Loudness

Overview

The Loudness component alters the frequency response curve to correspond approximately to the equal loudness curves of the ear.

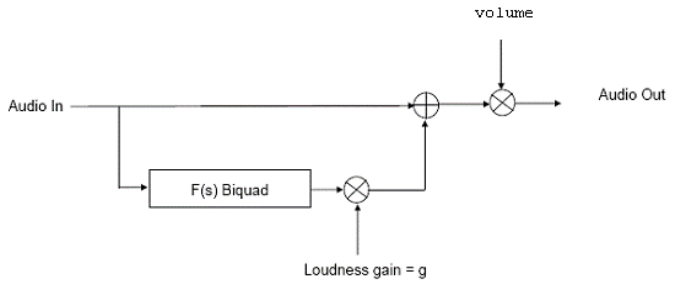

Figure 1: Loudness Block Diagram

Note: F(s) Biquad contains a pair of second-order filters in cascade

Loudness compensation employs a Biquad filter whose output is scaled by a factor loudness gain, ***g***, which is a function of volume control setting **`volume`**. This output is then added to the audio stream itself as shown in Figure 1. **`volume`** is external to the loudness component and is coming from the volume component.

IMPORTANT: The Loudness component uses the volume level from a volume component to set its gain, ***g***. Therefore a Volume component **must** be present in the design and **must** follow the Loudness component as the first instance of volume. When multiple volume components are present, the loudness component will use the volume level from the first instance of the volume component.

Loudness compensation allows audio data to be given a spectral adjustment (as per equal loudness curve) as determined by the programmable loudness gain, ***g***. As explained below the value of ***g*** can be controlled by 4 different configurable properties from the properties window.

The loudness gain ***g*** is expressed as:

$$g = f(\texttt{volume}) = [(\texttt{volume})^{\texttt{Log\_Gain}} \times 2^{\texttt{Log\_Offset}} \times \texttt{Linear\_Gain}] + \texttt{Linear\_Offset}$$

Typically, **`Log_Gain`** and **`Log_Offset`** are used to derive the desired loudness compensation function. **`Linear_Gain`** is used to adjust the dependence of loudness gain on **`volume`** and **`Linear_Offset`** is used to adjust loudness gain that is independent of **`volume`**.

If **`Linear_Gain`** is set to 0.0 and **`Linear_Offset`** is set to 0.0, loudness compensation is disabled.
If **`Linear_Gain`** is set to 0.0 and **`Linear_Offset`** is set to 1.0, then the biquad-filtered audio is directly added to the input audio with no affect by **`volume`** change.

The final Audio output is
Audio Out = (Audio In) x **`volume`** * [1+ ***g*** x *F(s) Biquad)*]

Where *F(s) Biquad* is output of Biquad. The response of this Biquad is close to the equal loudness reponse curve of the ear.

Configurable Properties (Run Time)

Coefficient	Scaling	Description	Default Value
volume	5.19	Volume level on Volume component	0
Log_Gain	5.19	Defines amount of loudness compensation that is dependent on volume change in logarithmic fashion.	-0.5
Log_Offset	5.19	Defines additional amount of loudness compensation dependent on volume change in logarithmic fashion.	0.0
Linear_Gain	5.19	Defines amount of loudness compensation that is dependent on volume change in linear fashion	1.0
Linear_Offset	5.19	Defines amount of loudness compensation that is independent of volume change.	0.0

Table 1 Configurable Properties

Default Biquad Filter
This equal loudness filter is implemented as a pair of bi-quadratic sections in cascade. The coefficient scaling and default values are shown in the table below.

Coefficient	Scaling	Default Value
BQ1B0	1.23	0.5073223114013671875
BQ1B1	2.22	-0.492538303136825561523437 5
BQ1B2	1.23	0.478591859340667724609375
BQ1A1	2.22	0.985390245914459228515625
BQ1A2	1.23	-0.971201300621032714843 75
BQ2B0	1.23	0.900089144706726074218 75
BQ2B1	2.22	-0.673261553049087524414062 5
BQ2B2	1.23	0.539675056934356689453125
BQ2A1	2.22	0.651605248451232910156 25
BQ2A2	1.23	-0.48969268798828125

Table 2 Default Filter coefficients

Example: Loudness compensation with default values

Log_Gain = -0.5
Log_Offset = 0
Linear_Gain = 1
Linear_Offset = 0

Audio Out = [Audio In x **volume**] + [Audio In x F(s)Biquad x sqrt(**volume**)]

The Default value Loudness frequency responses are shown in Figure 2 (**volume** ranges from 0db to -90 db, step is -10db)

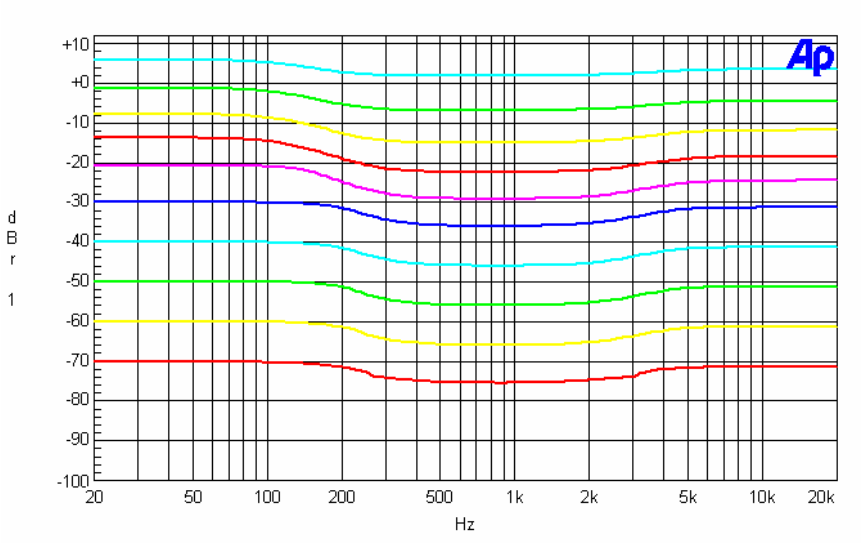

Figure 2 Default Value Loudness Frequency Responses

Usage

The Loudness component can be used to alter the frequency response curve to correspond approximately to the equal loudness curves of the ear.

I2C Interface

The I2C interface to Loudness is shown in Table 3.

I2C Address	DSP Memory Address	Size	Description
I2CAddress1	DspCoefBlockStart1	1	**Log Gain**
I2CAddress2	DspCoefBlockStart2	1	**Log Offset**
I2CAddress3	DspCoefBlockStart3	1	**Linear Gain**
I2CAddress4	DspCoefBlockStart4	1	**Linear Offset**
I2CAddress5	DspCoefBlockStart5	1	**Biquad 1 B0**
I2CAddress6	DspCoefBlockStart6	1	**Biquad 1 B1**
I2CAddress7	DspCoefBlockStart7	1	**Biquad 1 B2**
I2CAddress8	DspCoefBlockStart8	1	**Biquad 1 A1**
I2CAddress9	DspCoefBlockStart9	1	**Biquad 1 A1**
I2CAddress10	DspCoefBlockStart10	1	**Biquad 2 B0**
I2CAddress11	DspCoefBlockStart11	1	**Biquad 2 B1**
I2CAddress12	DspCoefBlockStart12	1	**Biquad 2 B2**
I2CAddress13	DspCoefBlockStart13	1	**Biquad 2 A1**
I2CAddress14	DspCoefBlockStart14	1	**Biquad 2 A2**

Table 3 I2C interface information