C55x CSL Audio Pre-Processing

DSP Processors

ABSTRACT

This application report describes the audio pre-processing for speech recognition framework provided in the C55x CSL. This demo illustrates the integration of Beamforming (BF), Adaptive Spectrum Noise Reduction (ASNR), Multiple Source Selection (MSS) and Dynamic Range Compression (DRC) components and provides a framework for application development.

Project collateral and source code can be downloaded from the following URL: http://www.ti.com/lit/zip/spracn7.

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1   Introduction

The key functions in this use case include:

- Read 2/4/6 audio input from the Circular Microphone Array Board (CMB)
- Generate 2/4/6 virtual mics using BF (Beamforming)
- Apply Adaptive Signal Noise Reduction (ASNR) on each virtual mic
- Use Multiple Source Selection (MSS) to select the best virtual mic from the 12 virtual mics
- Do Dynamic Range Compression (DRC) on the best virtual mic
- Send the processed audio and by-passed audio input to on board codec (C5517 EVM, P9, HP out[left/right channels])

This demo utilizes other components:

- DSP/BIOS application utilizing DSP/BIOS features for DSP-C55x core
- XDAIS application utilizing XDAIS features for DSP-C55x core

The audio components are available in AER and VOLIB packages, which are optimized for C55x cores, so this demo not available. The demo is only supported on C5517 device using TMDSEVM5517 evaluation module.
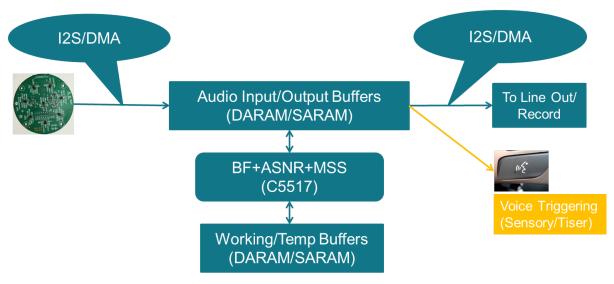

Figure 1. Demo Setup

2 Requirements

The following materials are required to run this demonstration:

- Hardware:
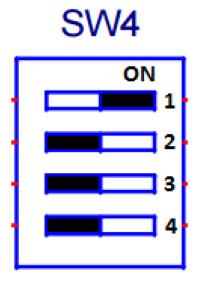 - Ensure that the correct dip switch settings are set for SW4 as illustrated below 1-ON, 2 to 4-OFF.

Figure 2. SW4

  - TMDSEVM5517
  - CMB
- Circular Mic Board (CMB) to C5517 EVM Connections
  - Optional: Circular Mic Board (CMB) 3D print file for stand-off (http://software-dl.ti.com/public/download/CMB_Enclosure.zip)

Table 1. Power

CMB	C5517 EVM	
CMB_3.3V	J10_Pin9	3.3 V
CMB_GND	J10_Pin5	Ground

Table 2. Signal for Mic1 and Mic2

CMB	C5517 EVM	
CMB_SCL	J14_Pin16	I2C SCL
CMB_SDA	J14_Pin20	I2C SDA
CMB_BCLK	J27_Pin3 (no jumper)	Bit Clock
CMB_LRCLK	J27_Pin4 (no jumper)	Frame Clock
CMB_DATA1	J30_Pin2 (no jumper)	Data 1
	J29_Pin1_Pin3 (jumper on)	
	J29_Pin2_Pin4 (jumper on)	
	J30_Pin1_Pin3 (jumper on)	

Table 3. Signal for Mic5 and Mic6

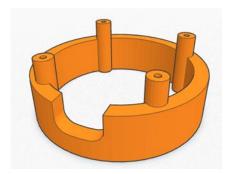| CMB	C5517 EVM	
I2X_USB_BCLK	J27_Pin1	Bit Clock
I2X_USB_LRCLK	J27_Pin2	Frame Clock
CMB_DATA2	J28_Pin2	Data 2
	J28_Pin1_Pin (no jumper)	
	J28_Pin2_Pin4 (no jumper)	

Figure 3. CMB Standoff

- Software
  - C55x CSL (3.07.00 or greater)
  - DSP/BIOS 5.42.02.10
  - Code Composer Studio™ 6.1.3
  - CGT for C5500 4.4.1
  - XDCTools 3.24.05.48
  - XDAIS 7.24.00.04
  - AER 17.0.0.0 (C55x, CPU rev 3.3) (http://www.ti.com/tool/TELECOMLIB)
  - VOLIB 2.1.0.1(C55x, CPU rev 3.3) (http://www.ti.com/tool/TELECOMLIB)

NOTE: In order to make the following build procedure to work, all above mentioned components have to be installed at the same location (ti/c55_lp by default).

3 Software Design

3.1 C5517 Audio Preprocessing TI Design Patch Files

- Applicable only to CSL v3.07

  The default CSL package audio preprocessing demo located at C:\ti\c55_lp\c55_csl_3.07\demos\audio-preprocessing is not configured for the four microphone Linear Microphone Board (LMB), instead it was configured for a larger eight microphone Circular Microphone Board (CMB). Thus, certain files need to be replaced in the source code to ensure correct filter coefficients and initialization of the hardware. The following files need to be replaced: AudioCodec_DMA.c, codec_pcm186x.c and sysbffilt.c.

  The default CSL package audio preprocessing demo located at C:\ti\c55_lp\c55_csl_3.07\demos\audio-preprocessing did not have the source code for the Dynamic Range Compression (DRC) module. The following files need to be added to C:\ti\c55_lp\c55_csl_3.07\demos\audio-preprocessing\common in order to include DRC functionality: debug.h, types.h, ecomem.h, bf_asnr_mss_vau.c ,bf_asnr_mss_vau.h.

NOTE: These patch files will no longer be needed once CSL 3.08 is released since they will be incorporated into the release source code.

The replacement files are located at: C5517 TIDEP-0077 VoiceProcessing patch2.

- Applicable only to CSL v3.08

The CSL v3.08 package audio pre-processing demo located at C:\ti\c55_lp\c55_csl_3.07\demos\audio-preprocessing has a bug where a patch is needed. Audio frequencies above 3KHz are not output on EVM5517 via the P9 headphone out. This resulted in audio output of degraded quality.

The problem was with an incorrect configuration of the Digital to Analog (DAC) converter on EVM5517. Replace the following files with the attached .zip files:

- C:\ti\c55_lp\c55_csl_3.08\demos\audio-preprocessing\c5517\codec_pcm186x.h
- C:\ti\c55_lp\c55_csl_3.08\demos\audio-preprocessing\c5517\codec_aic3254.c

The replacement files are located at: C5517 TIDEP-0077 VoiceProcessing freqcutoffpatch3.

3.2 More About Processing Algorithms

The application will use AER and VOLIB APIs for its noise reduction processing needs. The following steps are performed for noise reduction:

- Read 2/4/6 audio input from the Circular Microphone Array Board (CMB)
- Generate 2/4/6 virtual mics using Beamforming (BF)
- Apply Adaptive Signal Noise Reduction (ASNR) on each virtual mic
- Use Multiple Source Selection (MSS) to select the best virtual mic from the 12 virtual mics
- Do Dynamic Range Compression (DRC) on the best virtual mic
- Send the processed audio and by-passed audio input to on board codec (C5517 EVM, P9, HP out[left/right channels])

3.3 Framework for Audio Pre-Processing

The current framework is based on DSP/BIOS. The following are the overall steps:

- The I2S/DMA is configured to generate a DMA Completion Interrupt every 10 ms.
- The DMA ISR prepares the audio frame buffer pointers for further processing.
- The DMA ISR also sends a semaphore to wake up the main task.
- When woke up, the main task performs the BF, ASNR, MSS and DRC.
- The main task also outputs the final processing audio frame and the unprocessed audio input to the I2S/DMA TX buffers.
- After completed, the audio frame processing, the main thread will wait on semaphore for next audio frames to come.

4   Circular Microphone Board Demo

4.1   How to Build the Demo

> **NOTE:** In order to make the following build procedure work, all above mentioned components have to be installed at the same location (ti/c55_lp by default).

4.1.1   C5517 EVM

For Windows:

- Launch CCS 6.1.3

```
Import CCS project --
 C55XXCSL_LP from c55_csl\c55_csl_3.xx\ccs_v6.x_examples\C55XXCSL_LP directory.
Import CCS project -- BF_rt_bios from c55_csl\c55_csl_3.xx\demos\audio-
preprocessing\c5517 directory.
Build CCS project -- BF_rt_bios
The BF_rt_bios.out file will be built at
    c55_csl\c55_csl_3.xx\demos\audio-preprocessing\c5517\Debug
```

4.2   How to Run the Demo

The demo works with the real-time audio input from CMB. After processing is complete, the audio output is sent to the line-out (left channel) of the C5517 EVM on-board audio codec(P9). For the purpose of comparison, the unprocessed center microphone (mic 1) is sent out to the line-out (right channel) of the C5517 EVM on-board audio codec (P9).

The following sections provide detailed steps for the C5517 EVM.

4.2.1   C5517 EVM

1. Connect the CMB to the C5517 EVM according to the instructions above.
2. Connect the on board emulator (J3 on C5517 EVM) to your PC USB port.
3. Plug power adaptor (5V) into the J18 of C5517 EVM and power on the EVM.
4. Launch CCS 6.1.3.
5. Import c55_csl\c55_csl_3.xx\build\C5517EVM_Onboard_Emulator.ccxml using "Import Target Configuration" from CCS 6.1.3.
6. Launch C5517EVM_Onboard_Emulator.ccxml using "Launch Selected Configuration" from CCS 6.1.3.
7. Then "Connect to C55xx".
8. Load and run the program BF_rt_bios.out.
9. The program runs the real time demo forever, taking the input from CMB and output to the on-board HP out.

5   How to Evaluate the Demo

5.1   Use Headphone

- You can plug in a headphone into the HP out.
- The left channel is the processed audio, while the right channel is the input from mic1 bypassed.
- Due to the audio jack (P9) issue, sometimes the left and right channel can be flipped.

5.2   Record Audio Data Using Adobe Audition

1. Connect the HP out of P9 to your PC line in (NOT mic in).
2. Launch the Adobe Audition CS5.5.
3. Record audio in stereo mode.
4. The left channel will be the processed audio, while the right channel will be the input from mic1 bypassed.
5. Due to the audio jack (P9) issue, sometimes the left and right channel can be flipped.

6   C55x Benchmark

Table 4. C55x Benchmark

	C5535 eZdsp	C5545 BSP	C5517 EVM	C5517 EVM	C5517 EVM
MIPS	100 Mhz	120 Mhz	200 Mhz	200 Mhz	200 Mhz
Number of physical mics	4 (2 I2Ss)	4 (2 I2Ss)	2 (I2S)	4 (I2Ss)	6 (3 I2Ss)
Mic array type	LMB or CMB	LMB or CMB	LMB or CMB	LMB or CMB	LMB or CMB
Number of virtual mics	4	4	2	4	6
Measured MIPS	33+27+1 = 61 MIPS	33+27+1 = 61 MIPS	10+13+1 = 24 MIPS	33+27+1 = 61 MIPS	68+39+1 = 107 MIPS
Memory usage (SARAM+DARAM)	168KB 152KB left	168KB 152KB left	144KB 176B left	166KB 152KB left	196KB 124KB left

NOTE: C5535/45/17 have 320KB total on chip memory. Measured MIPS includes BF+ASNR+MSS.

7   References
- TMS320VC55XCSL Low Power

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