Assignment 2 - Audio Effect Programming
Digital Audio Effects
ECS730P Queen Mary University

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1 Introduction

This paper is a discussion of the implementation of a multi band compressor and review of the quality of the compressor. A multi band compressor VST plug in, developed using the Juce platform, was created. This paper discussed the design decisions made while creating this compressor and analyses the output to prove the functionality of the multi band compressor.

2 Design and Implementation

The compressor implemented is a three band compressor. A three band compressor was chosen to demonstrate the implementation of a pass band crossover, along with a high and low pass compressor. This proves a certain computational complexity within the implementation, as oppose to a simple crossover implementation.

2.1 Compressor

Queen Marys plugin demonstration code was used for the initial implementation of a compressor [1]. This code was then extended to include the use of a soft knee [2]. The implemented knee uses second order interpolation. The knee operates so that if the audio amplitude is within region of the threshold plus or minus the knee width, then a second order polynomial curve is fitted to the 'knee area', as a function of knee width, threshold, input gain and compression ratio.
The soft knee equation is defined formally [3]

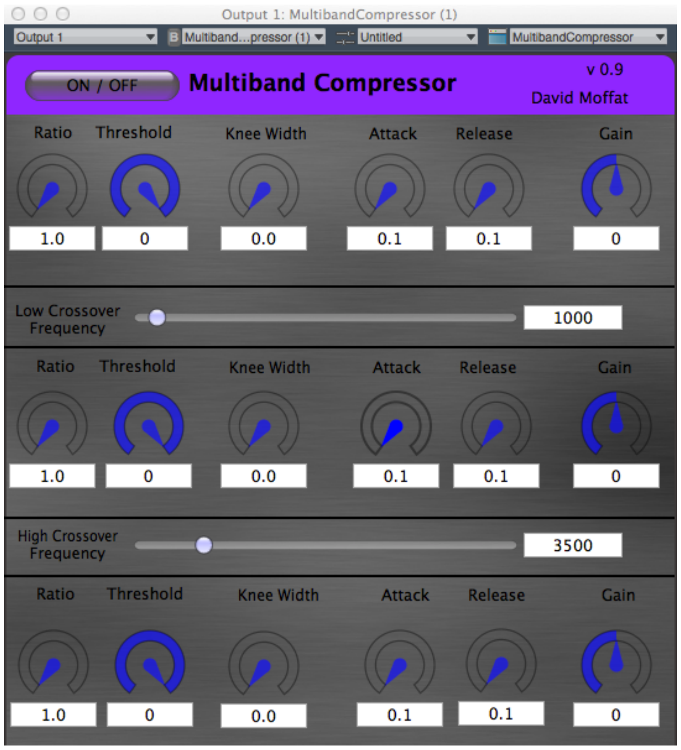
$$\text{If } 2|(x_g - T)| \leq W$$

$$\text{then } y_g = x_g + \frac{\left(\frac{1}{R-1}\right)\left(x_g - T + \frac{W}{2}\right)^2}{2W}$$

Where y_g is the output amplitude, x_g in the input amplitude, R is the compression ratio, T is the compression threshold and W is the knee width.

2.2 Crossover

The crossover was produced using the Juce *IIR-Coefficients* and *IIRFilter* libraries, however the crossover was extended to allow for the use of a Linkwitz Riley second order crossover to be implemented [4]. The coefficients for this crossover were taken from [5]. This crossover was chosen for is quality of performance in frequency and phase response and is described as "best suited for general use" [6], particularly as crossovers [5]. A key aspect of the Linkwitz Riley filter, when implemented, is the requirement that every alternating filter output is phase inverted, as such, every even indexed compressor has the output phase inverted. The implementation of a band pass filter was a series implementation of both a high pass and a low pass filter, making the resulting band pass filter a fourth order filter.


Output 1: MultibandCompressor (1)

Output 1 | Multiband...pressor (1) | Untitled | MultibandCompressor

ON / OFF **Multiband Compressor** v 0.9 David Moffat

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	0.0	0.1	0.1	0

Low Crossover Frequency 1000

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	0.0	0.1	0.1	0

High Crossover Frequency 3500

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	0.0	0.1	0.1	0

Figure 1: Compressor Setting, Resulting in Figure 3

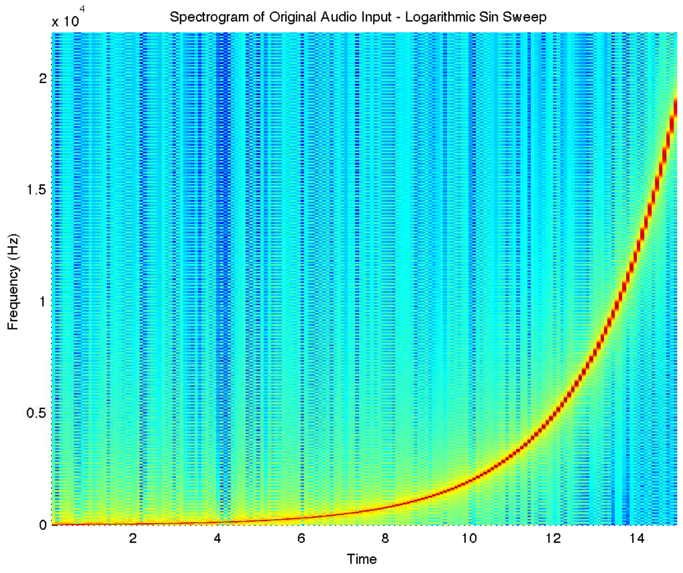


Figure 2: Spectrogram of Original Audio Source File

2.3 Graphic User Interface (GUI)

The GUI is based on the demonstration plugin compressor, however the control has been extended to allow for control of all attributes of the compressor for each band, including the addition of a knee width control, allowing the knee of the compressor to be changed from zero (off) to twenty (20dB knee width). In addition to this, two sliders have been added, one between each set of compressor controls, to allow for control of the crossover frequency between each band. The GUI is shown in figure 1.

3 Signal Analysis

To visualise the output of the multi band compression, a logarithmic sine wave sweep was passed as the input to the plugin. A spectrogram of the input signal is presented in figure 2.
Given this input signal, the time-amplitude domain representations of various compressor settings can be seen in figures 3, 4, 5 and 6.
The sine sweep was passed through the compressor when all setting were turned off, to allow for visualisation of a control case, for comparison for each of the following implementation tests. The results of the control experiment can be seen in figure 3.
The sin sweep passed to the compressor with three different settings, to visualise each of the bands of the compressor independently. The setting for each of the compressor are demonstrated on the GUI, in Appendix A in figures 8, 9 and 10.
The low pass filter with compression is demonstrated in 4, where it can be seen the audio signal is compressed where the original signal is of a frequency below 1kHz.
It can be seen in figure 5 that the compression range falls into the centre part of the signal, under the band pass, as specified in appendix A figure 9,
And similarly with figure 6 and the high pass filter as identified by the top range of the previous bandpass signal.

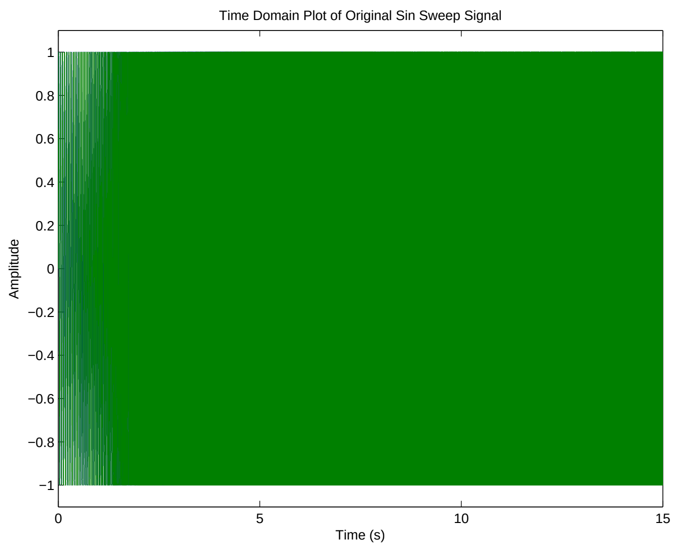


Figure 3: No Turned Off, as per Figure 1

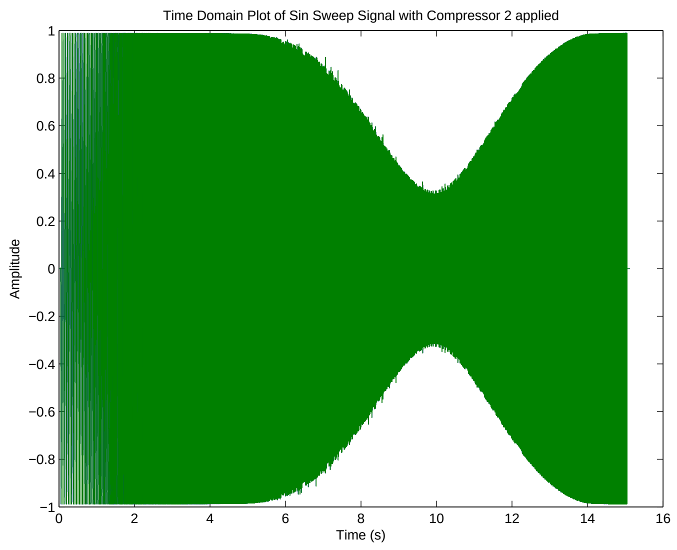


Figure 5: Compressor 2 Set, as per Figure 9

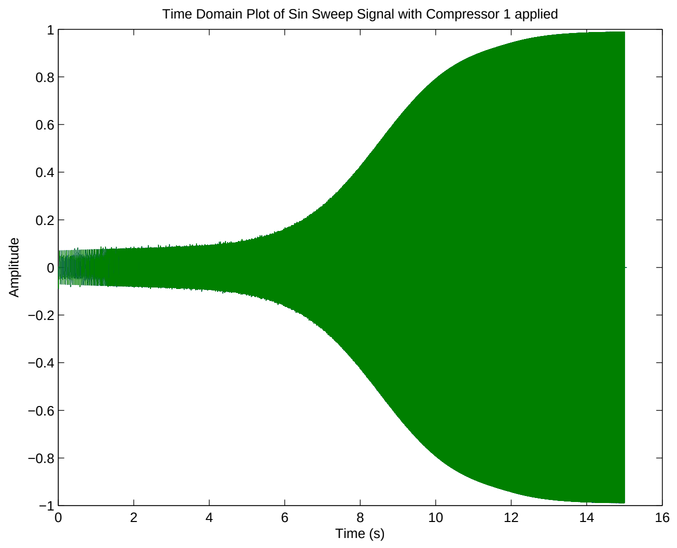


Figure 4: Compressor 1 Set, as per Figure 8

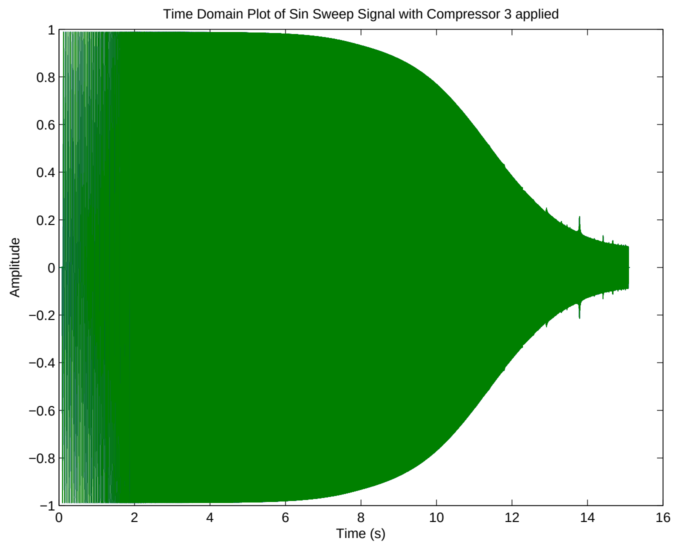


Figure 6: Compressor 3 Set, as per Figure 10

4 Evaluation

It is shown in section 3 that the compressor does perform as specified, that we can separate audio into distinct bands and apply different levels of compression. In addition to this, several additional features have been produced within the implementation of this multi band compressor, including

- Second order interpolation soft knee implemented for each filter.
- User control over two crossover frequencies which are applied in real time.
- Three bands of compression, thus including a pass band filter.
- Implementation of a Linkwitz Riley second order filter, as this is popularly believed to be a very suitable filter to use.
- Intuitive interface.

Despite all of these additions, there are some artefacts introduced by the implemented filter. The crossover in the filter does not work perfectly, and as such the amplitude of the sin sweep is often modified with no compression being heard. This can be heard generally in audio, by modifying the crossover frequencies, there is an audible approx 3dB cut in the specified audio band. The results are visualised in 7, given the compressor setting from figure 11.
It is believe that this artefact is a result of the Linkwitz Riley second order crossover, and that a Linkwitz Riley fourth order would potentially be more suitable.

5 Conclusion

The aim of this paper was to produce an functional multi band compressor VST plugin, developed using Juce. This task was successfully fulfilled with further work begin carried out on aspects of the assignment. Despite this, there are significant improvements that could be made to the existing compressor.

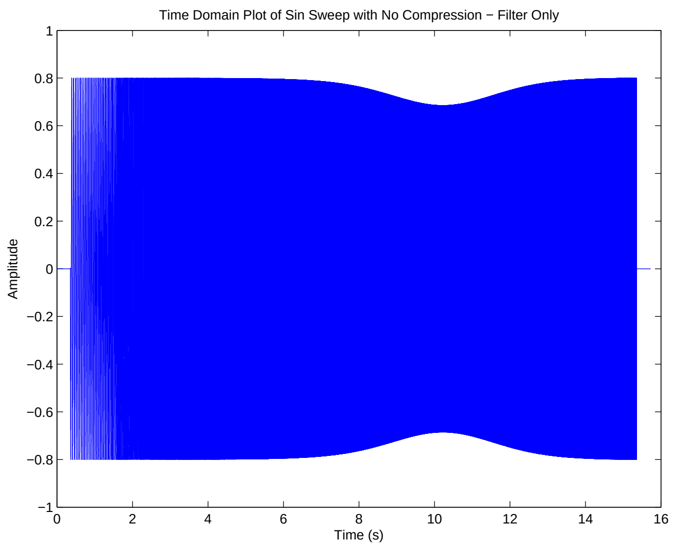


Figure 7: Compressor 3 Set, as per Figure 11

5.1 Further Work

The potential to extend work further on this assignment would be significant. The implementation of a fourth order Linkwitz Riley crossover, as discussed in section 4, would certainly have the potential to remove audible artefacts from the audio signal. Further extension of the compressor would also be possible, with the implantation of RMS detection, rather than the existing peak detection. The implementation of ballistics in the logarithmic (dB) domain, rather than linear domain could potentially also improve the compressor, however this would be a very subjective change and would require user studies to decide whether this could be considered an improvement, rather simply a modification. A further potential improvement would be in the GUI, allowing users a series of further option in the GUI including

- Visual display metering of inputs, outputs and applied compression.
- User drawable compression curves, including the implementation of non-linear compression curves
- Graphical displays for compression bands and display of real time FFT of signal and of compression in each band eg. an FFT of in-

put and output with isolation lines for each compression band.

- Allow the option of converting each compressor into an expander, to increase functionality or equalise the dynamic range of a performance across the spectrum.

- Implementation of adaptive filter techniques to allow for automated compression band selection and automated compression ratio selection to allow for a signal to be equalised automatically, based on the incoming audio signal and how it fills the spectrum. This could be particularly useful in attempting to combat audio masking.

6 Implementation Environment

All implementation was undertaken using Xcode v5.0.2, using Juce v3.0.1 and the VST SDK v3.6.0. Testing was undertaken in AU Lab v2.3 and Logic v10.0.6. Plugins were compiled as 64-Bit.

References

[1] J. Reiss and A. McPherson, "C4DM standard audio effect plugins," VST Plugin, 2014.

[2] J. Reiss, "ECS730 Digital Audio Effects," University Lecture Material, 2014.

[3] D. Giannoulis, M. Massberg, and J. D. Reiss, "Digital dynamic range compressor designa tutorial and analysis," *Journal of the Audio Engineering Society*, vol. 60, no. 6, pp. 399–408, 2012.

[4] D. Bohn, "Linkwitz-Riley crossovers: A primer," 1989.

[5] W. Pirkle, *Designing Audio Effect Plug-Ins in C++: With Digital Audio Signal Processing Theory.* Taylor & Francis, 2012.

[6] S. P. Lipshitz and J. Vanderkooy, "In-phase crossover network design," *Journal of the Audio Engineering Society*, vol. 34, no. 11, pp. 889–894, 1986.

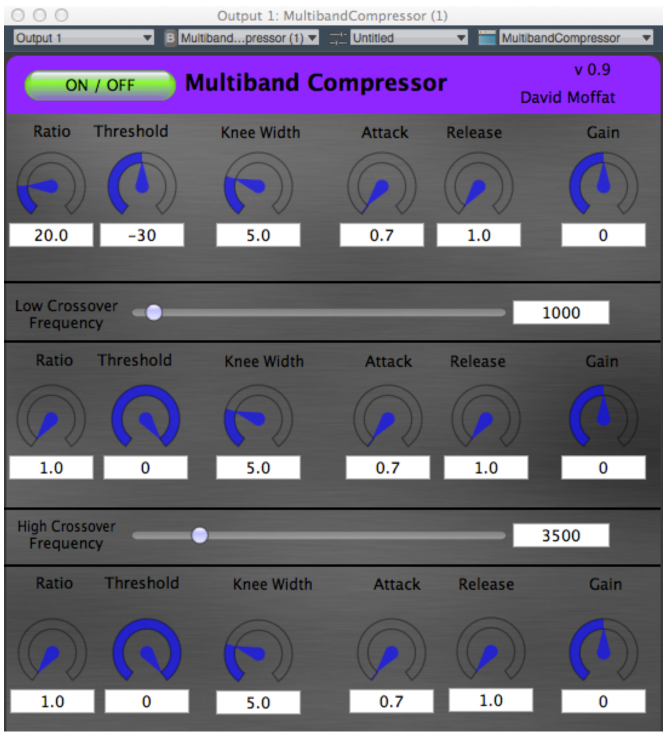
[7] B. Mulgrew, P. M. Grant, and J. Thompson, *Digital signal processing: concepts and applications.* Macmillan Press, 1999.

[8] S. K. Mitra and Y. Kuo, *Digital signal processing: a computer-based approach.* McGraw-Hill New York, 2006, vol. 2.

[9] R. Boulanger and V. Lazzarini, *The Audio Programming Book.* The MIT Press, 2010.

[10] D. Coulter, *Digital audio processing.* CRC Press, 2000.

A Appendix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20.0	-30	5.0	0.7	1.0	0

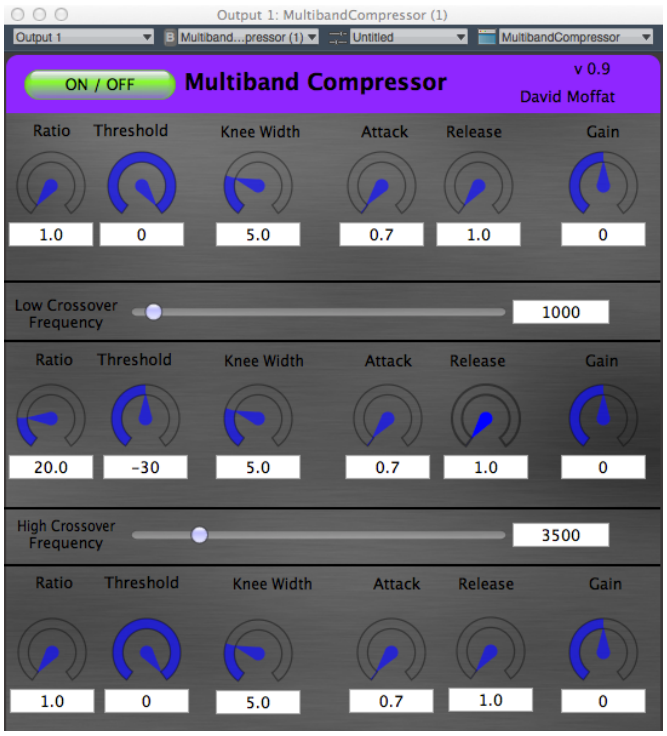
Low Crossover Frequency 1000

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	5.0	0.7	1.0	0

High Crossover Frequency 3500

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	5.0	0.7	1.0	0

Figure 8: Compressor Setting, Resulting in Figure 4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Ratio	Threshold	Knee Width	Attack	Release	Gain
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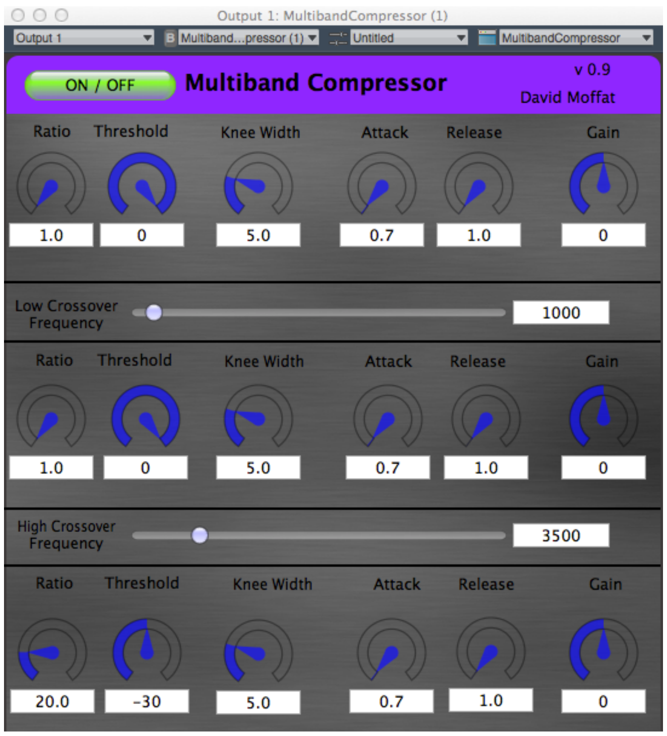
Figure 9: Compressor Setting, Resulting in Figure 5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High Crossover Frequency 3500

Ratio	Threshold	Knee Width	Attack	Release	Gain
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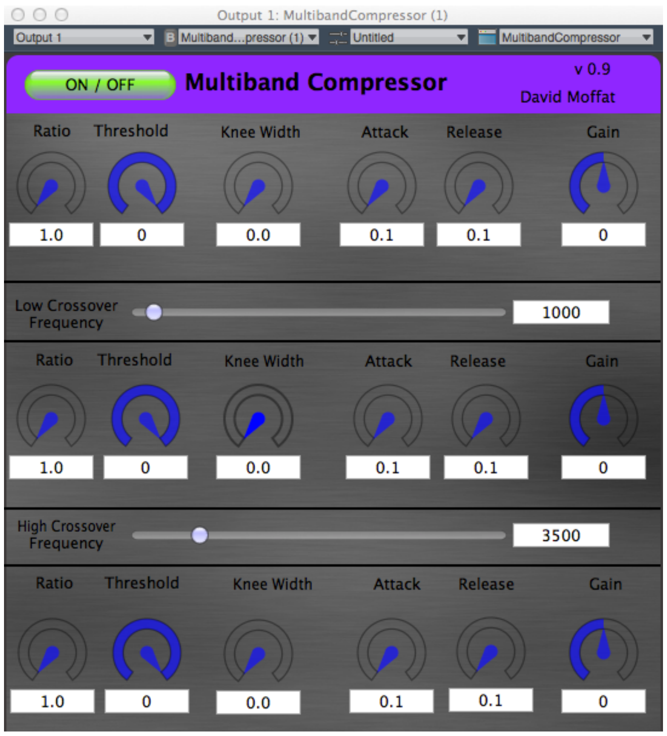
Figure 10: Compressor Setting, Resulting in Figure 6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Low Crossover Frequency 1000

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	0.0	0.1	0.1	0

High Crossover Frequency 3500

Ratio	Threshold	Knee Width	Attack	Release	Gain
1.0	0	0.0	0.1	0.1	0

Figure 11: Compressor Setting, Resulting in Figure 7