I²C Procedure For 5.1 Applications Using the DDX-8000

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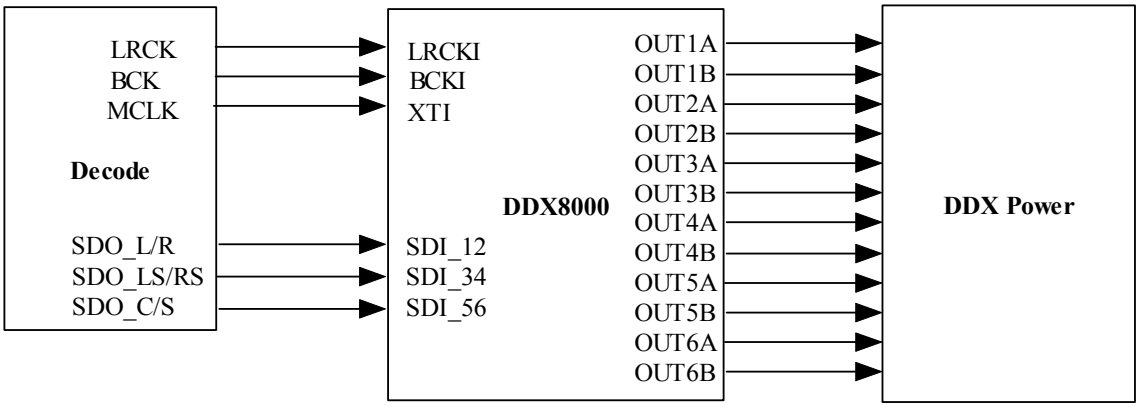
Introduction

DDX-8000 is capable of offering a wide range of features that can be used in the design of 5.1 applications. Most prominent features being Bass management, Bass/treble tone control, EQ, digital amplification, etc. The following sections illustrate a 5.1 application example describing the settings that need to be done within the DDX-8000 device. The figure below shows the three main components used in a typical 5.1 design.



DDX-8000 Initialization using I²C Protocol

Register Address	Register Data	Comment
00h	100xxxxxb	Configuration Register A, Set IR and MCS

The input sample frequency and the ratio of the input clock to this sample frequency will determine the settings of the IR and MCS bits. These must be set any time the input sample frequency or clock changes. The default setting for these bits are for 32-48 kHz sample rate and an input clock of 256Fs. The table below shows the settings for the IR and MCS bits in order to handle other sample rates.

Input Sample Rate – Fs (kHz)	IR (1…0)	MCS (2…0)				
		1xx	011	010	001	000
32, 44.1, 48	00	128Fs	256Fs	384Fs	512Fs	768Fs
88.2, 96	01	64Fs	128Fs	192Fs	256Fs	384Fs
176.4, 192	10	64Fs	128Fs	192Fs	256Fs	384Fs

**THIS TABLE IS NOT A PART OF THE INITIALIZATION PROCEDURE, BUT IS ONLY PROVIDED FOR REFERENCE.*

Register Address	Register Data	Comment
01h	01xxxx10b	Configuration Register B, Set Serial Audio Input Format

The SAI bits determine the format of the serial audio interface. The default setting is for the IIS format, MSB first.

Register Address	Register Data	Comment
09h	xxxxxxxxb	Channel 1 Volume/Gain
0Ah	xxxxxxxxb	Channel 2 Volume/Gain
0Bh	xxxxxxxxb	Channel 3 Volume/Gain
0Ch	xxxxxxxxb	Channel 4 Volume/Gain
0Dh	xxxxxxxxb	Channel 5 Volume/Gain
0Eh	xxxxxxxxb	Channel 6 Volume/Gain
0Fh	xxxxxxxxb	Channel 7 Volume/Gain
10h	xxxxxxxxb	Channel 8 Volume/Gain

Channel volume/gain settings default to a setting of 0dB. Changing these settings can add gain to these channels and perform volume offsets between these channels. Normally the Subwoofer channel 6 will be set to a higher volume/gain setting than the other channels. How much higher this channel is set should be determined though listening tests of the system. These volume settings can also be used to achieve channel volume "trim" control, which typically is ± 6dB.

Register Address	Register Data	Comment
05h	10000000b	Configuration Register F, Set EAPD

Setting the EAPD disables the external amplifier power-down signal.

Register Address	Register Data	Comment
07h	xxxxxxxxb	Master Volume

The default setting for Master volume is mute; therefore this must be set to the initial volume setting to obtain an output signal.

Sample Rate Switching/Selection

In order to switch to a different input sample rate intermittently, certain steps need to be followed to effect the changes correctly. Based on the new sample rate and the desired input clock, determine the IR and MCS bit settings from the table given earlier. To make the change, first mute all the channels, set the IR and MCS bits to the new setting and then un-mute all channels to resume normal operation. Table below shows the I^2C commands.

This does not have to be done when switching from 44.1kHz to 48kHz as the over sampling ratio remains the same. Only from either of these sample rates to a higher sample rate such as 96kHz or 192kHz.

Register Address	Register Data	Comment
06h	xxxxxxx1b	Mute all channels
00h	100xxxxxb	Set the IR and MCS bits for the new sample rate
06h	xxxxxxx0b	Un-mute all channels

Bass Management (Configuration #1) for a 5.1 system using the DDX-8000

The DDX-8000 can perform bass-management configuration #1 using the scale and mix and biquad functionality. These functions are implemented using I^2C to interface to the internal registers and to the internal RAM segment. The internal RAM stores the scale and mix variable and the biquad coefficients. Writing to this segment via the I^2C is described in Section 6.1.5 of the DDX-8000 datasheet. The table given below shows the 24-bit data to be written into this RAM segment.

The biquad filter coefficients are obtained for a 120 Hz crossover frequency. Coefficients for other crossover frequencies can be determined very easily, some of which are provided in the appendices. If the scale and mix function is accomplished within the decoder, only the biquad coefficient write commands should be used.

These values should be written to RAM via I^2C during the initialization sequence before the final unmuting.

RAM Address	24-Bit Data	Comment
D0h	16C310h	Channel 1 Left Scale Factor (-15dB)
D1h	16C310h	Channel 2 Right Scale Factor (-15dB)
D2h	16C310h	Channel 3 Left Surround Scale Factor (-15dB)
D3h	16C310h	Channel 4 Right Surround Scale Factor (-15dB)
D4h	16C310h	Channel 5 Center Scale Factor (-15dB)
D5h	47FACCh	Channel 6 LFE Scale Factor (-5dB)
00h	7FA51Fh	Channel 1 Left b_2 coefficient
01h	3FD2E9h	Channel 1 Left $b_0/2$ coefficient
02h	80B581h	Channel 1 Left $-a_2$ coefficient
03h	7FA4FFh	Channel 1 Left $-a_1/2$ coefficient
04h	805AE1h	Channel 1 Left $b_1/2$ coefficient
19h	7FA51Fh	Channel 2 Right b_2 coefficient
1Ah	3FD2E9h	Channel 2 Right $b_0/2$ coefficient
1Bh	80B581h	Channel 2 Right $-a_2$ coefficient
1Ch	7FA4FFh	Channel 2 Right $-a_1/2$ coefficient
1Dh	805AE1h	Channel 2 Right $b_1/2$ coefficient
32h	7FA51Fh	Channel 3 Left Surround b_2 coefficient
33h	3FD2E9h	Channel 3 Left Surround $b_0/2$ coefficient
34h	80B581h	Channel 3 Left Surround $-a_2$ coefficient
35h	7FA4FFh	Channel 3 Left Surround $-a_1/2$ coefficient
36h	805AE1h	Channel 3 Left Surround $b_1/2$ coefficient
4Bh	7FA51Fh	Channel 4 Right Surround b_2 coefficient
4Ch	3FD2E9h	Channel 4 Right Surround $b_0/2$ coefficient
4Dh	80B581h	Channel 4 Right Surround –a2 coefficient
4Eh	7FA4FFh	Channel 4 Right Surround $-a_1/2$ coefficient
4Fh	805AE1h	Channel 4 Right Surround $b_1/2$ coefficient
64h	7FA51Fh	Channel 5 Center b_2 coefficient
65h	3FD2E9h	Channel 5 Center $b_0/2$ coefficient
66h	80B581h	Channel 5 Center $-a_2$ coefficient
67h	7FA4FFh	Channel 5 Center $-a_1/2$ coefficient
68h	805AE1h	Channel 5 Center $b_1/2$ coefficient
7Dh	000020h	Channel 6 LFE b_2 coefficient
7Eh	000010h	Channel 6 LFE $b_0/2$ coefficient

7Fh	80B581h	Channel 6 LFE $-a_2$ coefficient
80h	7FA4FFh	Channel 6 LFE $-a_1/2$ coefficient
81h	000020h	Channel 6 LFE $b_1/2$ coefficient

Bass Management for a 2.1 system using the DDX-8000

The DDX-8000 can perform bass-management to support 2.1 applications using the scale and mix and biquad functionality. The discussion above for 5.1 systems can be applied here as well; with the exception that the LFE content from only two channels is redirected into the subwoofer channel 6. The table given below shows the 24-bit data to be written into the RAM segment. The same biquad filter coefficients for a 120 Hz crossover frequency can be used.
These settings can be used when a 5.1 system is in stereo mode.

These values should be written to RAM via I²C during the initialization sequence before the final unmuting.

RAM Address	24-Bit Data	Comment
D0h	3FFFFFh	Channel 1 Left Scale Factor (-6dB)
D1h	3FFFFFh	Channel 2 Right Scale Factor (-6dB)
00h	7FA51Fh	Channel 1 Left b_2 coefficient
01h	3FD2E9h	Channel 1 Left $b_0/2$ coefficient
02h	80B581h	Channel 1 Left $-a_2$ coefficient
03h	7FA4FFh	Channel 1 Left $-a_1/2$ coefficient
04h	805AE1h	Channel 1 Left $b_1/2$ coefficient
19h	7FA51Fh	Channel 2 Right b_2 coefficient
1Ah	3FD2E9h	Channel 2 Right $b_0/2$ coefficient
1Bh	80B581h	Channel 2 Right $-a_2$ coefficient
1Ch	7FA4FFh	Channel 2 Right $-a_1/2$ coefficient
1Dh	805AE1h	Channel 2 Right $b_1/2$ coefficient
7Dh	000020h	Channel 6 LFE b_2 coefficient
7Eh	000010h	Channel 6 LFE $b_0/2$ coefficient
7Fh	80B581h	Channel 6 LFE $-a_2$ coefficient
80h	7FA4FFh	Channel 6 LFE $-a_1/2$ coefficient
81h	000020h	Channel 6 LFE $b_1/2$ coefficient

Pre-set EQ functions using DDX-8000 Biquads

Each channel of the DDX-8000 controller has five dedicated biquads to their disposal, which could be used to achieve specialized EQ settings such as ROCK, JAZZ, CLASSICAL, ACOUSTIC, etc. Shown below is an example of ROCK EQ setting implemented for Channel 1. The last four of the five biquads for channel 1 are used to obtain this setting. The first biquad of each channel is made available to implement crossover for bass-management functionality.
It is also recommended that while implementing special EQ settings, depending upon the cumulative boost being applied, a pre-determined pre-scale is included for each channel. Say, if the maximum cumulative boost for ROCK setting is +5 dB, set the pre-scale for that channel to –5 dB so as to avoid the saturation of the filters. Based on the different EQ settings provided here, a fixed pre-scale of -6 dB can be used for all the settings. This will keep the average volume/level from changing when the preset EQ settings are changed.
When the EQ settings are changed all five coefficients of each biquad should be updated at one time such that no audible noise can be heard.
An unlimited number of preset EQ settings can be performed. It is suggested that these be developed using the Apogee DDX filter editor software program.

These values should be written to RAM via I^2C during the initialization sequence before the final unmuting.

RAM Address	**24-bit Data**	**Comment**
C8h	C00000h	Channel 1 Pre-scale (-6dB)
05h	7FD532h	Channel 1 biquad#2 coefficient: b_2
06h	400273h	Channel 1 biquad#2 coefficient: $b_0/2$
07h	8025E6h	Channel 1 biquad#2 coefficient: $-a_2$
08h	75ED02h	Channel 1 biquad#2 coefficient: $-(a_1/2)$
09h	8012Feh	Channel 1 biquad#2 coefficient: $b_1/2$
0Ah	7FDD84h	Channel 1 biquad#3 coefficient: b_2
0Bh	4003E6h	Channel 1 biquad#3 coefficient: $b_0/2$
0Ch	801AAFh	Channel 1 biquad#3 coefficient: $-a_2$
0Dh	7FF28Ch	Channel 1 biquad#3 coefficient: $-(a_1/2)$
0Eh	800D74h	Channel 1 biquad#3 coefficient: $b_1/2$
0Fh	7EDB91h	Channel 1 biquad#4 coefficient: b_2
10h	3FDEEAh	Channel 1 biquad#4 coefficient: $b_0/2$
11h	81669Ah	Channel 1 biquad#4 coefficient: $-a_2$
12h	7F4B21h	Channel 1 biquad#4 coefficient: $-(a_1/2)$
13h	80B4DFh	Channel 1 biquad#4 coefficient: $b_1/2$
14h	622EB9h	Channel 1 biquad#5 coefficient: b_2
15h	442D27h	Channel 1 biquad#5 coefficient: $b_0/2$
16h	9576F8h	Channel 1 biquad#5 coefficient: $-a_2$
17h	714597h	Channel 1 biquad#5 coefficient: $-(a_1/2)$
18h	8EBA69h	Channel 1 biquad#5 coefficient: $b_1/2$

Appendix A: Crossover Filters

120Hz	Low-Pass Filter	High-Pass Filter
b_2	000020h	7FA51Fh
$b_0/2$	000010h	3FD28Fh
$-a_2$	80B581h	80B581h
$-a_1/2$	7FA4FFh	7FA4FFh
$b_1/2$	000020h	805AE1h

100Hz	Low-Pass Filter	High-Pass Filter
b_2	000016h	7FB440h
$b_0/2$	00000Bh	3FDA20h
$-a_2$	809753h	809753h
$-a_1/2$	7FB429h	7FB429h
$b_1/2$	000016h	804BC0h

150Hz	Low-Pass Filter	High-Pass Filter
b_2	000032h	7F8E71h
$b_0/2$	000019h	3FC738h
$-a_2$	80E2B9h	80E2B9h
$-a_1/2$	7F8E3Eh	7F8E3Eh
$b_1/2$	000032h	80718Fh

80Hz	Low-Pass Filter	High-Pass Filter
b_2	00000Eh	7FC363h
$b_0/2$	000007h	3FE1B1h
$-a_2$	80791Eh	80791Eh
$-a_1/2$	7FC354h	7FC354h
$b_1/2$	00000Eh	803C9Dh

Appendix B: Preset EQ settings

JAZZ EQ setting coefficients: Min. pre-scale required: -5.45dB = B4207Fh

	Biquad#2	Biquad#3	Biquad#4
b_2	7F2DCAh	733E51h	622EB9h
$b_0/2$	401D71h	40BB29h	442D27h
$-a_2$	809753h	8B4B5Dh	9576F8h
$-a_1/2$	7FB3A3h	794E5Ah	714597h
$b_1/2$	804C5Dh	86B1A6h	8EBA69h

CLASSICAL EQ setting coefficients: Min. pre-scale required: -4 dB = A9078Ah

	Biquad#2	Biquad#3	Biquad#4
b_2	7F5F72h	7C373Ch	548F22h
$b_0/2$	40049Dh	40609Ah	427D5Ah
$-a_2$	809753h	82ED90h	A67628h
$-a_1/2$	7FB3A3h	7E77E0h	5E3269h
$b_1/2$	804C5Dh	818820h	A1CD97h

ACOUSTIC EQ setting coefficients: Min. pre-scale required: -2.45 dB = 9AC726h

	Biquad#2	Biquad#3	Biquad#4	Biquad#5
b_2	7FD7CAh	7FBB8Ah	67C1A4h	548F22h
$b_0/2$	400127h	4003ECh	4163B2h	427D5Ah
$-a_2$	8025E6h	803C9Dh	9576F8h	A67628h
$-a_1/2$	7FED02h	7FE194h	714597h	5E3269h
$b_1/2$	8012FEh	801E6Ch	8EBA69h	A1CD97h