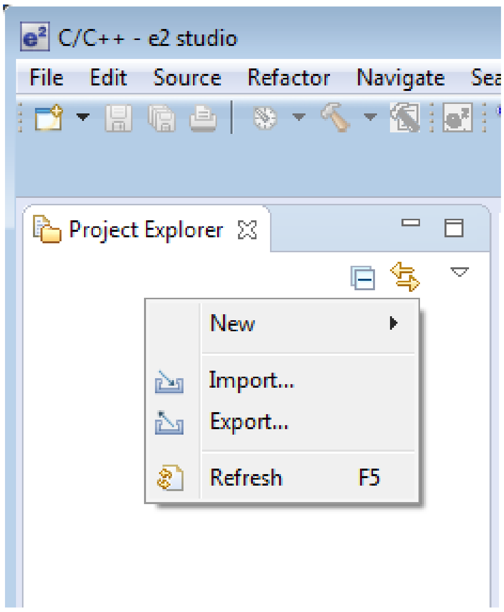
Start e² studio by selecting it from the Windows™ Start Menu. The first dialog box to appear will be the Workspace Launcher.



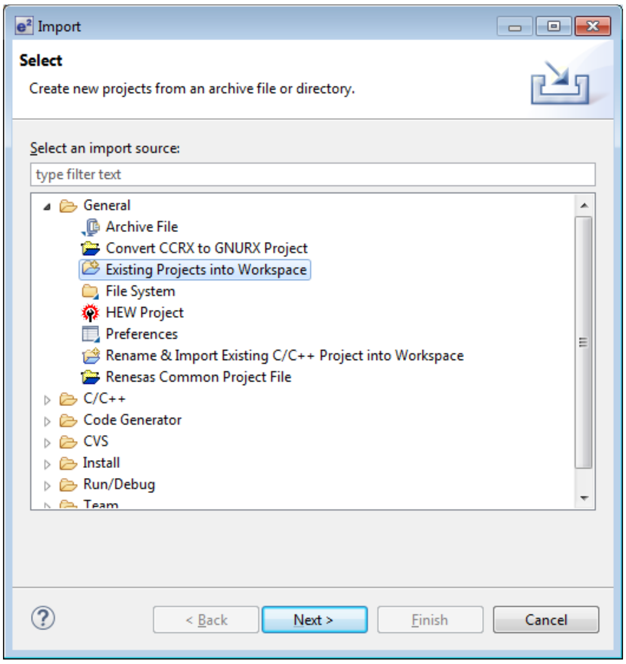
Click 'Browse' and select a suitable location to store your workspace, using the 'Make New Folder' option as necessary. Click 'OK'.

The e² studio welcome splash screen will appear. Click the 'Go to the e² studio workbench' arrow button on the far right (circled in the screenshot opposite).

Once the environment has initialized, right click in the 'Project Explorer' window and select 'Import…'



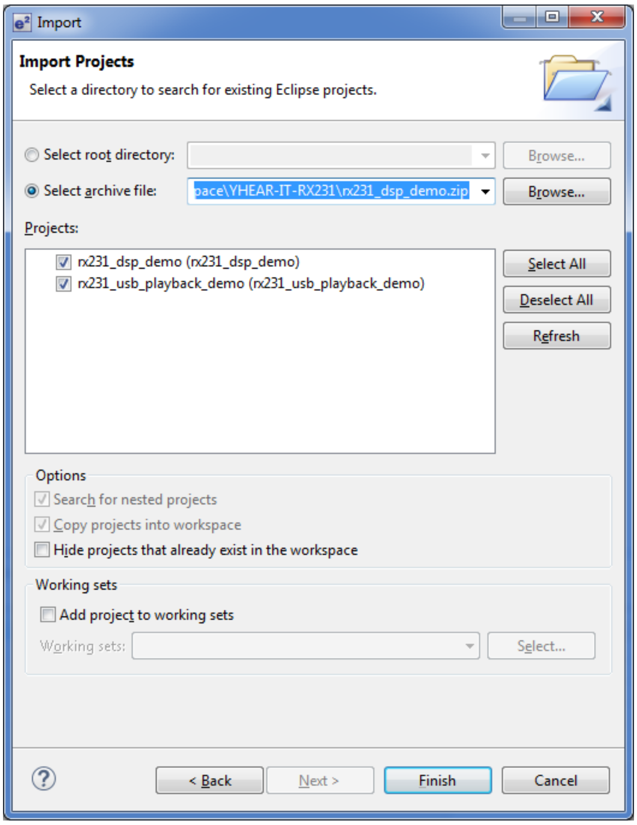
The Import dialog box will be shown. Expand the ‘General’ folder icon, and select ‘Existing Projects into Workspace’, then click ‘Next’.



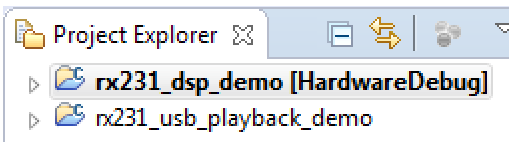
The Import dialog box will allow you to specify projects to import. Click the ‘Select archive file:’ button, then click “Browse…” and locate the following directory:

C:\Renesas\Workspace\Y-HEAR-IT-RX231

Select the file ‘rx231_dsp_demo.zip’ and click ‘Open’. Ensure that both projects are selected and then click ‘Finish’.



The projects will be imported into the workspace:



5.3 Software Configurations

5.3.1 Streaming Sample Application

The Hear-it! Streaming sample application, "rx231_dsp_demo" has various configurable options. These are located in the source file main.h.

5.3.1.1 Input Channel Selection

The input audio channel to be used for the DSP processing can be configured by setting the AUDIO_CHANNEL #define to the LEFT channel or the RIGHT channel. This can be seen in Figure 5-1 where AUDIO_CHANNEL is set to LEFT (default setting).

```
/*****************************************************************************
 Set active channel in streaming mode to LEFT or RIGHT as required
 *****************************************************************************/
        #define AUDIO_CHANNEL       (LEFT)

        #define LEFT                (1)
        #define RIGHT               (2)
```

Figure 5-1 : Streaming Input Channel Configuration

5.3.1.2 Output Channel Selection

The application can be configured to select the channel or combination of channels to use for the processed audio output. The default setting is for both channels to be used as the output.

```
/******************************************************************************
 Set active output channel in streaming mode to LEFT, RIGHT or BOTH_CHANNELS,
 as required
 ******************************************************************************/
    #define AUDIO_OUTPUT_CHANNEL    (BOTH_CHANNELS)

    #define LEFT                          (1)
    #define RIGHT                         (2)
    #define BOTH_CHANNELS                 (3)
```

Figure 5-2 : Streaming Output Channel Configuration

5.3.1.3 Volume Control Scheme

The sample application by default uses a software attenuation function to control the volume of the audio signal. It is possible to configure the application to use the CODEC to control the volume. In order to select this, uncomment the following #define

```
/* Comment out the define VOLUME_CONTROL_FW_ATTENUATOR to use the CODEC to control volume.
 * Otherwise the DSP attenuation function will control volume
 * (and the CODEC will be set to max volume).
 */
    #define VOLUME_CONTROL_FW_ATTENUATOR    (1)
```

Figure 5-3 : Streaming Volume Configuration Selection

5.3.1.4 Microphone Input

The microphone input, CN8 is not fitted to the Hear-it! board by default. If the microphone input is to be used in the streaming application, the CODEC must be configured to enable its internal PGAs (Programmable Gain Amplifiers) in order to allow the audio signal from the MIC input to be used.

This is achieved by un-commenting the #define ENABLE_MICROPHONE, in the main.h file.

```
/******************************************************************************
 Define ENABLE_MICROPHONE to allow the microphone input to be used
 ******************************************************************************/
/* #define ENABLE_MICROPHONE */
```

Figure 5-4 : Enabling the MIC input CN8

5.3.2 USB Playback Application

5.3.2.1 File Selection

This sample allows the user to select .wav files from a USB drive attached to the USB Host connector CN9 and to play the audio on the speaker/headphones. The USB drive must contain a folder called ‘Music’. The Music folder may hold a maximum of 16 .wav files. Ensure the USB drive contains the ‘Music’ folder as seen in the figure below and contains .wav files. The available .wav files will be shown on the display connected on PMOD™ connector CN2. Use pot R43 and switch SW3 to select the desired track to play.

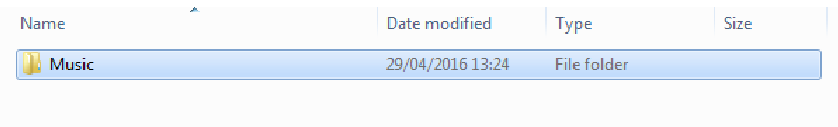


Figure 5-5 : Music Folder on USB Drive

5.3.2.2 Volume Control Scheme

The sample application by default uses a software attenuation function to control the volume of the audio signal. It is possible to configure the application to use the CODEC to control the volume. In order to select this, uncomment the following #define in main.h

```
/* Comment out the define VOLUME_CONTROL_FW_ATTENUATOR to use the CODEC to control volume.
 * Otherwise the DSP attenuation function will control volume
 * (and the CODEC will be set to max volume).
 */
   #define VOLUME_CONTROL_FW_ATTENUATOR     (1)
```

Figure 5-6 : Streaming Volume Configuration Selection

5.4 Build Configuration

The e^2 studio project has two build configurations for each sample: ‘HardwareDebug’ and ‘Release’:

HardwareDebug

This Build Mode has all optimisation turned off, and provides full debug information. This is the best configuration to use whilst developing code as C code execution will be linear.

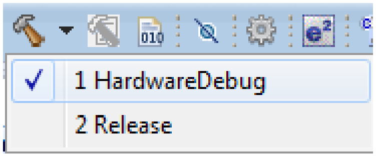
Release

This Build Mode has optimisation turned on, and provides no debug information. The C code execution may appear to be out of order, due to the way compiler optimises the code. This build configuration is intended for final ROM-programmable code.

By default, the project is configured to HardwareDebug build configuration.

Setting the build configuration

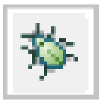
Click the top level ‘rx231_dsp_demo’ or ‘rx231_usb_playback_demo’ folder, then the arrow next to the build button (hammer icon), and select the required option.

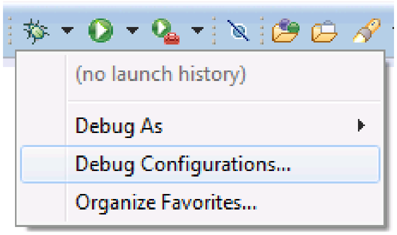


e^2 studio will then set the current build configuration to the selected option and build accordingly.

5.5 Running in Debug Mode

Click the arrow next to the debug button (bug icon). Select 'Debug Configurations

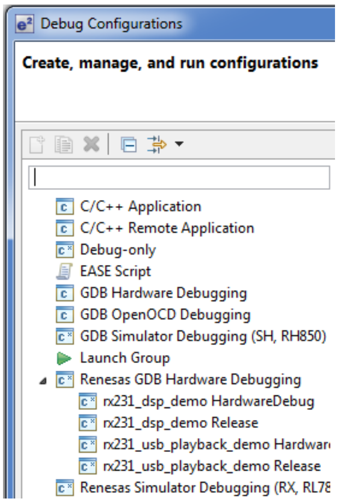




The 'Debug Configurations' dialog box will appear. Click the small arrow next to the 'Renesas GDB Hardware Debugging' option.

The debug configurations for each project will appear. The examples for the streaming application rx231_dsp_demo are shown to the right. Select the entry for the required debug configuration.

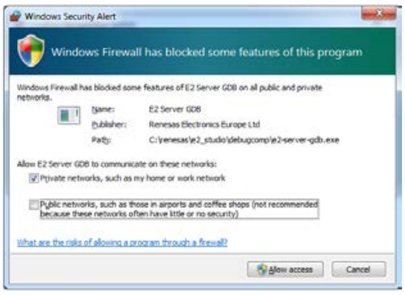
If the configuration has been built and the required executable is present, the 'Debug' button in the bottom right of the window will be active.



Click the 'Debug' button to continue. e^2 studio will now connect to the debugger and download the code to the target.

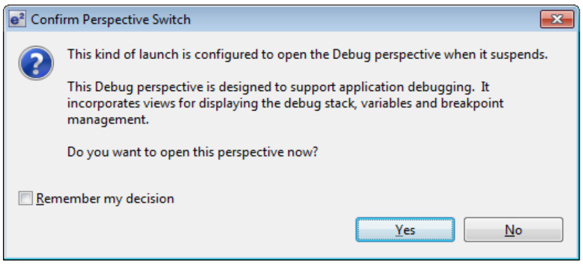
A firewall warning may be displayed for 'e2-server-gdb.exe'. Check the 'Private networks, such as my home or work network' box and click 'Allow access'.

A user account control dialog may be displayed. Enter the administrator password and click 'Yes'.



After downloading the code a dialog box will appear asking if you would like to switch to the 'Debug perspective'. Click 'Remember my decision' to prevent this dialog box from appearing in future, then click 'Yes'.

e^2 studio will load the new perspective, which is optimised for debugging.



5.6 Running the Hear-it! Application Code

Once the code has been downloaded, click the 'Resume' button  to run the code to the main function. The main function is the default program entry point. The program counter will stop on the first instruction in the main function.

Click the 'Resume' button  in the 'Debug' perspective to run the rest of the code.
Follow the instructions on the PMOD™ display.

6. Description of Software

The choice between USB audio playback and streaming from line-in or MIC input is achieved through conditional compilation of the application software project. Refer to section 5.3 for details of the conditional compilation required to change operating modes.

6.1 USB Playback Sample

6.1.1 Operation

After reset, the sample waits for a USB mass storage device to be connected to the USB connector CN9. Once this occurs, the user is first presented with a list of available .wav files in the 'Music' folder. The user can choose an audio file from the list by using the potentiometer and pressing SW3 to select. Once the file has been selected, file playback is paused so that the user can adjust the volume to a suitable level, using the pot R43 (as the pot has just been used to select the file, the volume may start at a surprising level). Pressing switch SW3 starts playback of the file, and SW3 can then be used to pause or resume during the file playback. The pot R43 can be used to control the volume of the speaker (and headphones if fitted). Visual indication of status, volume and progress are shown on the display.

Caution:
Headphones should be connected to the 3.5mm line-out connector CN5. Connector CN6 is designed to connect to a speaker only. It is not recommended to attach headphones to speaker connection CN6, as damage to the headphones may occur. Refer to section 4.2.6 for further information.

6.1.2 PCM Data Transfer

The transfer of PCM data from the .wav file on the USB drive to the audio CODEC is managed by a receive buffer for data pulled from the USB drive and a corresponding transmit buffer to send data to the CODEC via the SSI interface. The Renesas TFAT FIT module is used to transfer data from the USB to the receive buffer. Internally, data is transferred from receive buffer to transmit buffer by a memcpy function. The 16-bit PCM data in the transmit buffer is sent to the CODEC via the SSI interface by the DMAC microcontroller peripheral, matching the sampling frequency of the wav files at 48kHz.

In order to achieve seamless playback each buffer is divided into 3 sub-blocks. The data being transferred into a buffer is always being placed into a different sub-block to the data being transferred out of the buffer to the next stage. The changeover process for updating the active read/write blocks is managed in the DMAC0 end of transfer interrupt, which is the slowest part of the chain from USB to CODEC. In this way, the CODEC has a continuous supply of data.
Figure 6-1 shows this transfer graphically. Table 6-1 shows the operations in progress at each step.

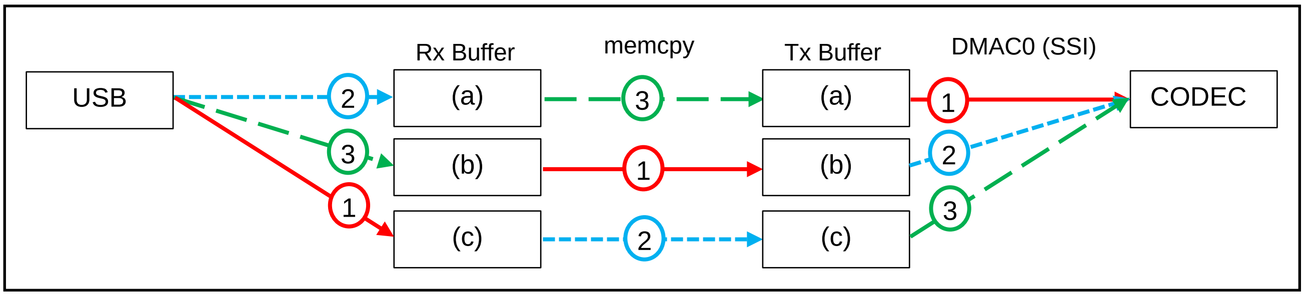


Figure 6-1 : USB Playback Mode Buffer Processing Overview

Step	USB operation	memcpy operation	DMAC0 operation
1	**data read into rx buffer (c)**	**rx buffer (b) to tx buffer (b)**	**tx buffer (a) to CODEC**
2	**data read into rx buffer (a)**	**rx buffer (c) to tx buffer (c)**	**tx buffer (b) to CODEC**
3	**data read into rx buffer (b)**	**rx buffer (a) to tx buffer (a)**	**tx buffer (c) to CODEC**

Table 6-1 : USB Playback Mode Buffer Operations

The SSITX empty interrupt triggers DMAC0 channel to transfer data from the active tx buffer to the CODEC. The DMAC0 transfer end interrupt handler updates the active sub-blocks for the g_pcm_buffer_tx and g_pcm_buffer_rx buffers. It also requests more data to be read from the USB device to be stored at the current receive buffer and triggers to transfer of data from the rx buffer to the tx buffer. The process is illustrated in Figure 6-2.

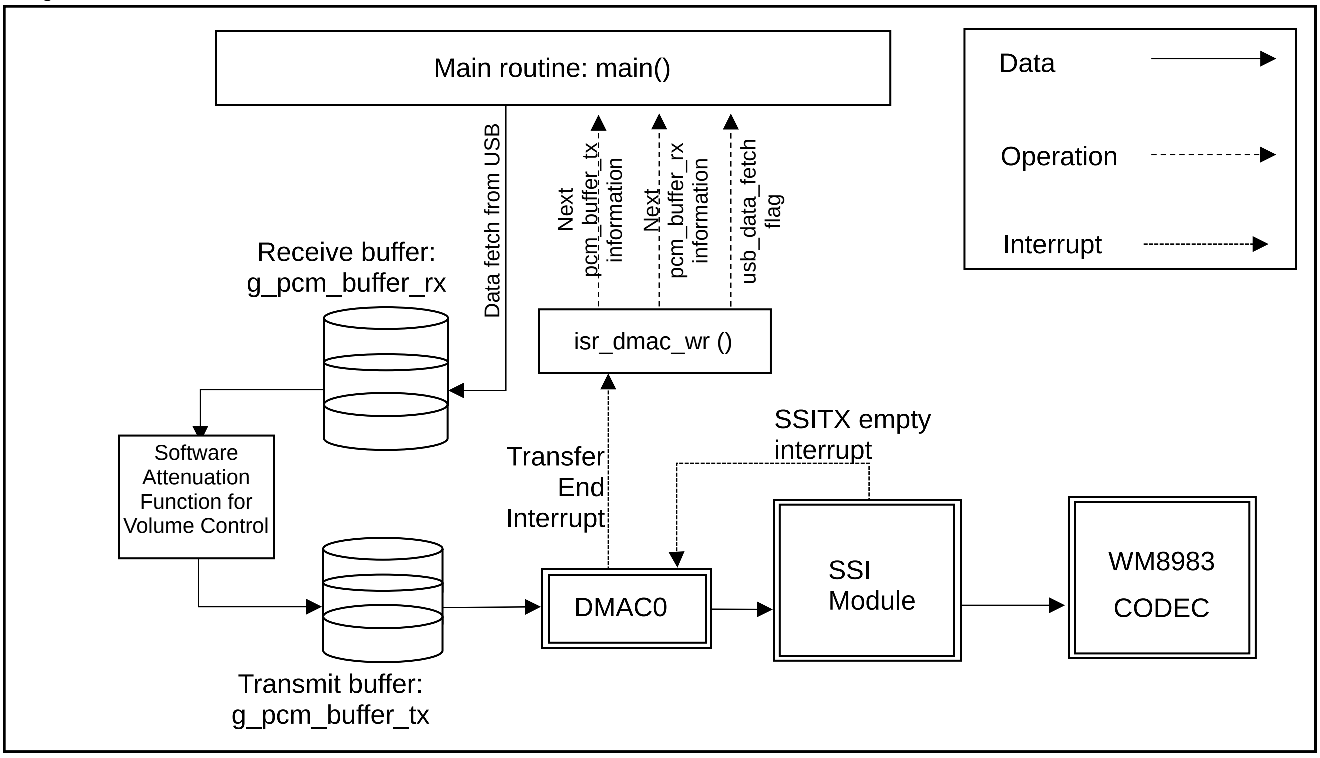


Figure 6-2 : Data Transfer Scheme in USB Playback Mode

6.1.3 Volume Control

The volume of the audio signal is controlled by default by an attenuation function in software. This is called when the audio block is transferred to the transmit buffer prior to transmission to the CODEC for output. Optionally, the volume can be controlled directly by the CODEC, based on configuration in the source code. See section 5.3.2.2 for further details.

6.1.4 USB Device File Searching

The sample currently searches the root directory of the USB device for a folder named 'Music'. If the folder exists, the sample searches for '.wav' files within the 'Music' folder and stores the file names in a RAM in a 'left child right sibling' data structure. Currently, the sample does not search directories other than the root and the 'Music' directory. It simply adds the found '.wav' files in 'Music' folder as "right-siblings" of the first found '.wav' file. However, the data structure can easily be adapted to implement a more complex search tool that includes searching multiple directories.

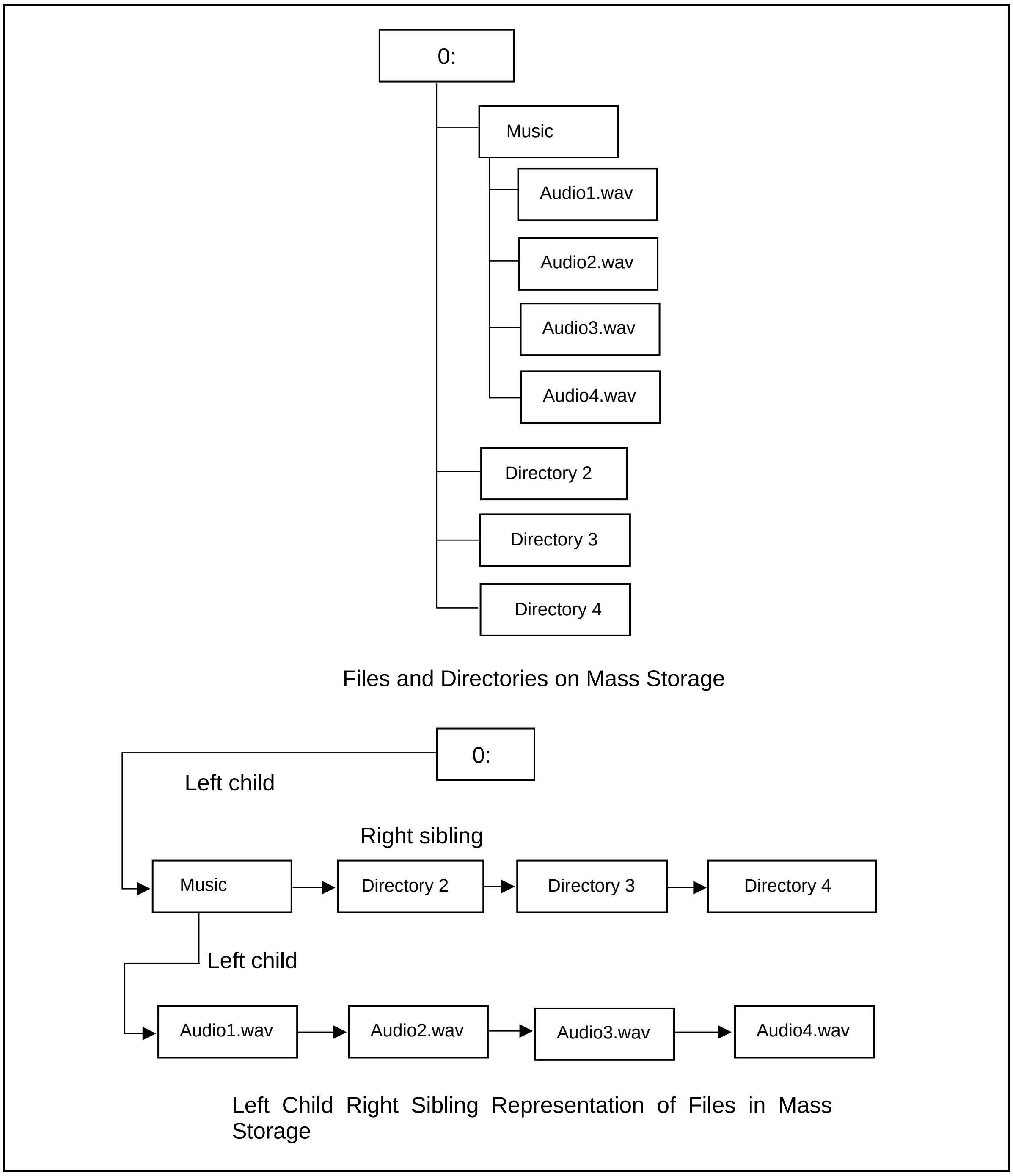


Figure 6-3 : Representation of Files in Mass Storage Device

6.2 Audio Streaming Sample

6.2.1 Operation

After reset, the sample sets up the display and begins streaming of audio from the selected input channel to the output. The user can switch between the available FIR filter profiles by pressing the button SW3. The pot R43 can be used to control the volume of the speaker (and headphones if fitted). Visual indication of status and volume are shown on the display.

Caution:
Headphones should be connected to the 3.5mm line-out connector CN5. Connector CN6 is designed to connect to a speaker only. It is not recommended to attach headphones to speaker connection CN6, as damage to the headphones may occur. Refer to section 4.2.6 for further information.

6.2.2 PCM Data Transfer – Audio Streaming Sample

16-bit PCM data is generated by the CODEC from the input source and transferred to the receive buffer from the RX231 SSI(rx) peripheral by DMAC channel 1. The received data is then passed through the DSP filter to the transmit buffer. This data is then transmitted to the CODEC by DMAC0 and the RX231 SSI(tx) peripheral for output to speaker/line-out. The sampling frequency for the PCM data is set to 24kHz.

In order to achieve seamless playback each buffer is divided into 3 sub-blocks. The data being transferred into a buffer is always being placed into a different sub-block to the data being transferred out of the buffer to the next stage. In this way a continuous supply of data can be maintained.

Figure 6-4 shows this transfer graphically and Table 6-2 shows the operations in progress at each step.

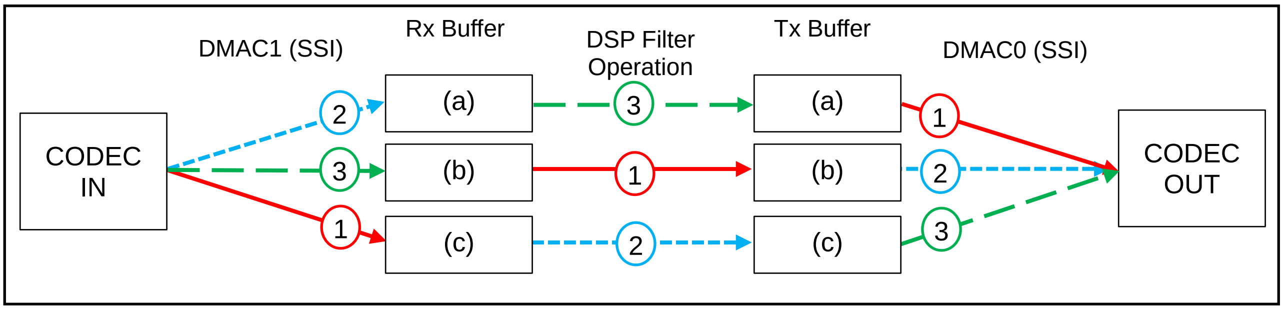


Figure 6-4 : Audio Streaming Mode Buffer Processing Overview

Step	DMAC1 operation	DSP filter operation	DMAC0 operation
1	**data read into rx buffer (c)**	**rx buffer (b) to tx buffer (b)**	**tx buffer (a) to CODEC**
2	**data read into rx buffer (a)**	**rx buffer (c) to tx buffer (c)**	**tx buffer (b) to CODEC**
3	**data read into rx buffer (b)**	**rx buffer (a) to tx buffer (a)**	**tx buffer (c) to CODEC**

Table 6-2 : Audio Streaming Mode Buffer Operations

PCM data transfer between the MCU and the audio Codec is handled by the SSI module and two DMAC channels. The SSITX empty and SSIRX full interrupts trigger DMAC0 and DMAC1 channels respectively. The process is illustrated in Figure 6-5.

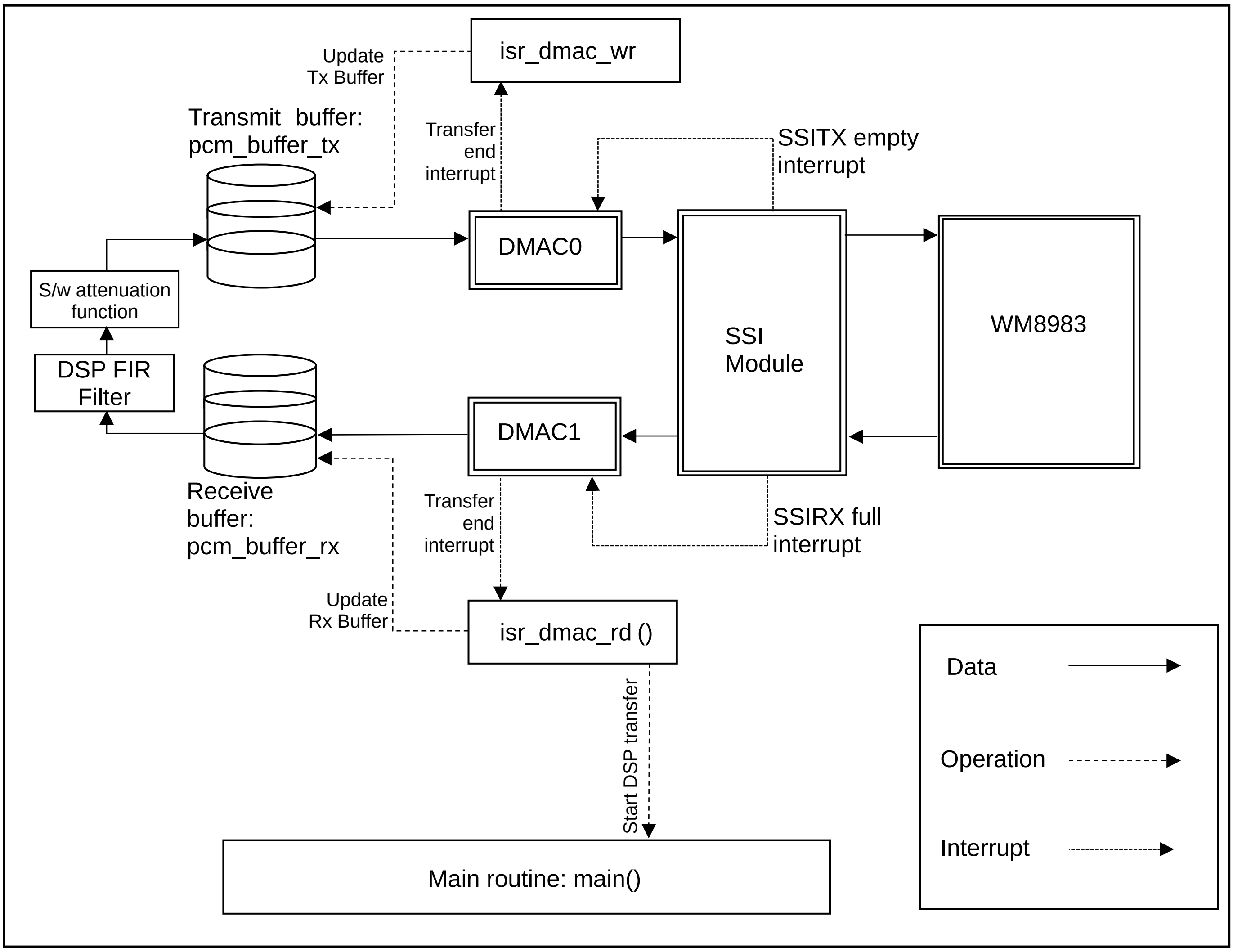


Figure 6-5 : Data Transfer Scheme in Audio Streaming Mode

6.2.3 DSP FIR Filter

As seen in Figure 6-5, the selected DSP FIR filter profile is applied to the sampled audio information when it is transferred from the receive buffer pcm_buffer_rx to the transmit buffer pcm_buffer_tx. There are 4 pre-set filter profiles; FLAT, LPF, HPF and BPF, defined for a sampling frequency of 24kHz.

These filter profiles are defined in the following files, located in the r_dsp_fir subfolder:

FLAT	coef_flat_i32.h
LPF	coef_lpf1k_i32.h
HPF	coef_hpf1500_i32.h
BPF	coef_bpf_200_8000_i32.h

These profiles are used to initialise the DSP fir filter, which is then called repeatedly to act on the audio information being transferred, in the file r_dsp_fir.c.

For further information concerning the DSP filter and its API, refer to the Renesas document R01UW0128ES which is located within the DSP Library c-source download on the Renesas website.

Various tools are available for creating FIR filter profiles on the internet, but it is beyond the scope of this document to investigate this further.

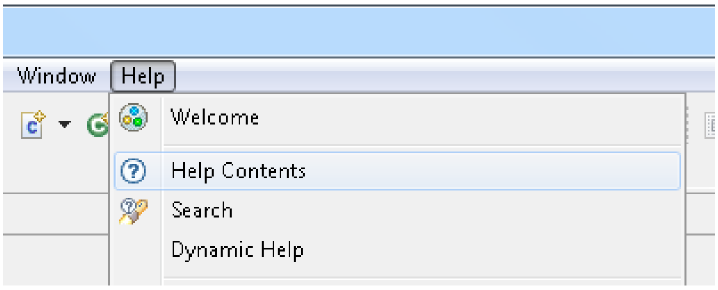
6.2.4 Volume Control

The volume of the audio signal is controlled by default by an attenuation function in software. This is called when the audio block is transferred to the transmit buffer prior to transmission to the CODEC for output. Optionally, the volume can be controlled directly by the CODEC, based on configuration in the source code. See section 5.3.1.3 for further details.

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 RX231 Group microcontrollers refer to the RX231 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 9 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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		Page	**Summary**
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1.10	Apr 03, 2017	—	Updated with application code

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