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ADK I²S

User Guide

Issue 3

Document History

Revision	Date	History
1	22 JAN 15	Original publication of this document
2	15 AUG 14	Sections 1, 2, 5.2, 5.5, 6 and Document References updated.
3	22 JAN 15	Update for digital amp in ADK 3.5.1

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Tables, Figures and Equations

1. Introduction

This document describes how to configure the Headset, Subwoofer or Soundbar applications in the ADK for I^2S operation.

I^2S operation can be configured to suit a variety of different I^2S audio devices and allows initialisation as well as volume control through the I^2C interface. Configuration is set using PS Keys.

This document provides an example configuration for use with an Analogue Devices SSM2518 external amplifier device.

Note:

PS Key configuration settings for the SSM2518 amplifier are used to explicitly show how to generate a PS Key configuration file. These PS Key settings are also hard-coded in the Sink application and can be enabled by setting **Plugin Type** to **SSM_2518 CSR I2S Dev Board**, see section 5.1. In this case, it is not necessary to follow the procedures given in section 4 to program PSKEY_USR35 and PSKEY_USR36.

2. Getting Started

The I^{2}S configuration described in this document should be used in conjunction with the *ADK Sink Application User Guide* or the *ADK Subwoofer User Guide*.

1. Install the latest ADK then load the sink or subwoofer workspace.

   Table 2.1 shows the configuration files required for the target device.

xIDE Project	Configuration Files
Headset-Release	sink_system_csr8670.psr sink_config_10001v4_stereo.psr
Soundbar-Release	sink_system_csr8670.psr sink_config_10001v4_soundbar.psr

Table 2.1: Configuration Files for CSR8670 Headset and Soundbar

xIDE Project	Configuration Files
Headset-Release	sink_system_csr8675.psr sink_config_H13179v2_H13374v1_stereo.psr
Soundbar-Release	sink_system_csr8675.psr sink_config_H13179v2_H13374v1_soundbar.psr

Table 2.2: Configuration Files for CSR8675 Headset and Soundbar

3. I²S Configuration

Two PS Keys are used to configure I²S functions, the PS Keys used dependent on the specific application, see Table 3.1 and Table 3.2:

PS Key	Contents
PSKEY_USR35	Initialisation data and raw data structure definitions
PSKEY_USR36	I²C commands raw data Volume commands raw data Shutdown commands raw data

Table 3.1: PS Keys for Sink and Soundbar

PS Key	Contents
PSKEY_USR6	Initialisation data and raw data structure definitions
PSKEY_USR7	I²C commands raw data Volume commands raw data Shutdown commands raw data

Table 3.2: PS Keys for ADK Subwoofer

Sections 3.1 and 3.2 describe the formats of the two PS Keys that configure I²S functions.

3.1. Initialisation Data

This section describes the PS Key that configures the Initialisation data and raw data structure.

PSKEY_USR35 has the format:

```
0001 0110 3708 022d 0128 0008 0000 00ff bb80 bb80 0100
```

Table 3.3 describes the structure of PSKEY_USR35.

Word	Type	Range	Description
0	Uint8	0-1	Plugin Type Specifies which plugin to use, currently available options are: 0 = user defined using PSKEY_USR35 and PSKEY_USR36 1 = SSM_2518 I²S development board 2 = Customer developed plugin
0	Uint8	0-1	Master or Slave operation: 0 = Slave 1 = Master
1	Uint4	0-1	Left or right justified I²S: 0 = left justified data format 1 = right justified data format
1	Uint4	0-1	Justified data delay by 1 bit 0 = no delay of I²S data output 1 = 1 bit delay of I²S data output
1	Uint8	0-255	Bits per sample Specifies the number of bits in each audio sample

Word	Type	Range	Description
2	Uint8	0-255	USR36 data key length Specifies the total length of the raw data commands contained in PSKEY_USR36, in words
2	Uint8	0-255	Number of init I^2C commands Specifies how many I^2C initialisation commands are specified in PSKEY_USR36
3	Uint8	0-255	Number of volume I^2C volume commands Specifies the number of individual volume commands that are sent to the I^2S capable device every time a volume change is made
3	Uint8	0-255	Volume commands offset Specifies the offset, in words, of the first I^2C volume command in PSKEY_USR36
4	Uint8	0-255	Number of I^2C shutdown commands Specifies the number of individual I^2C commands that will be sent to the I^2C capable device every time it is shut down. i.e. close of SCO or A2DP media stream
4	Uint8	0-255	Shutdown commands offset Specifies the offset, in words, of the first I^2C shutdown command in PSKEY_USR36
5	Uint16	0-65535	Volume number of bits Specifies the number of bits of the volume setting in the I^2C command
6	Uint16	0-65535	Volume range max Specifies the maximum volume that will be sent to the I^2S device to indicate maximum output level
7	Uint16	0-65535	Volume range min Specifies the minimum volume level that will be sent to the I^2S device to indicate minimum output level
8	Uint16	0-65535	Music resampling frequency Specifies whether the music (A2DP, codecs, USB, wired audio) output rate needs to be resampled to a fixed rate. A value of 0 indicates that no resampling is performed. Otherwise this value specifies the required output frequency, e.g. 48000
9	Uint16	0-65535	Voice resampling frequency Specifies whether the voice (CVC, tones, voice prompts) needs to be resampled to a fixed rate. A value of 0 indicates that no resampling is performed. Otherwise this value specifies the required output frequency e.g. 48000
10	Uint16	0-65535	Bit clock scaling factor Specifies the scaling factor for the I^2S bit clock. This overrides the bit clock frequency. e.g 256 x 48000 = 12.28 MHz If it is set to zero, the bit clock is calculated as follows for 16 bit 48 kHz audio: 16 x 2 (stereo) x 48000 = 1.536 MHz

Table 3.3: PSKEY_USR35 Data Fields

3.2. PSKEY_USR36 Raw I²C commands

PSKEY_USR36 contains raw I²C commands, Table 3.4 shows example values. A worked example showing how to create values for PSKEY_USR36 is shown in section 4.3.

Packet Length	Volume Offset	I²C ID	I2CData[0]	I2CData[1]
0x0003	0x0000	0x0068	0x0000	0x0004
0x0003	0x0000	0x0068	0x0001	0x0000
0x0003	0x0000	0x0068	0x0002	0x0000
0x0003	0x0000	0x0068	0x0003	0x0000
0x0003	0x0000	0x0068	0x0005	0x0040
0x0003	0x0000	0x0068	0x0006	0x0040

Table 3.4: PSKEY_USR36 Data Format

3.3. Packet Length

This is the length of the packet in words, the data bytes are packed as words in the PS Key.

For example, for an I²C initialisation command packet of `0x68, 0x00, 0x81` has a packet length of 3.

Note:

`Packet Length` and `Volume Offset` are not included in the `Packet Length` calculation.

3.4. Volume Offset

This word is only applicable to data packets that set the volume/audio level output for the left/right channels. Its value is ignored for non-volume related packets.

For example, for an I²C volume packet as described in Table 3.5

I²C ID	Set Volume Command	Volume Level
0x68	0x05	0x??

Table 3.5: I²C Set Volume Data

The volume level offset would be 1 since the first data byte is always the I²C device ID. Data byte[0] is `0x05` (set volume command). Data byte[1] is the actual volume level.

The volume level is not necessarily 8 bits, its size is configured using word 5 in PSKEY_USR35. If the volume level size is larger than 1 byte then the volume level offset indicates the start of the data to be replaced with the current sink or subwoofer volume level.

Packet Length	Volume Offset	I²C ID	Set Volume Command	Volume Level
0x0003	0x0001	0x0068	0x0005	0x0040

Table 3.6: Set Volume Command with 8 Volume Bits

Packet Length	Volume Offset	I²C ID	Set Volume Command	Volume Level[0]	Volume Level [1]
0x0004	0x0001	0x0068	0x0005	0x00ff	0x00ff

Table 3.7: Set Volume Command with 16 Volume Bits

Packet Length	Volume Offset	I²C ID	Set Volume Command[0]	Set Volume Command[1]	Volume Level
0x0004	0x0002	0x0069	0x0001	0x0006	0x0040

Table 3.8: Set Volume Command with 8 Volume Bits and 16 Command Bits

3.5. Packet Data

The packet data is an array of I²C command bytes whose length is specified by the `Packet Length` value.

For example, for an I²C initialisation command as described in Table 3.9

I²C ID	Set Sample Rate	Automatic Sample Rate Control
0x68	0x01	0x01

Table 3.9: I²C Set Sample Rate Command

The complete packet and header information would comprise of five words and would look like:

Packet Length	Volume Offset	I²C ID	Set Sample Rate	Automatic Sample Rate Control
0x0003	0x0000	0x0068	0x0001	0x0001

Table 3.10: Set Sample Rate PS Key Data

4. How to Create I²S/I²C Configuration PS Keys

This section gives an annotated example for the PS Keys corresponding to the SSM2518 device. However if you wish to use this configuration you can set **Plugin Type** to **SSM_2518 CSR I2S Dev Board** in the Sink Configuration Tool, see section 5.1.

4.1. PSKEY_USR35

The PS Key has the raw data:

```
&02ad = 0001 0110 3708 022d 0128 0008 0000 00ff bb80 bb80 0100
```

This is interpreted in Table 4.1.

Word	Description	Value	Comment
0	Plugin Type	0x00	Fully Configurable by PSKEY_USR35 and PSKEY_USR36
0	I²S Master Mode of operation	0x01	Master
1	I²S Data Format	0x01	Left justified 1 bit delay of I²S data output
1	Number of bits per sample	0x10	16 bits per sample
2	Length of raw data PS Key	0x37	Length of PSKEY_USR36
2	Number of initialisation commands	0x08	8 I²C initialisation commands
3	Number of volume I²C commands	0x02	2 volume I²C commands
3	Offset in words of first I²C volume command	0x2d	Volume command offset in PSKEY_USR36
4	Number of shutdown I²C commands	0x01	1 I²C shutdown command
4	Offset in words of first I²C shutdown command	0x28	Shutdown command offset in PSKEY_USR36
5	Number of bits of volume level to replace	0x0008	Volume setting is 8 bits for this device
6	Volume maximum accepted by I²C volume command	0x0000	Volume is inverted for this device
7	Volume minimum accepted by I²C volume command	0x00ff	Volume is inverted and scaled appropriately
8	Music resampling frequency	0xbb80	Music resampling frequency = 48 kHz
9	Voice resampling frequency	0xbb80	Voice resampling frequency = 48 kHz
10	Bit clock scaling factor	0x0100	BCSF = 256 x fs

Table 4.1: PSKEY_USR35 Example

Note:

The length of PSKEY_USR36 has to be manually configured, even if the Sink Configuration Tool is used to set this value.

4.2. Setting PSKEY_USR35 Using the Sink Configuration Tool

4.2.1. I²S Initialisation Commands

The number of I²C initialisation commands can also be configured using the Sink Configuration Tool, see Figure 4.1. The initialisation commands are sent every time the external I²S amplifier is turned on.

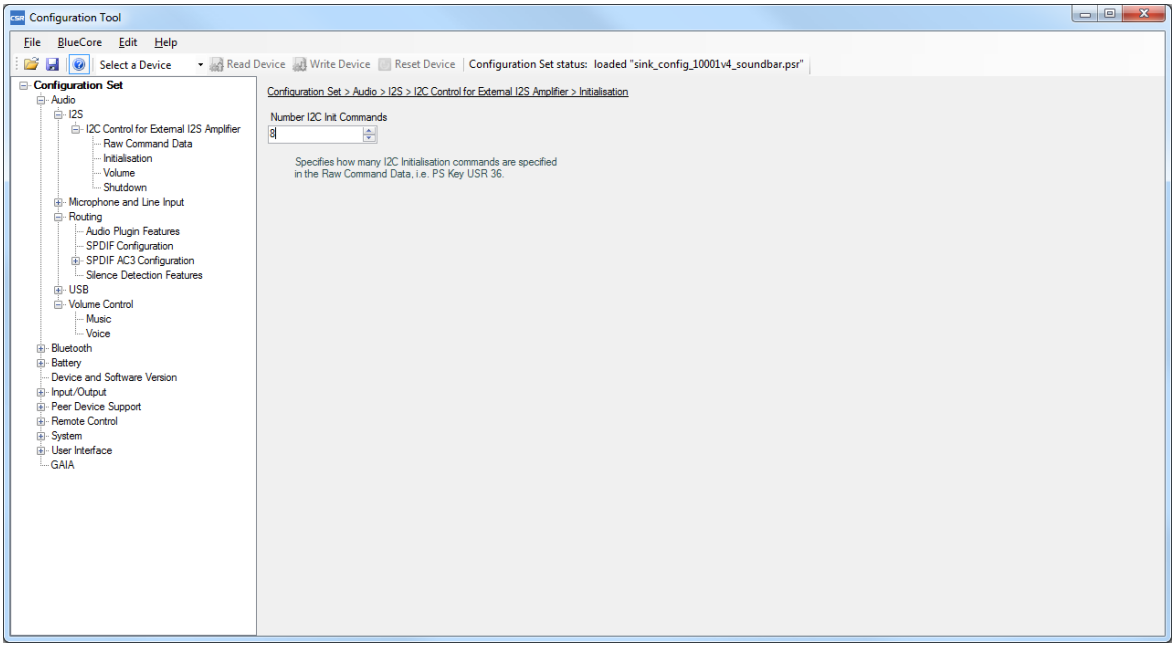

Figure 4.1: I²C Initialisation Commands

4.2.2. I²C Volume Commands

The number of I²C Volume commands and the offset in PSKEY_USR36 can also be configured using the Sink Configuration Tool, see Figure 4.2.

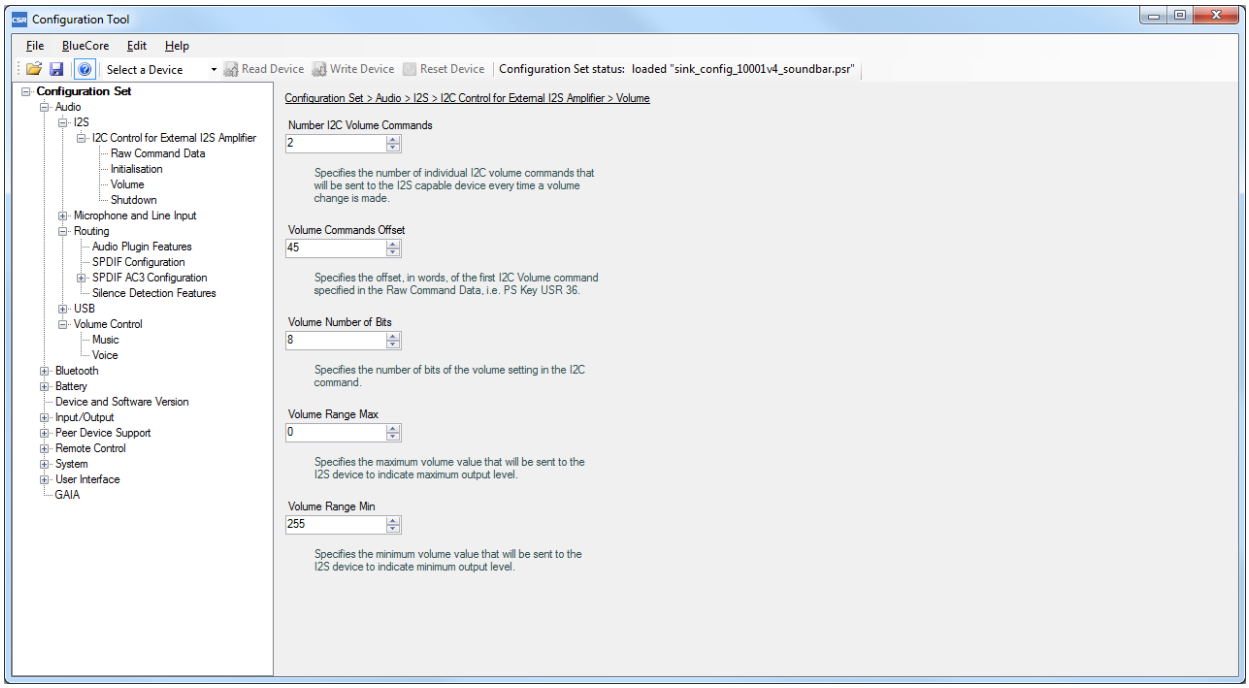

Figure 4.2: I²C Volume Commands

4.2.3. I²C Shutdown Commands

The number of I²C shutdown commands and the shutdown command offset can also be configured using the Sink Configuration Tool, see Figure 4.3:

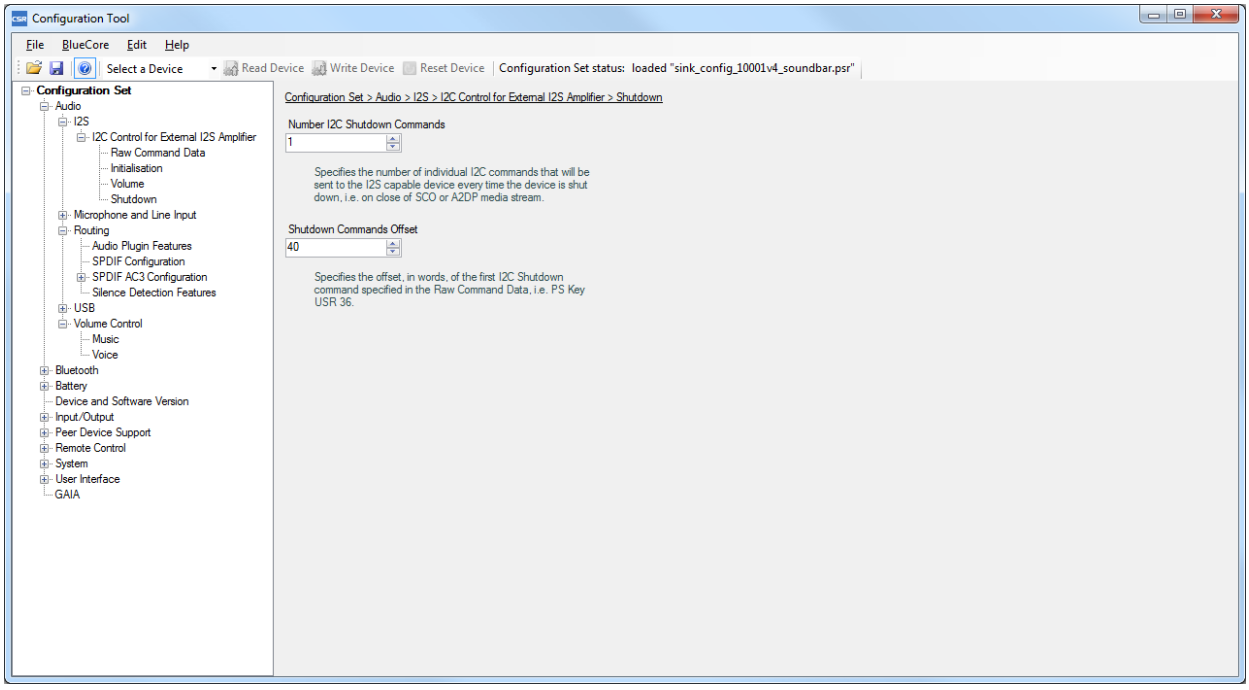

Figure 4.3: I2C Shutdown Commands

4.3. PSKEY_USR36

The PS Key has the raw data:

```
&02ae = 0003 0000 0068 0000 0004 0003 0000 0068 0001 0000 0003 0000 0068 0002 0000
0003 0000 0068 0003 0000 0003 0000 0068 0005 0040 0003 0000 0068 0006 0040 0003 0000
0068 0007 0000 0003 0000 0068 0009 0098 0003 0000 0068 0007 0001 0003 0001 0068 0005
0040 0003 0001 0068 0006 0040
```

To interpret this data, it is split into 5 word chunks, and also into separate tables for initialisation, shutdown and volume commands

The number of initialisation, shutdown and volume commands are configured using PSKEY_USR35. The volume and shutdown command offsets are also configured in PSKEY_USR35.

Data	SSM2518 Register Name	Description
0003 0000 0068 0000 0004	Reset_power_control	SPWN = 0 Normal operation MCS = 0010 256 x fs (Master clock select, value must match Word 10 in PSKEY_USR35) NO_BCLK = 0 BCLK pin used as bit clock source RESERVED = 0 S_RST = 0 Normal operation
0003 0000 0068 0001 0000	Edge_clock_control	ASR = 0 Automatic detection enabled EDGE = 0 No edge rate control RESERVED = 0
0003 0000 0068 0002 0000	Serial_interface_sample_rate_control	FS = 0 (only required if ASR = 1 in register 0x01) SAI = 0 I2S left justified, or right justified stereo depending on SDATA_FMT) SDATA_FMT = 0 I^2S standard, data is delayed by one BLCK cycle RESERVED = 0
0003 0000 0068 0003 0000	Serial_interface_control	RESERVED = 0 BLCK_EDGE = 0 Rising BLCK edge used SLOT_WIDTH = 00 32 BLCK cycles per slot SAI_MSB = 0 MSB first LRCLK_POL = 0 Rising edge (normal) LRCLK_MODE = 0 50% duty cycle BCLK_GEN = 0 Bit clock from BCLK pin is used
0003 0000 0068 0005 0040	Left_volume_control	Set left volume to 0 dB
0003 0000 0068 0006 0040	Right_volume_control	Set right volume to 0 dB

Data	SSM2518 Register Name	Description
0003 0000 0068 0007 0000	Volume_mute_control	M_MUTE = 0 Normal operation L_MUTE = 0 Normal operation R_MUTE = 0 Normal operation VOL_LINK = 0 Normal operation DEEMP_EN = 0 De-emphasis disabled (normal operation) ANA_GAIN = 0 Matched to 3.6 V supply RESERVED = 0 AMUTE = Automute enabled
0003 0000 0068 0009 0098	Power_fault_control	APWDN_EN = 0 Automatic power down disabled L_PWDN = 0 Normal operation R_PWDN = 0 Normal operation DAC_LPM = 1 Low power operation AMP_LPM = 1 Low power operation RESERVED = 0 AR_TIME = 10 40 ms autorecovery delay

Table 4.2: PSKEY_USR36 Initialisation Commands

Data	SSM2518 Register Name	Description
0003 0000 0068 0007 0001	Volume_mute_control	M_MUTE = 1 Master Mute L_MUTE = 0 Normal operation R_MUTE = 0 Normal operation VOL_LINK = 0 Normal operation DEEMP_EN = 0 De-emphasis disabled (normal operation) ANA_GAIN = 0 Matched to 3.6 V supply RESERVED = 0 AMUTE = Automute enabled

Table 4.3: PSKEY_USR36 Shutdown Commands

Data	SSM2518 Register Name	Description
0003 0001 0068 0005 0040	Left_volume_control	Set left volume command. The number of bits that are replaced is configured using PSKEY_USR35
0003 0001 0068 0006 0040	Right_volume_control	Set right volume command. The number of bits that are replaced is configured using PSKEY_USR35

Table 4.4: PSKEY_USR36 Set Volume Commands

5. Additional Configuration

5.1. Plugin Type

This document shows how to create PSKEY_USR35 and PSKEY_USR36 for an AD SSM2518 I^{2}S device with a user defined configuration, i.e. with **Plugin Type** set to **User Defined via PS Keys USR35 USR36**, see Figure 5.1:

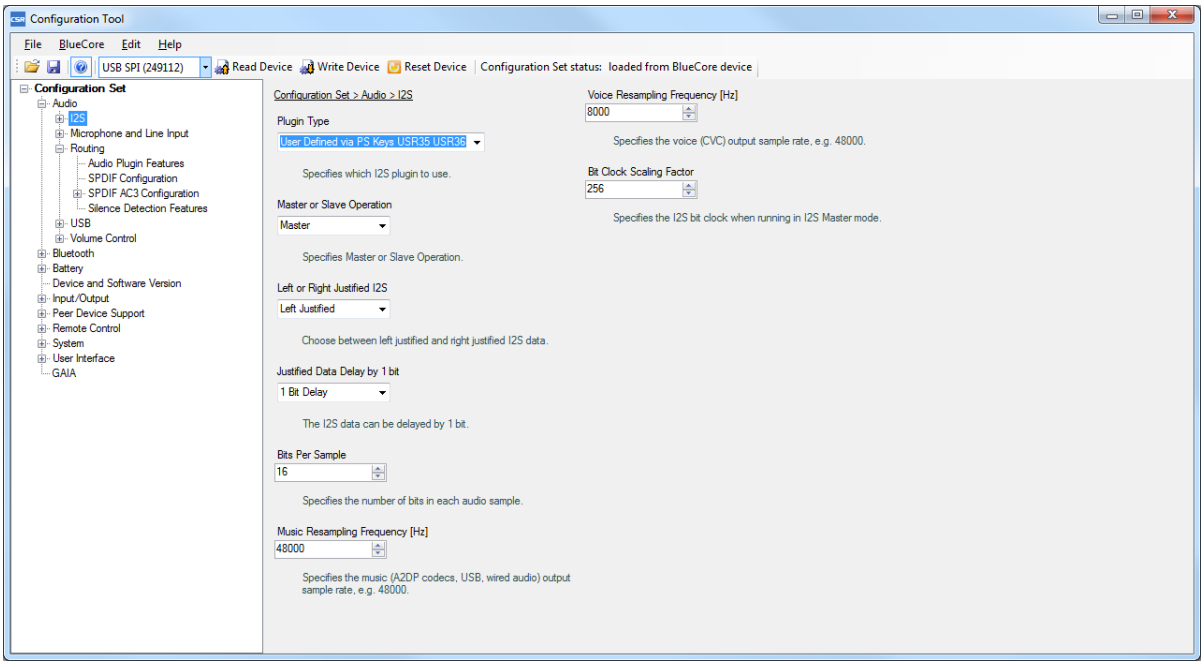

Figure 5.1: User Defined Plugin Type

The AD SSM2518 can also be enabled using the Sink Configuration Tool by setting the **Plugin Type** to **Plugin Type to SSM_2518 CSR I2S Dev Board**. No additional configuration data is required in PSKEY_USR35 and PSKEY_USR36 when using this type of configuration.

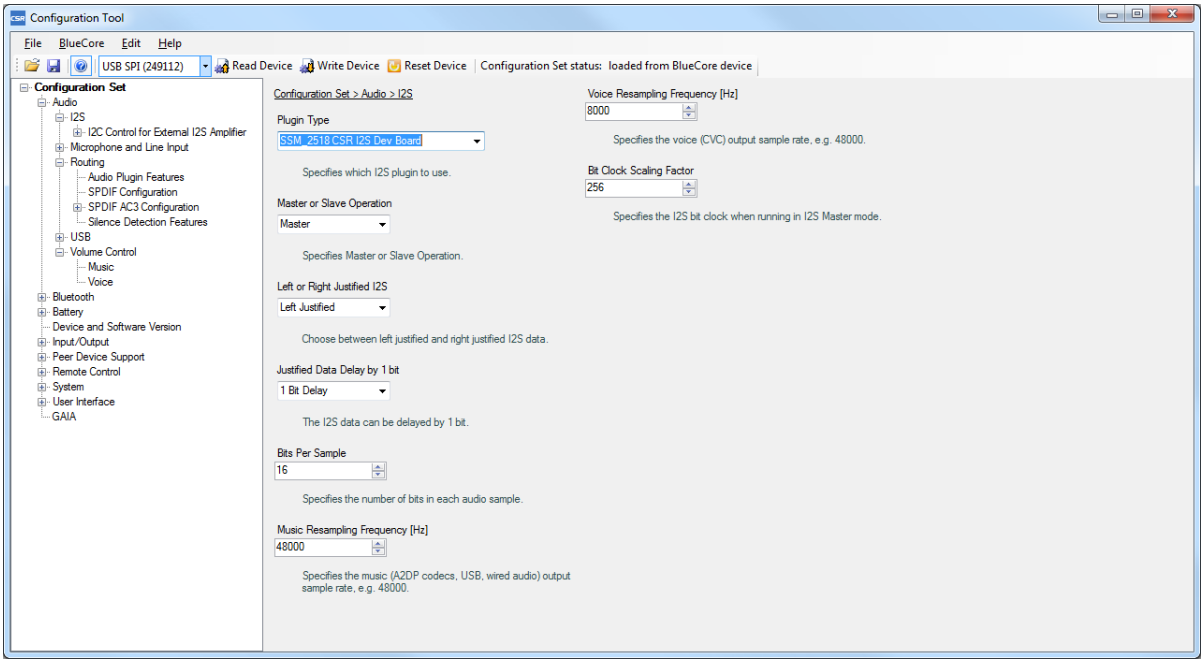

Figure 5.2: Analogue Devices SSM2518 Plugin Type

5.2. Audio Routing

I^{2}S output is enabled using the Sink Configuration Tool by modifying **Configuration Set > Audio > Routing > Audio Plugin Features** so that the **Audio Output Type** is set to **I2S**. When enabled, all audio output is redirected to an I^{2}S capable device, including tones and voice prompts, see Figure 5.3.

When CSR8670 and CSR8675 run Soundbar application, the power down mode for the external audio amplifier stage can be managed using configurable PIOs depending on the hardware design.

For the Soundbar application to drive PIOs to switch off the external amplifier when going into stand-by mode (i.e. Limbo state) and switch it on while powering on, PS Key configuration item **Amplifier Power Down by PIO** must be enabled. For detailed information about this configuration item, see *ADK Sink Application User Guide.*

The PIOs used to generate the correct logic for amplifier “Power” and “Mute” signals will then be configured as in Section 5.5.

Figure 5.3: Configuring I^{2}S Audio Output Type

5.3. Volume Control

Volume Control Type must be configured to **External** for volume control commands to work using the I^{2}C interface. This is because the raw I^{2}S digital audio contains no volume data, so I^{2}C commands must be sent to the I^{2}S amplifier to configure the final output volume.

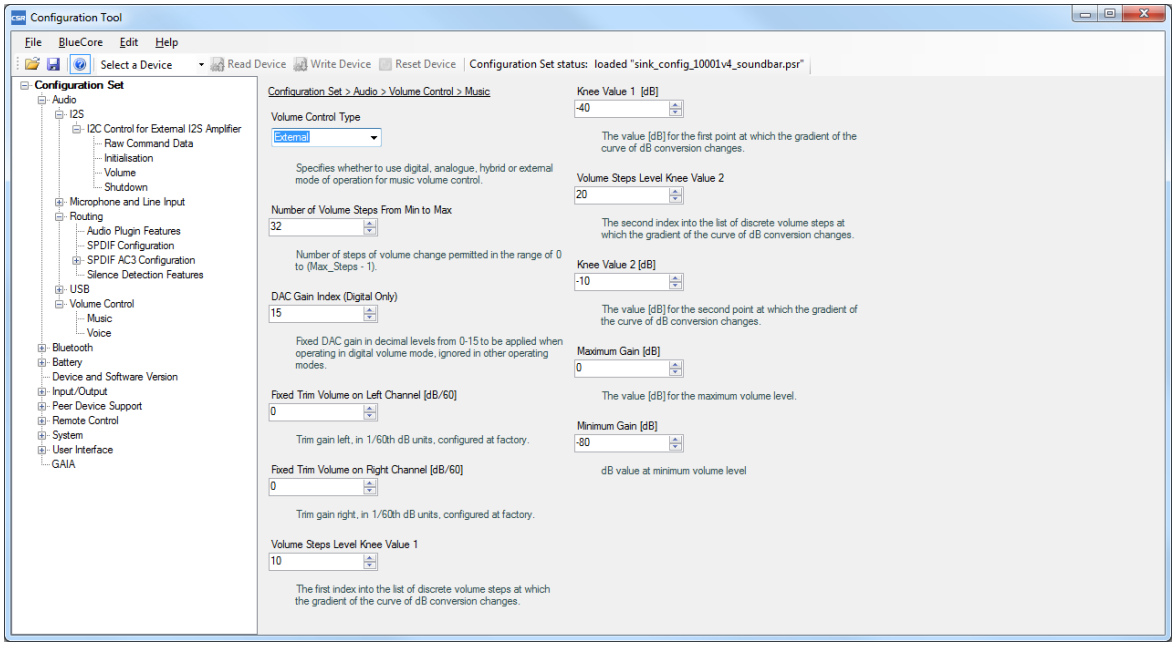

Figure 5.4: Volume Control Setting

5.4. Input PIOs

To use the I^{2}S amplifier with CSR8675, the **SPDIF Input PIO** must be configured to **Disable**:

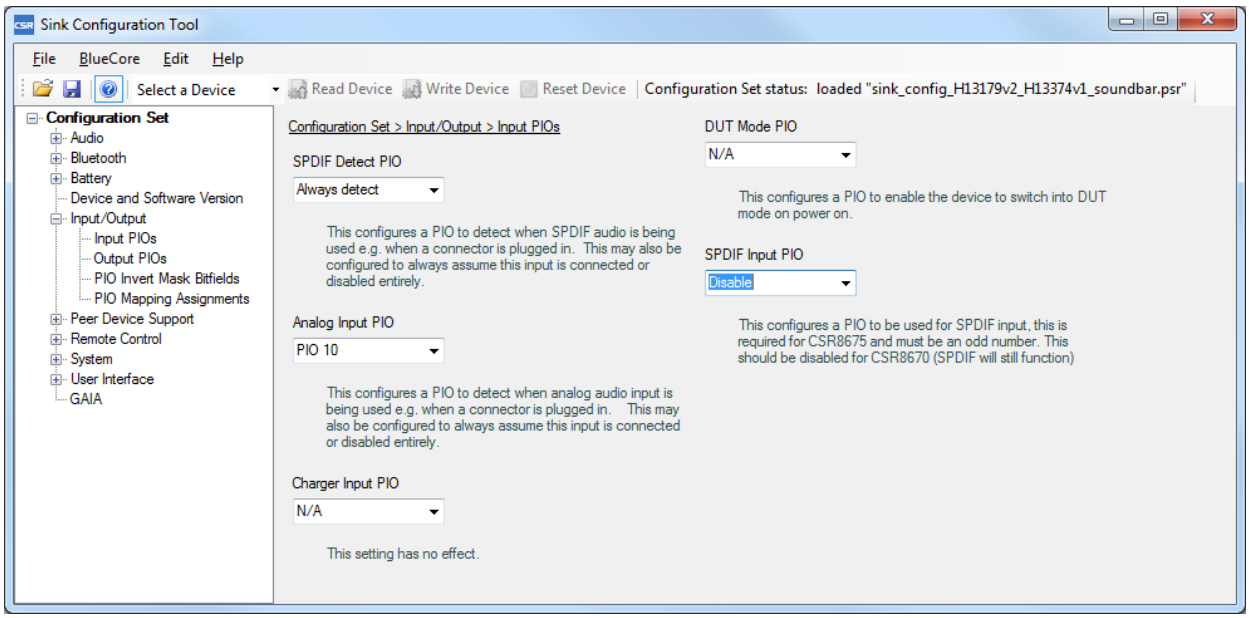

Figure 5.5: Input PIO Configuration

5.5. Output PIOs

To use the I^{2}S amplifier with CSR8675, the **SPDIF Output PIO** must be configured to **N/A**, see Figure 5.6:

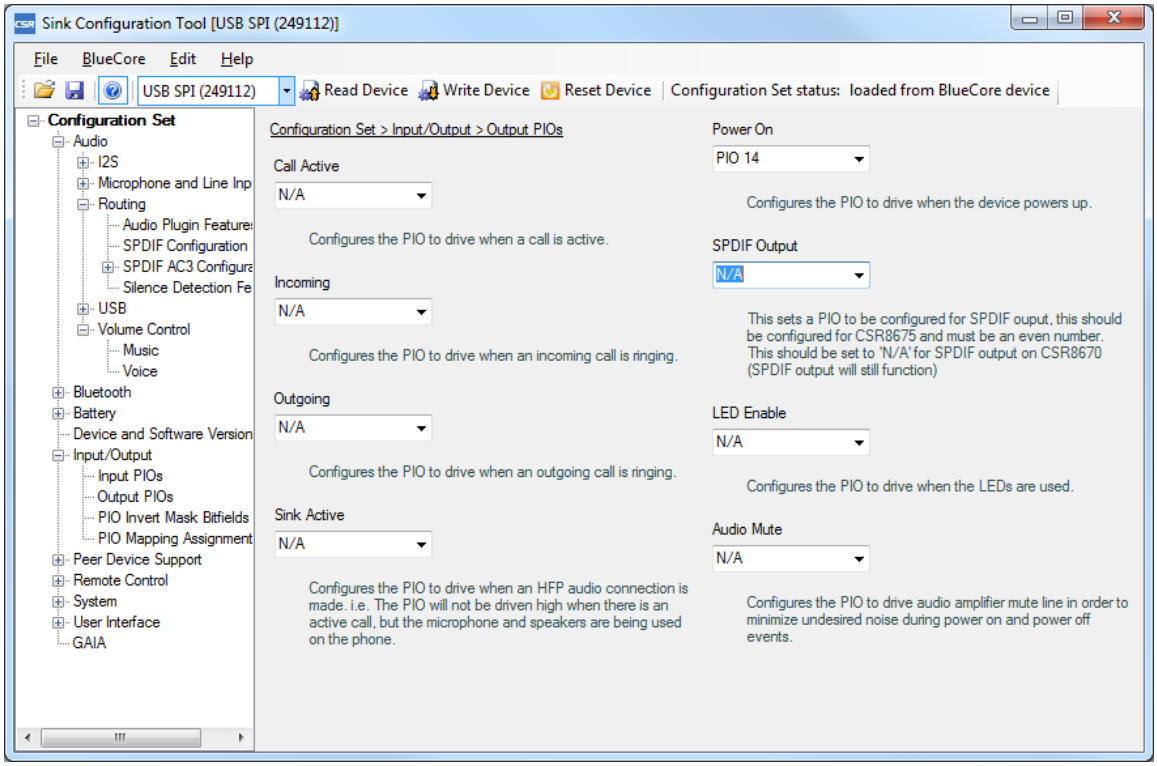

Figure 5.6: Output PIO Configuration

Power up and power down operations for an external amplifier can be managed using PIOs. Power pin may be available on the external amplifier which provides hardware shut down option when required, e.g. when the system goes into stand-by mode.

When reference external amplifier board, i.e. H13117, is in use, **Power On** PIO must be configured to **PIO14** to toggle the external amplifier power pin logic levels when sink device is powered on or powered off.

Mute pin may also be available on some external amplifiers. For Soundbar application, Mute pin is also driven by the **Audio Mute** PIO before **Power On** PIO in order to minimize pops and clicks during power up and power down events. **Audio Mute** PIO must be configured to **N/A** when reference external amplifier board, i.e. H13117, is in use.

When **Audio Mute** and **Power On** PIOs are configured to values other than **N/A**:

Action	Sequence of PIO Activity		
	1 - Audio Mute PIO	2 - Power On PIO	3 - Audio Mute PIO
Power Off (Go into Standby Mode)	Goes High	Goes Low	Goes Low
Power On	Goes High	Goes High	Goes Low

Table 5.1: Audio Mute and Power On PIO Operation

5.6. Soundbar Button Translation

The default Soundbar configuration requires a change to the button translation table for **Input 10**. This is because the default configuration uses **PIO5** which is also used by the I2S_1_CLK line.

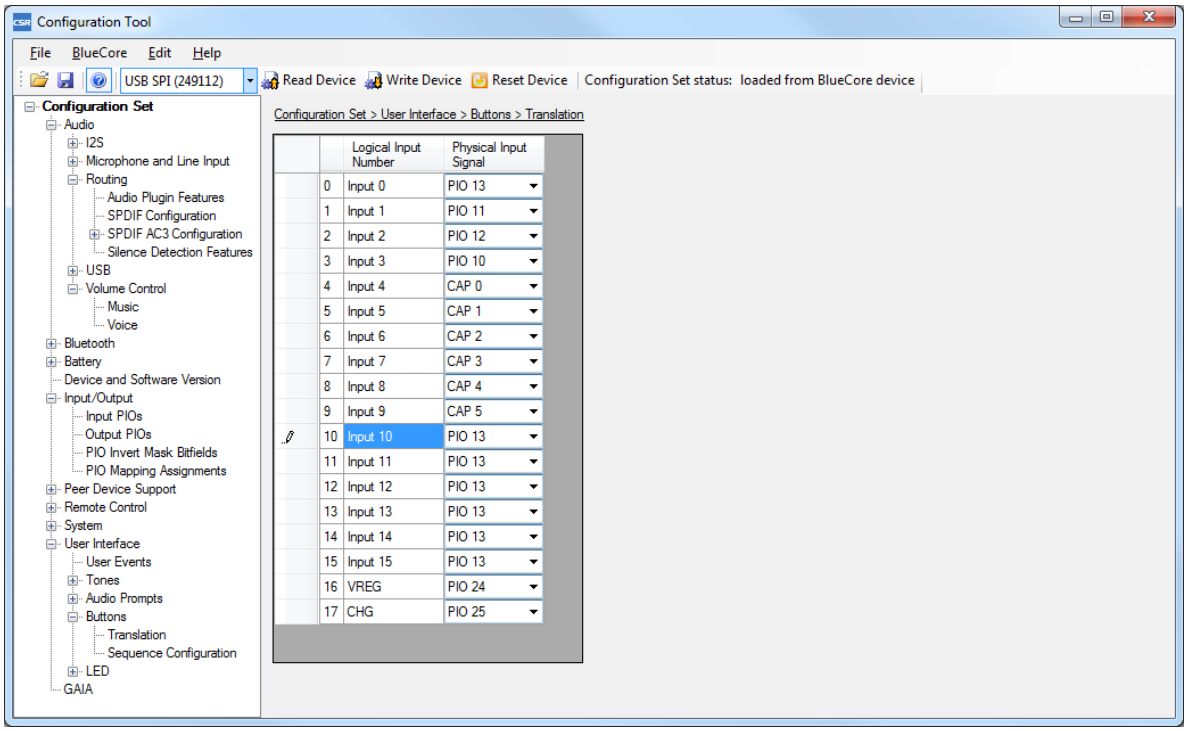

Figure 5.7: Soundbar Button Translation

5.7. Soundbar Input Select

To hear streaming audio from a connected AG on the Soundbar it is necessary to change the input select. Press the **Cap Sense** button SENSE_3 to choose **Select Audio Source AG1**, see Figure 5.8.

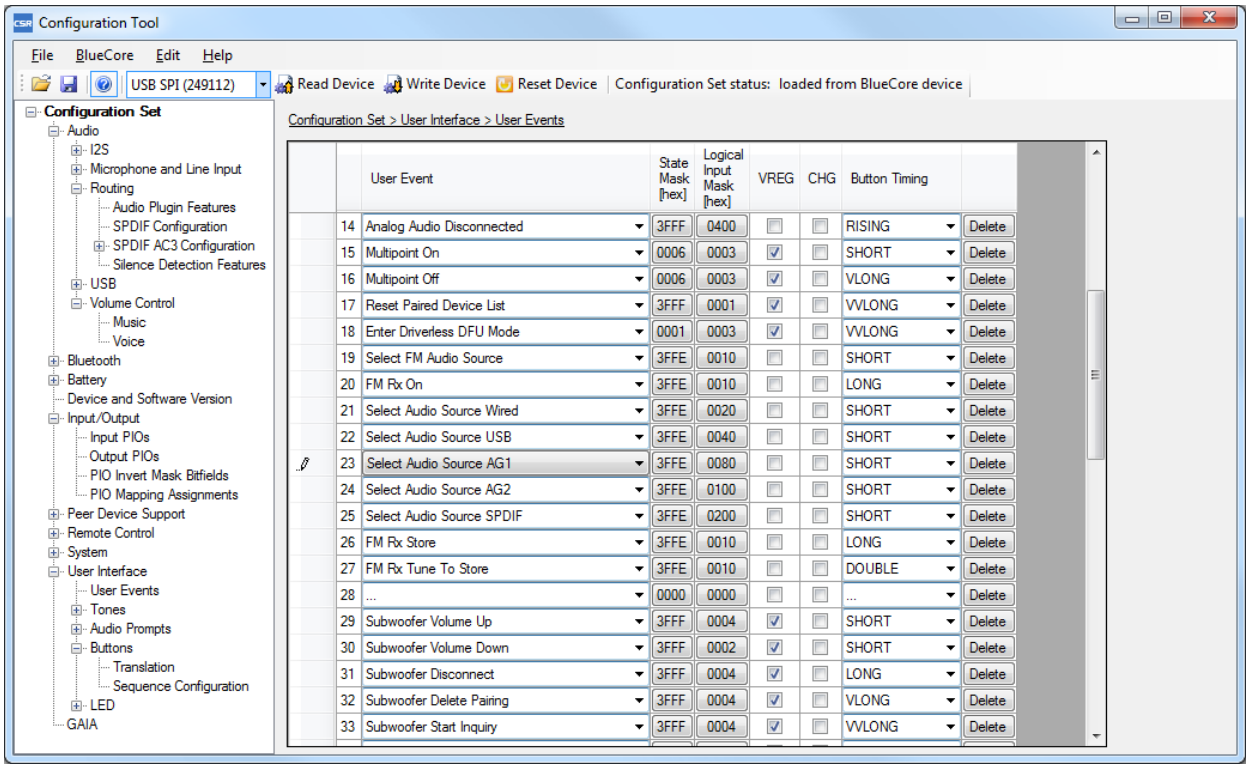

Figure 5.8: Soundbar User Event Configuration

5.8. I²C PIO Mapping

Using PSTool, configure **I2C SCL PIO Mapping** and **I2C SDA PIO Mapping**:

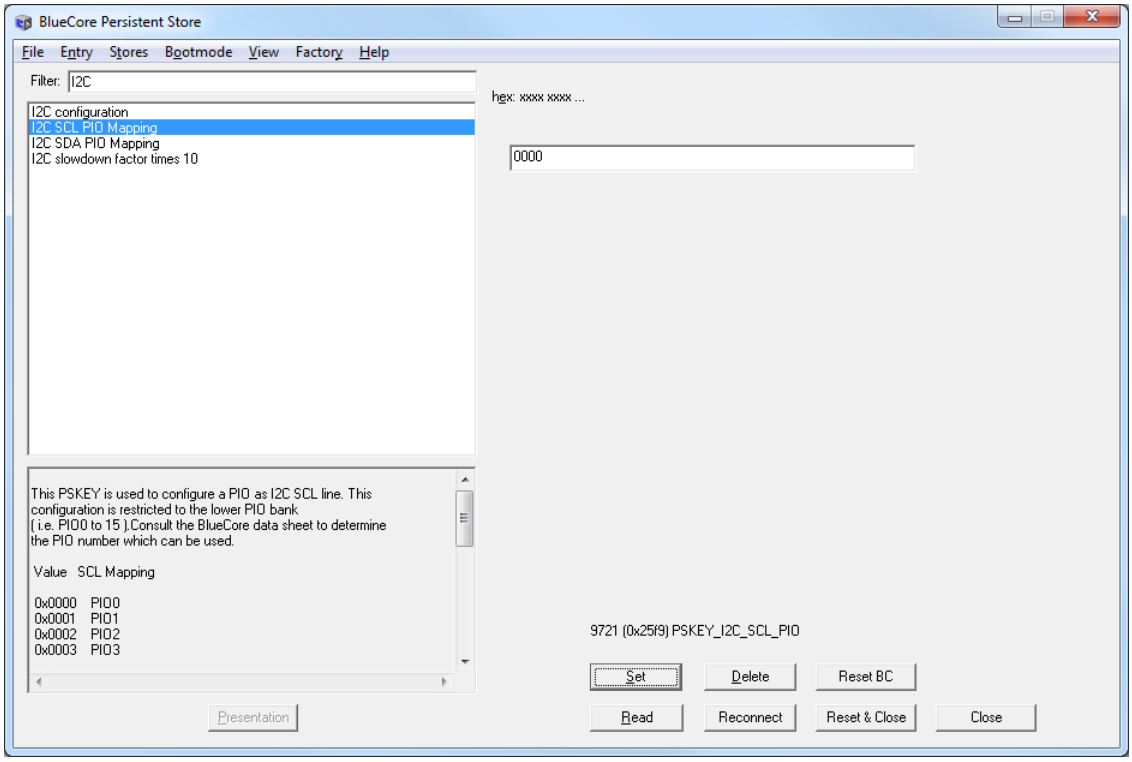

Figure 5.9: I²C SCL PIO Mapping

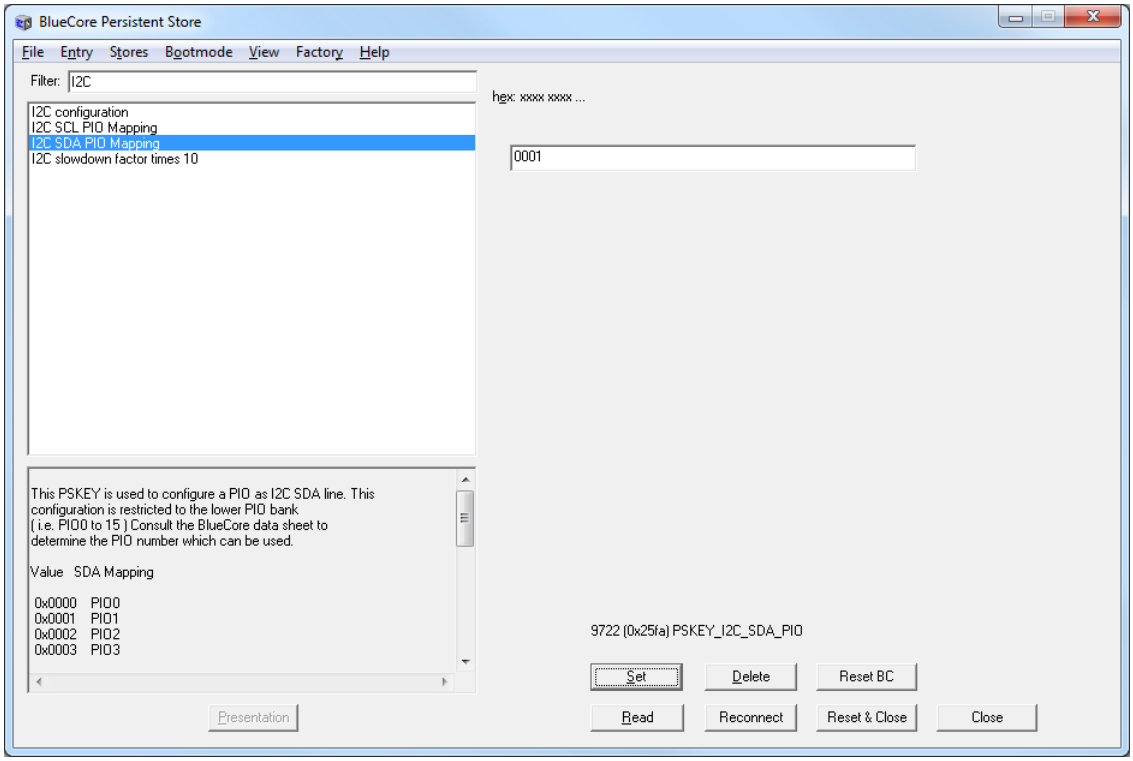

Figure 5.10: I²C SDA PIO Mapping

5.9. xIDE Project Settings

CSR recommends that resampling is always used with I^{2}S and the resampling plugins must be used in the project for tones and voice prompts to work correctly, see Table 5.2.

Plugin	Resample plugin
csr_voice_prompts_plugin	csr_voice_prompts_plugin_resample
audio	audio_tone_resample

Table 5.2: Resample Plugins

6. Subwoofer Use of I²S

To use the I²S output feature with the subwoofer it is necessary to follow the above steps for PSKEY_USR6 and PSKEY_USR7 instead of PSKEY_USR35 and PSKEY_USR36 with the same format.

Enabling the I²S on the Subwoofer is different to the Sink application and it requires that the audio output type is configured in PSKEY_USR0.

Table 6.1 shows the PSKEY_USR0 settings to enable I²S output on the Subwoofer:

Subwoofer version	PSKEY_USR0 setting	Example
ADK 2.5 and 2.5.1	Set Bit[4] of word 3	PSKEY_USR0 = 01f4 0904 1e18
ADK 3	Set Bit[1] of word 8	PSKEY_USR0 = 000a 00c8 0005 0005 00c8 000a 0904 000b 021e 000a 0384
CSRA65700 Subwoofer ROM	Set Bit[1] of word 8	PSKEY_USR0 = 000a 00c8 0005 0005 00c8 000a 0904 000b 001e

Table 6.1: Subwoofer I²S Configuration

7. Hardware Configuration

The I^{2}S example PS Keys were tested using the hardware configuration in Table 7.1.

CSR PCB ID	Name
H13179	Dev board for H13180
H13180	CSR8670 Bluetooth module
H13117	Audio Amplifier

Table 7.1: Hardware Configuration for I^{2}S Audio Development

Table 7.2 shows the changes made to the hardware configuration using jumper wire.

PIO Connection Using Jumper Wire	Notes
PIO0 -> PIO6	SCLK
PIO1 -> PIO7	SDA

Table 7.2: PIO Connections to Enable I^{2}S Audio Output

Appendix A I²S Implementation

A.1 Capabilities of I²S implementation

Only support for Master operation i.e. no support for Slave operation.

A.2 Limitations of I²S implementation

The CSR device should always be Master I²S to avoid rate matching problems.

The CSR I²S implementation cannot generate a separate master clock. However, the bit clock scaling can be used to provide a faster bit clock which can be used as a master clock. The bit clock is generated by dividing down the 48 MHz chip clock so cannot be guaranteed to have a constant mark/space ratio.

Document References

Document	Reference
Analog Devices SSM2518 Data Sheet	http://www.analog.com
ADK Sink Application User Guide	CS-236868-UG
ADK Subwoofer User Guide	CS-310152-UG

Terms and Definitions

A2DP	Advanced Audio Distribution Profile
AD	Analogue Devices
ADK	Audio or Application Development Kit
BlueCore®	Group term for CSR's range of Bluetooth wireless technology chips
Bluetooth®	Set of technologies providing audio and data transfer over short-range radio connections
CSR	Cambridge Silicon Radio
CVC®	Clear Voice Clarity
e.g.	*exempli gratia*, for example
i.e.	*Id est*, that is
I^2C	Inter-Integrated Circuit (multimaster serial single-ended computer bus)
I^2S	Integrated Interchip Sound
ID	Identifier
ID	IDentifier
MSB	Most Significant Bit
PIO	Programmable Input/Output
PS	Persistent Store
ROM	Read Only Memory
SCO	Synchronous Connection-Oriented
SDA	Serial Data (line)
USB	Universal Serial Bus