End-to-end equalization with convolutional neural networks

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Introduction

- Equalization (EQ)
  - Audio effect widely used in the production and consumption of music.
  - Modification of frequency content through positive or negative gains which change the characteristics of the audio.
  - Recording, Mixing, Mastering, Home Audio Systems.

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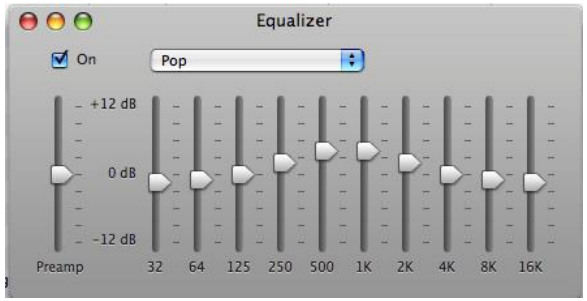
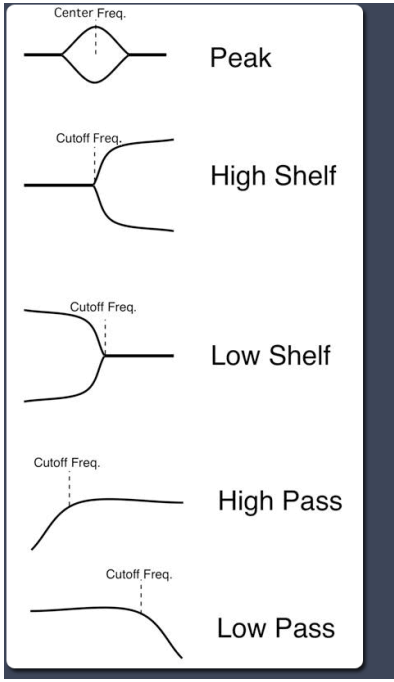




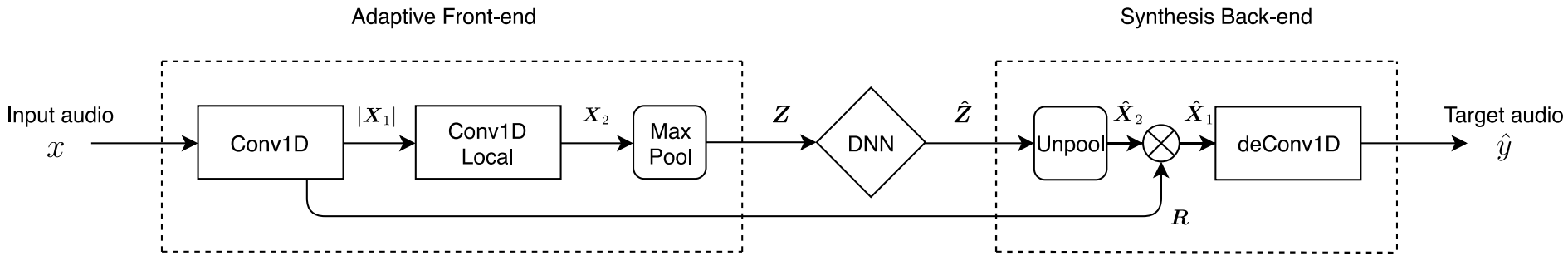
Task

- Given an **arbitrary** EQ configuration, our task is to train a deep neural network to learn and apply the specific transformation.

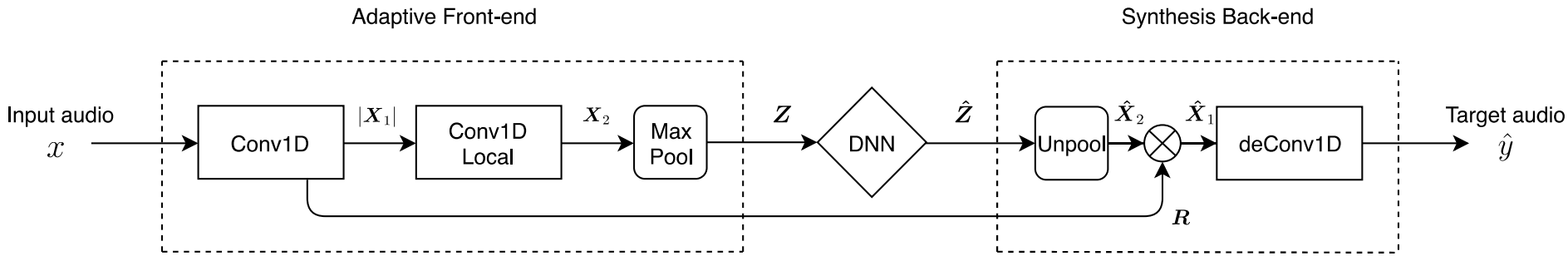
- Using an **end-to-end architecture**, where raw audio is both the input and the output of the system.

- We attempt to find a general deep learning architecture to perform audio processing in the context of matched equalization.

Model


Adaptive Front-end
Synthesis Back-end
Input audio
x
Conv1D
$|X_1|$
Conv1D Local
X_2
Max Pool
Z
DNN
$\hat{Z}$
Unpool
$\hat{X}_2$
$\hat{X}_1$
deConv1D
Target audio
$\hat{y}$
R

Model



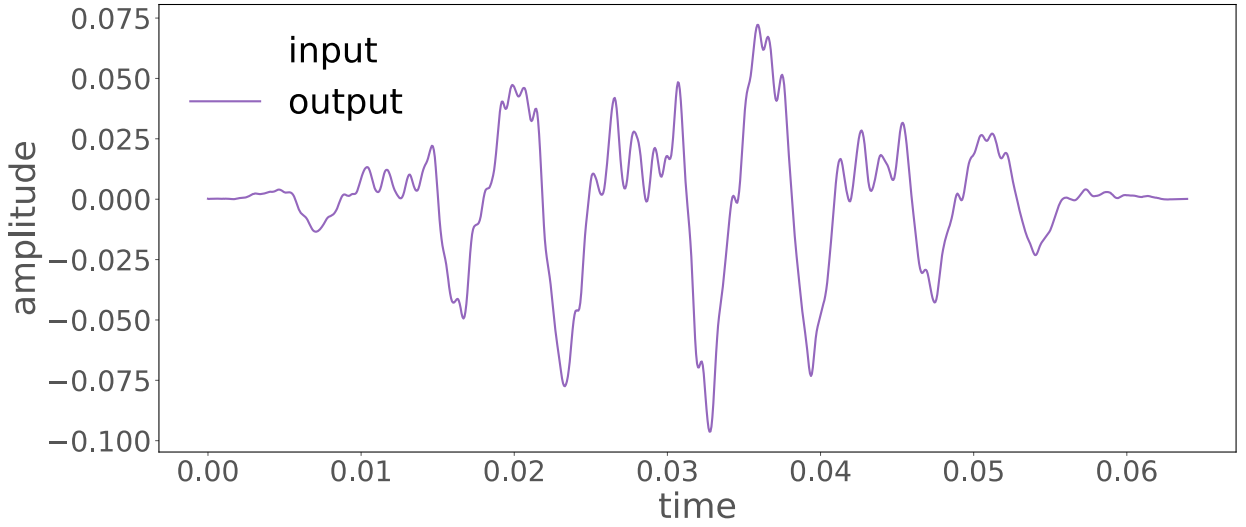
- Adaptive Front-end
  - 2 CNN layers, 1 pooling layer and 1 residual connection.
  - **Conv1D**: 128 filters of size 64, *absolute value* function.
  - **Conv1D Local**: 128 filters of size 128, softplus.
- Latent-space DNN
  - 2 layers of locally connected and fully connected dense layers
- Synthesis Back-end
  - 1 unpooling layer and 1 CNN layer.
  - **deConv1D**: deconvolution operation; implemented by transposing Conv1D filters.

Training

- The training of the model is performed in two steps.
  - The first step is to train both the adaptive front-end and the synthesis back-end for an *unsupervised learning* task.
  - The second step consists of an *end-to-end supervised learning* task based on a given EQ target.

- The unsupervised and supervised learning steps were performed for each type of EQ target. Then, the models were tested with samples from the test dataset.

Results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output
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0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100
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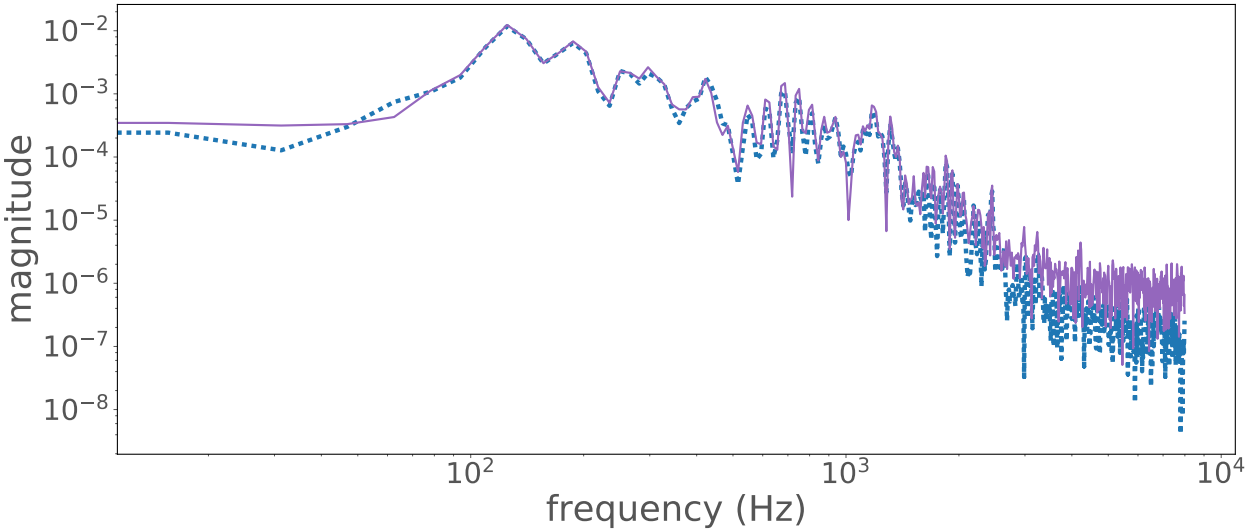
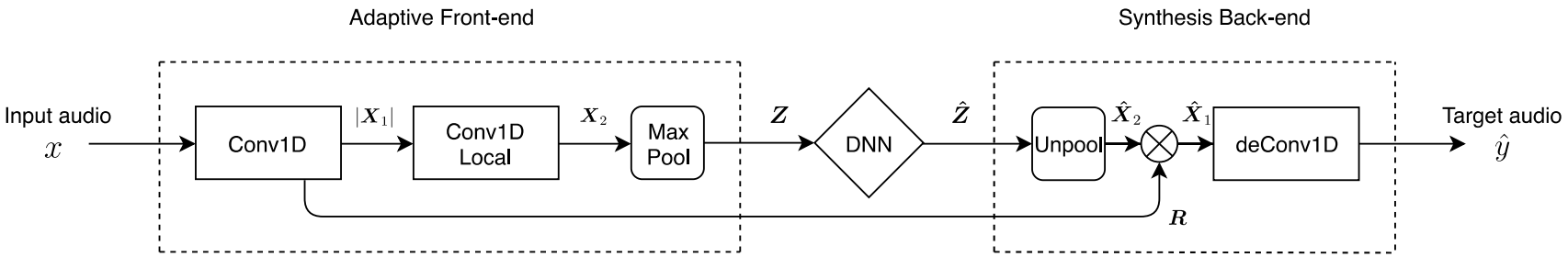
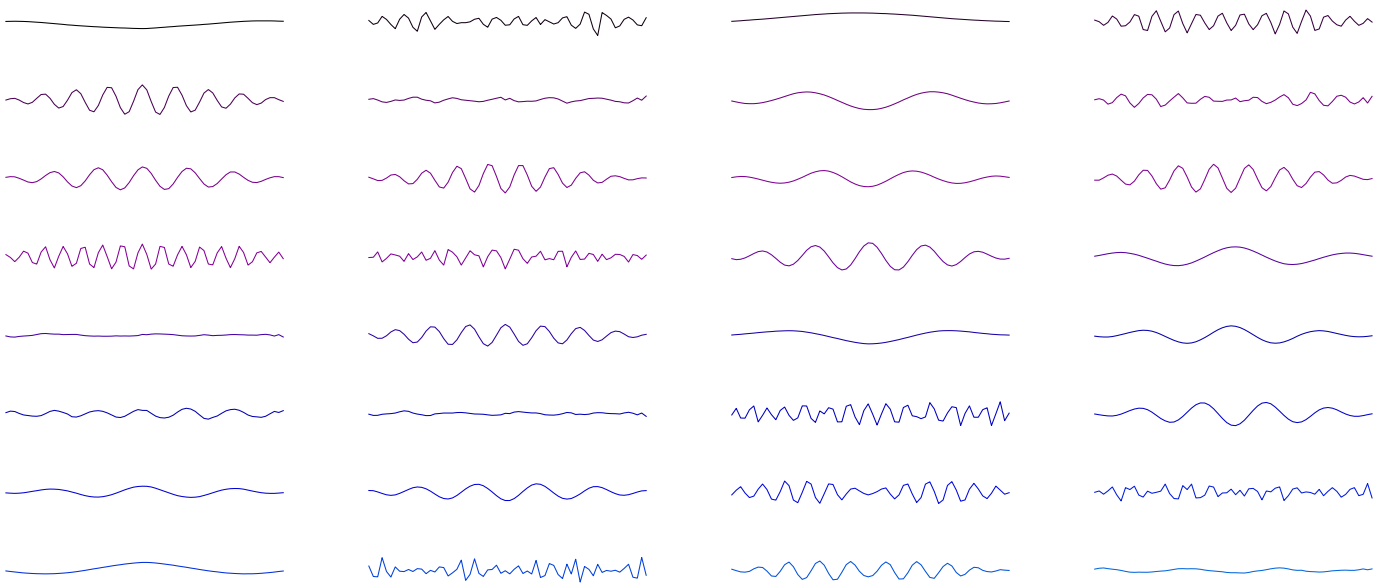
0.01
0.02
0.03
0.04
0.05
0.06


magnitude
frequency (Hz)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{2}
10^{3}
10^{4}

Results



Conv1D filters



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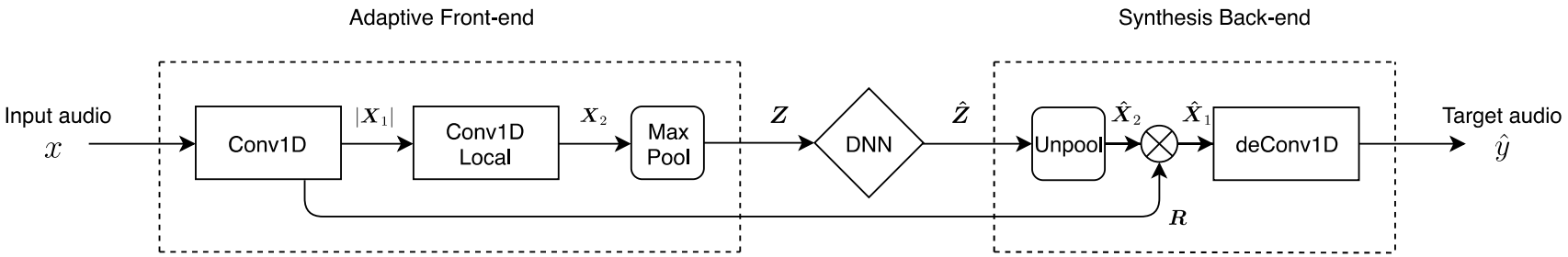
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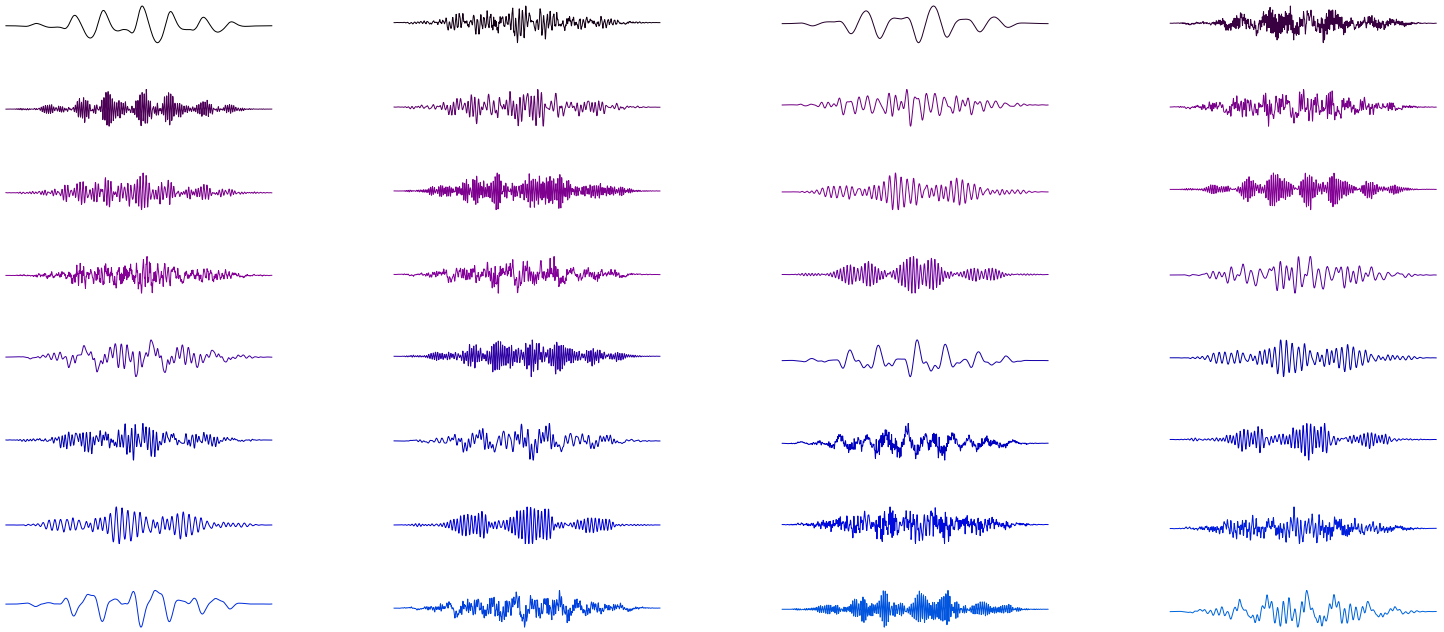
$\hat{y}$
R

X_1



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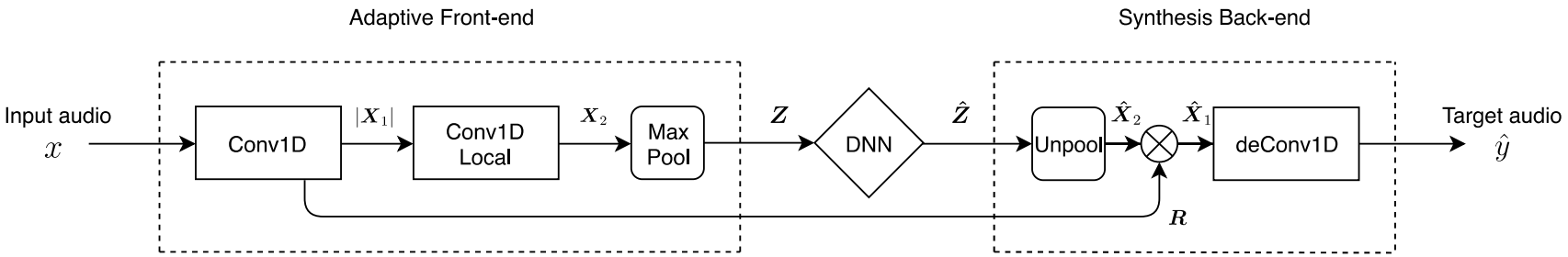
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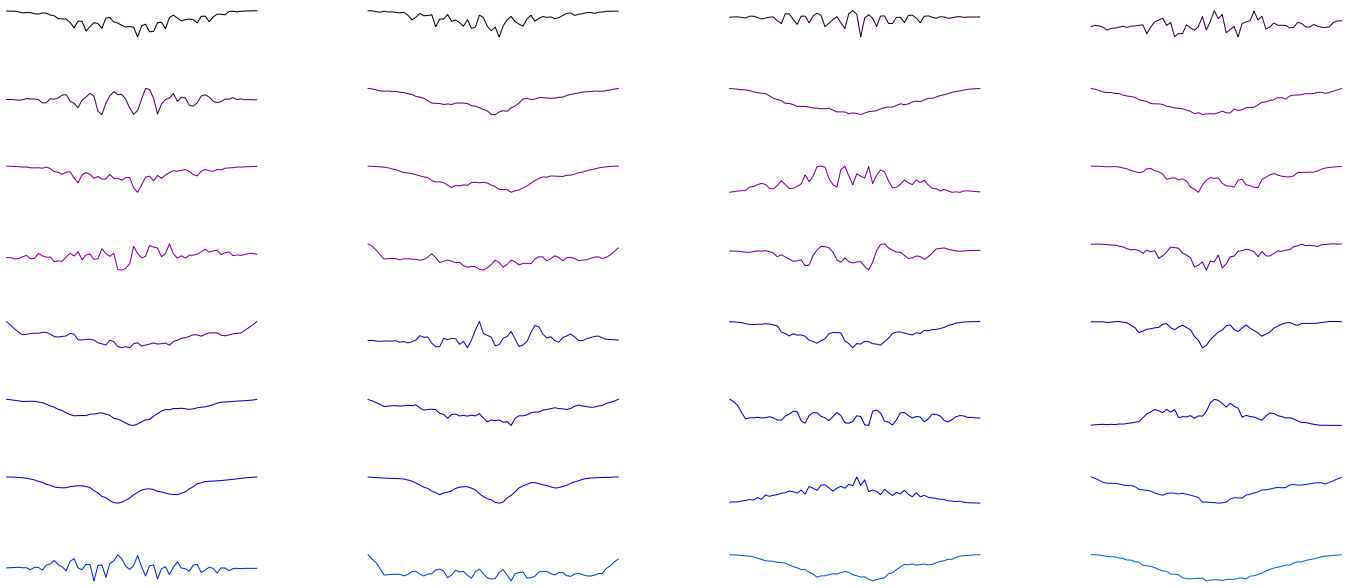

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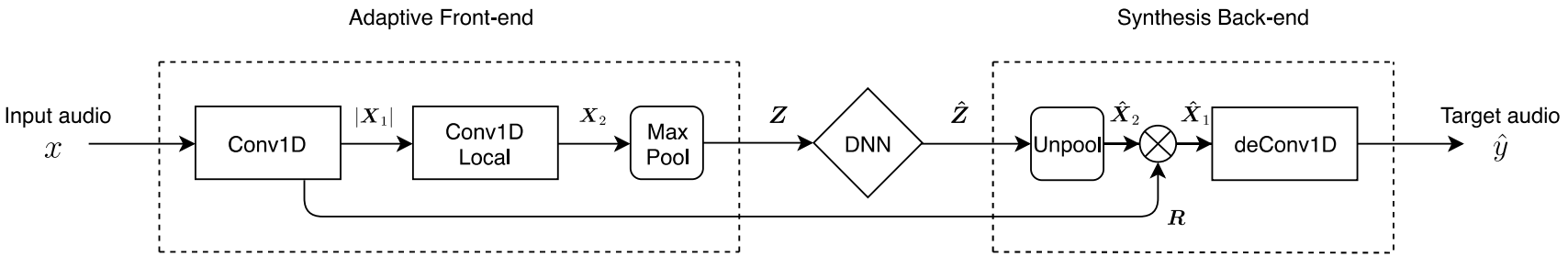

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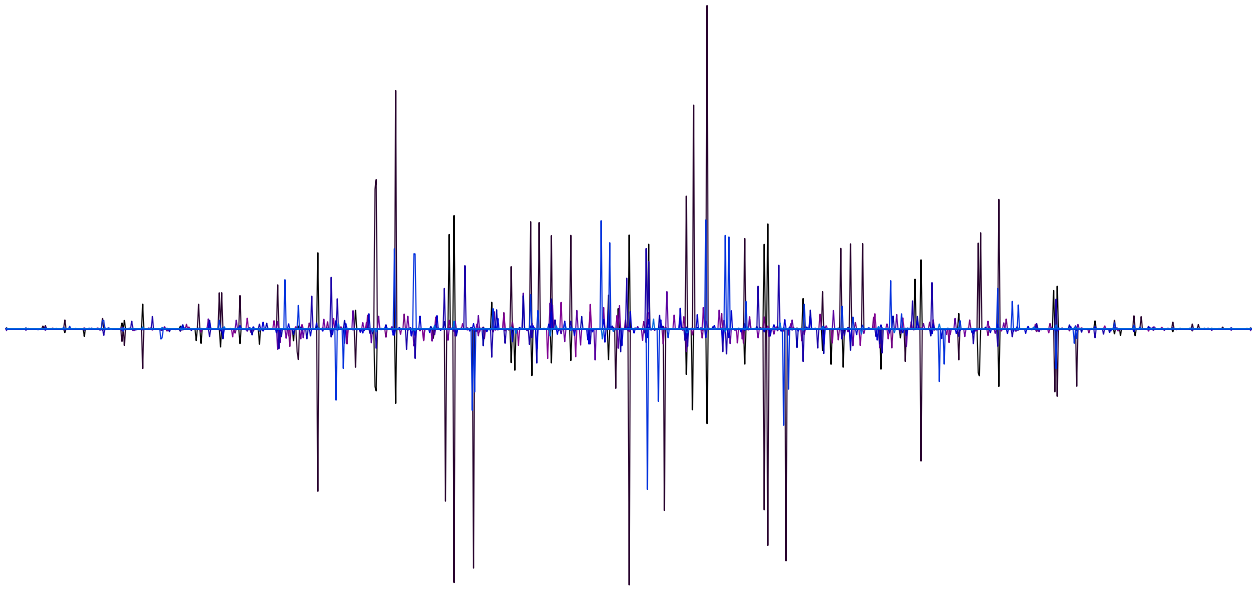

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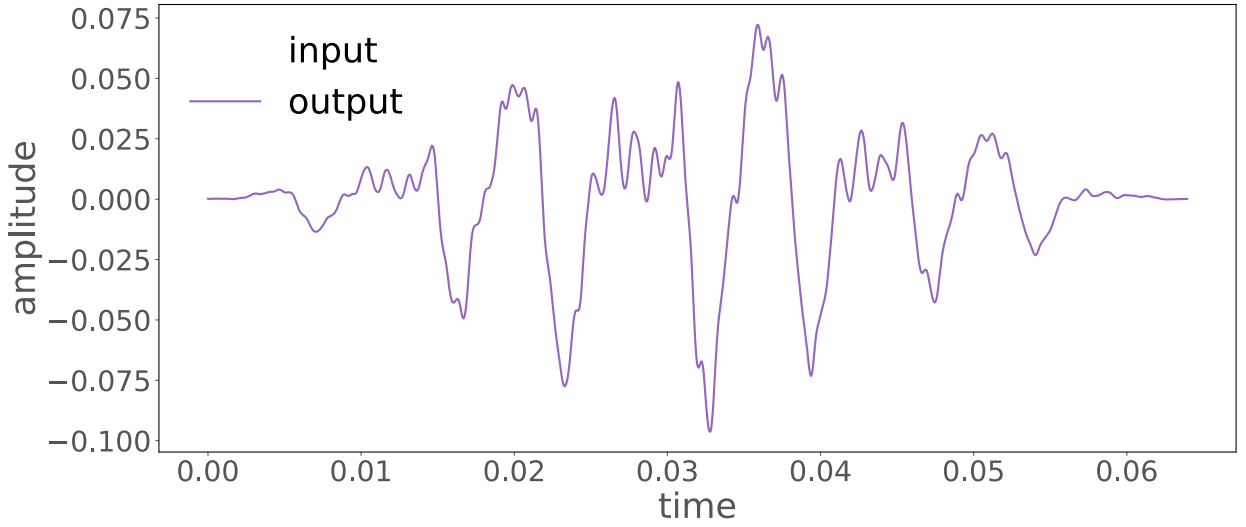
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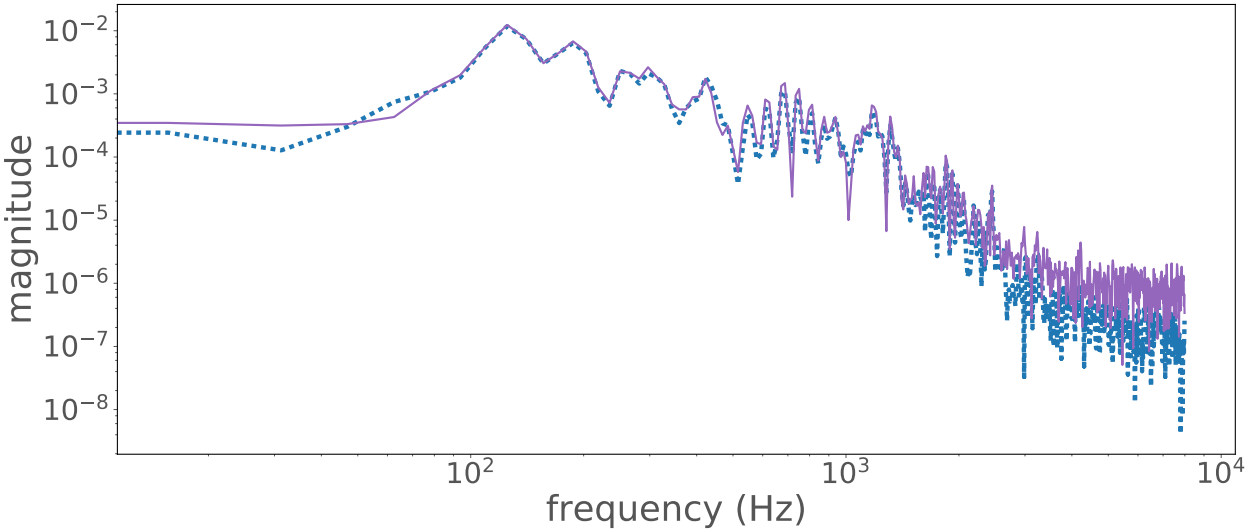
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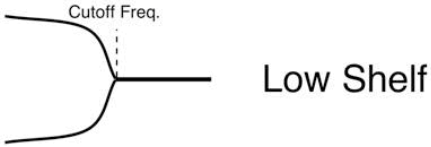
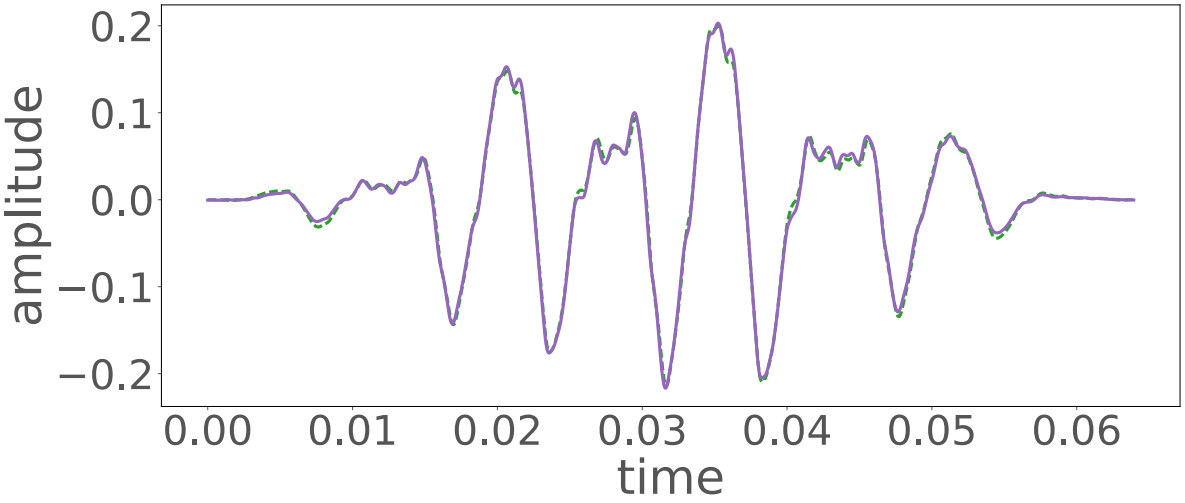
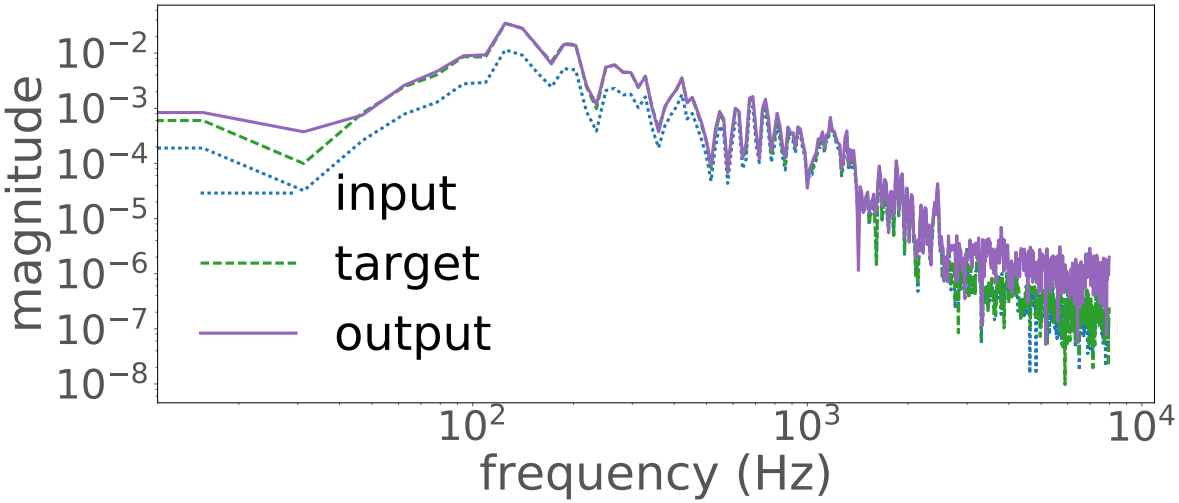
Results

Shelving







Results

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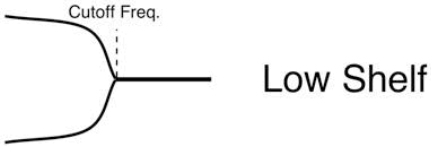
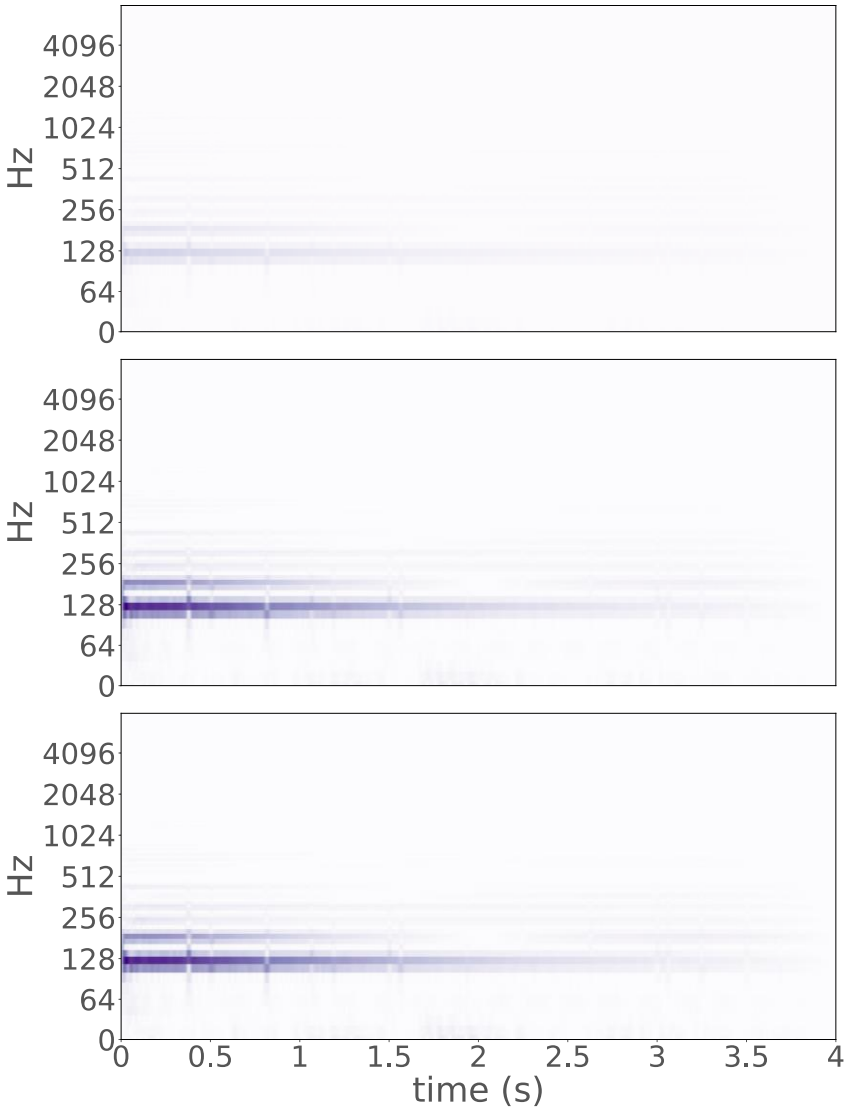


Input

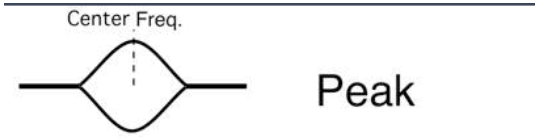
Target

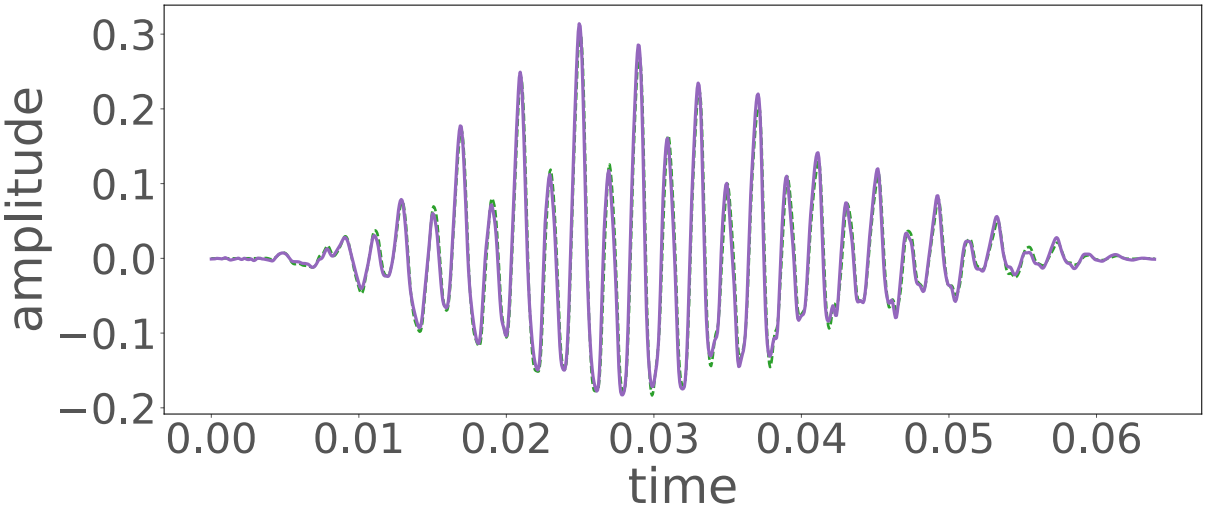
Output

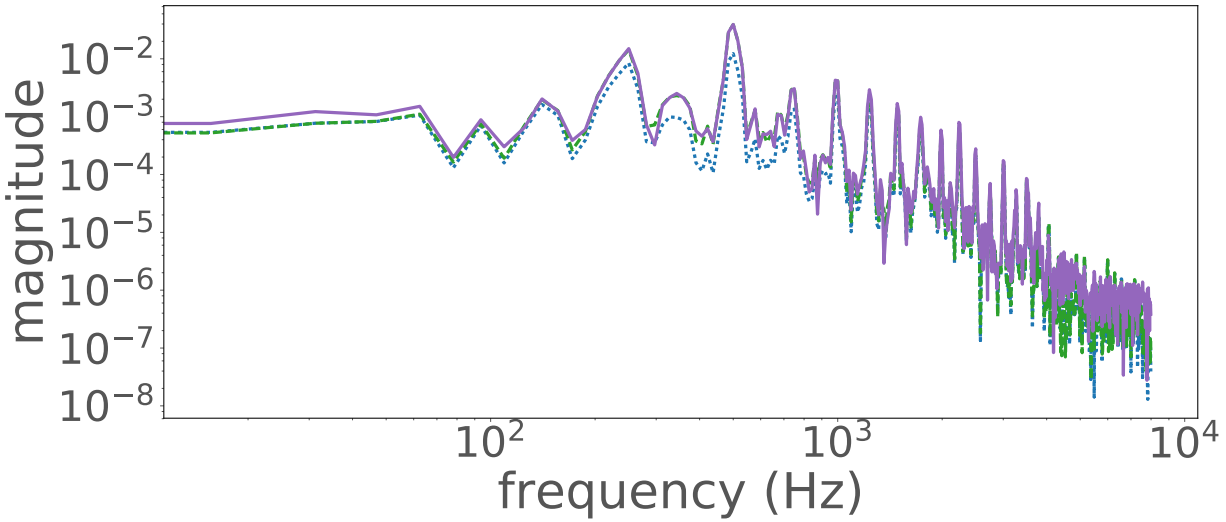


Results

Peaking







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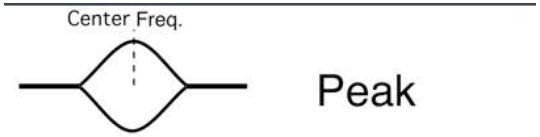

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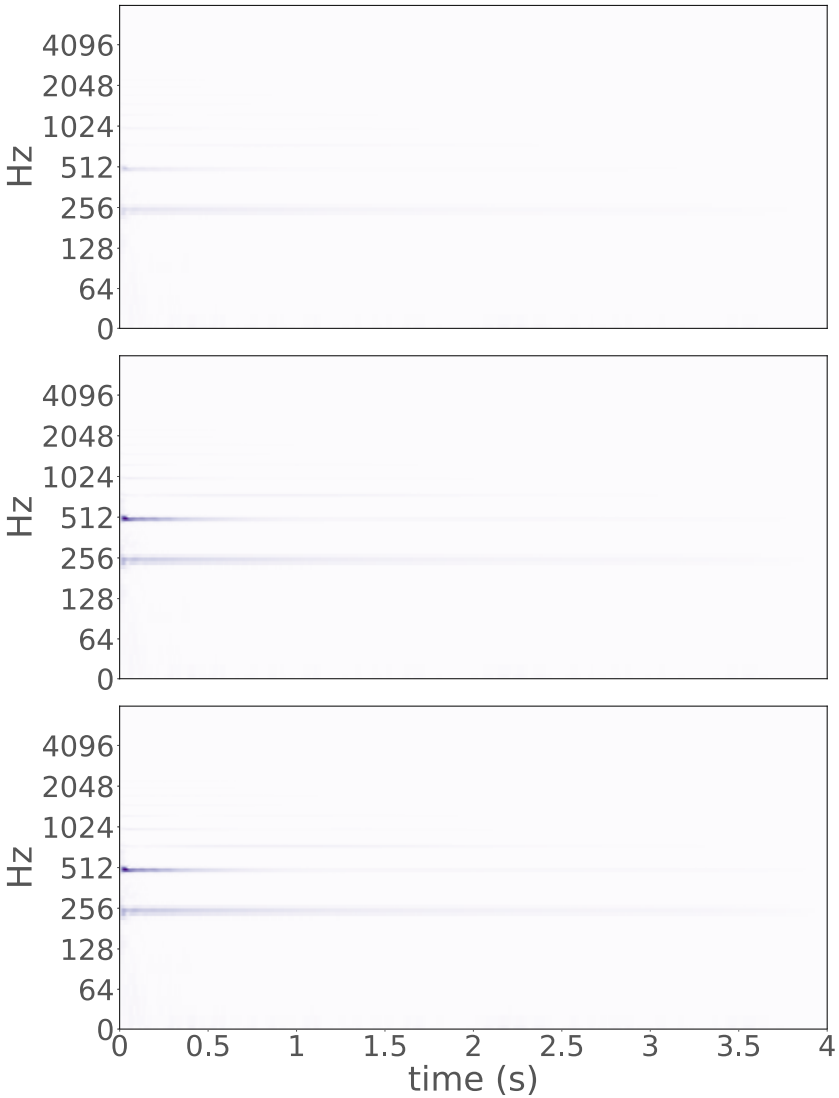
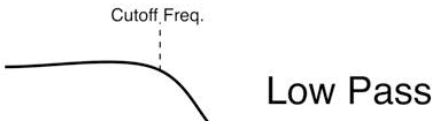
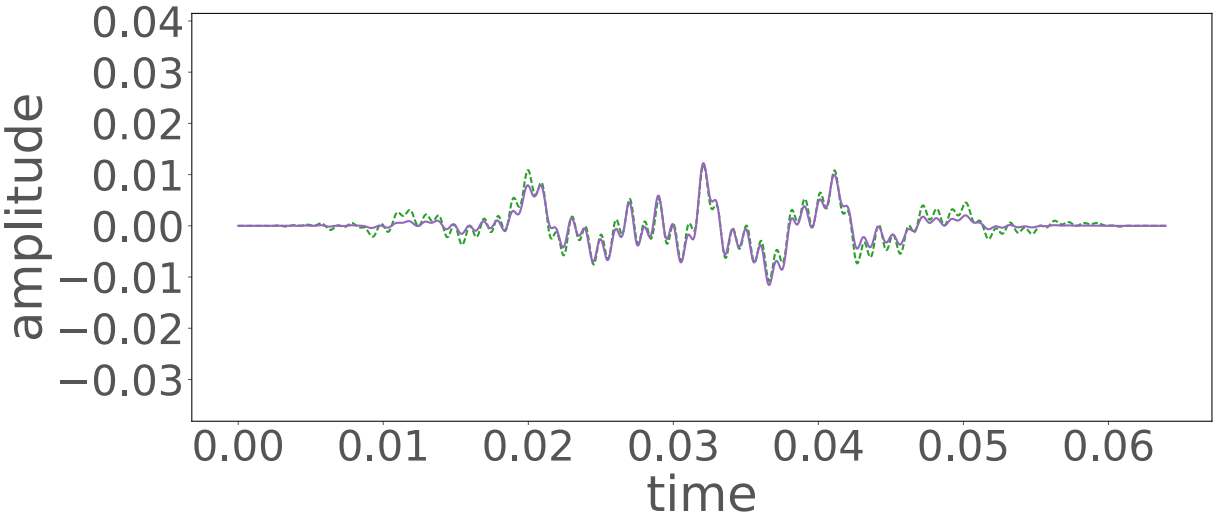
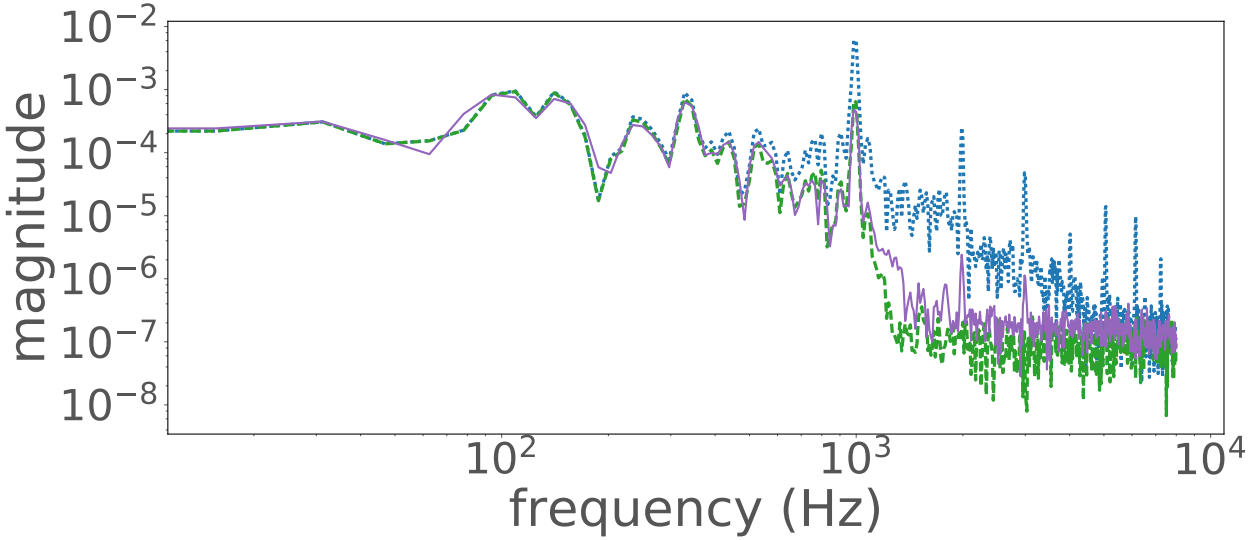


Results

Lowpass







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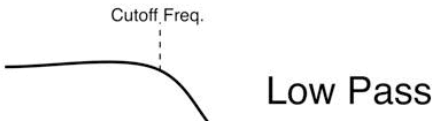
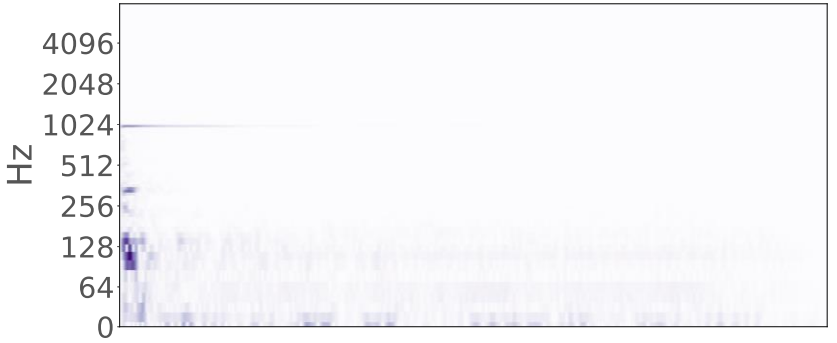


Input

Target



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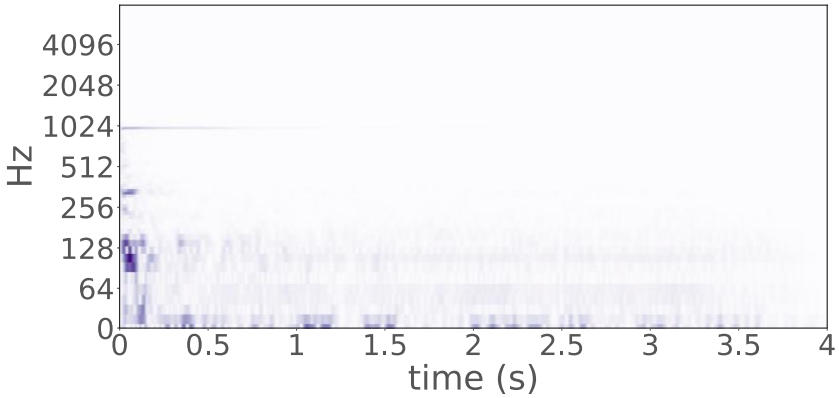
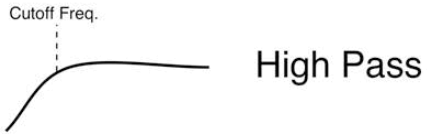
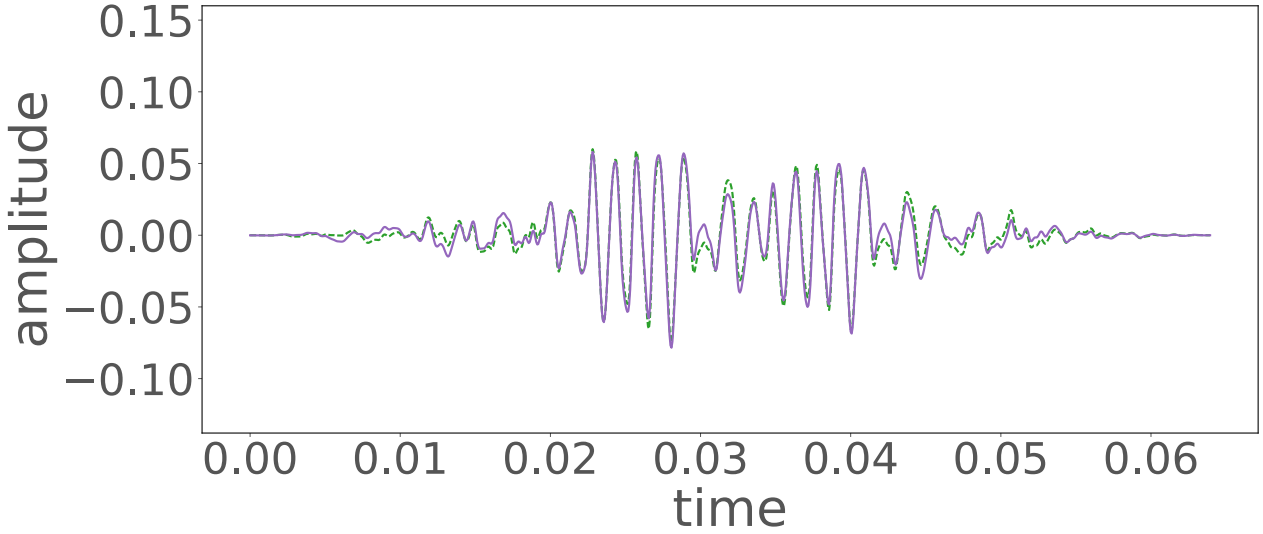
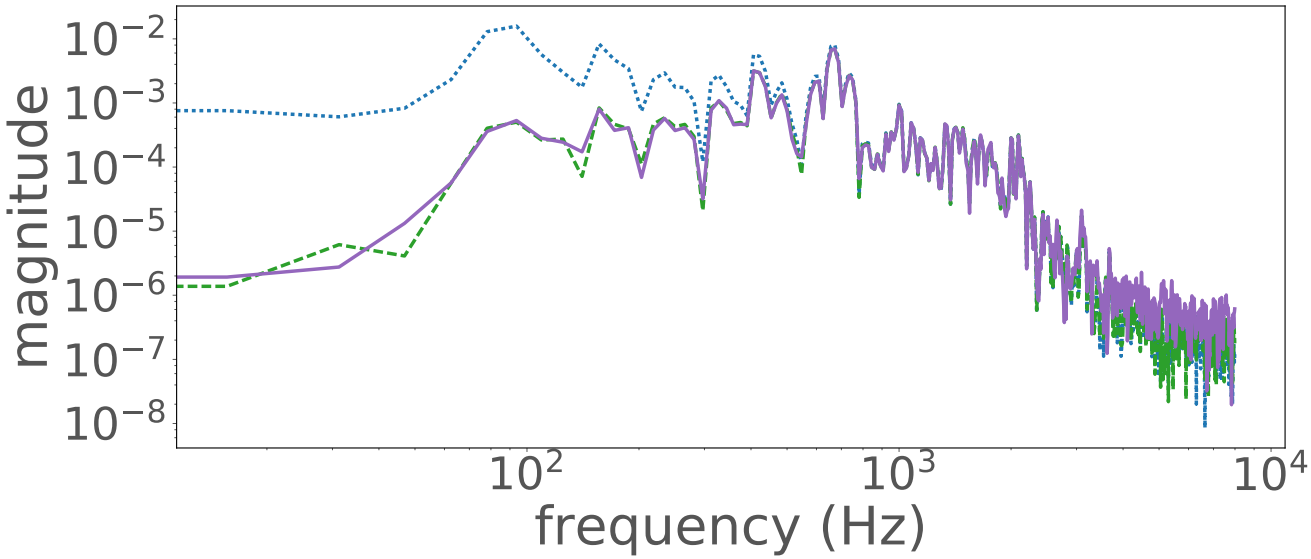


Results

Highpass

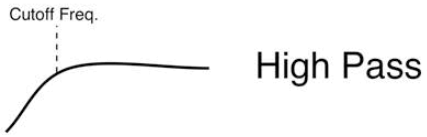






Results

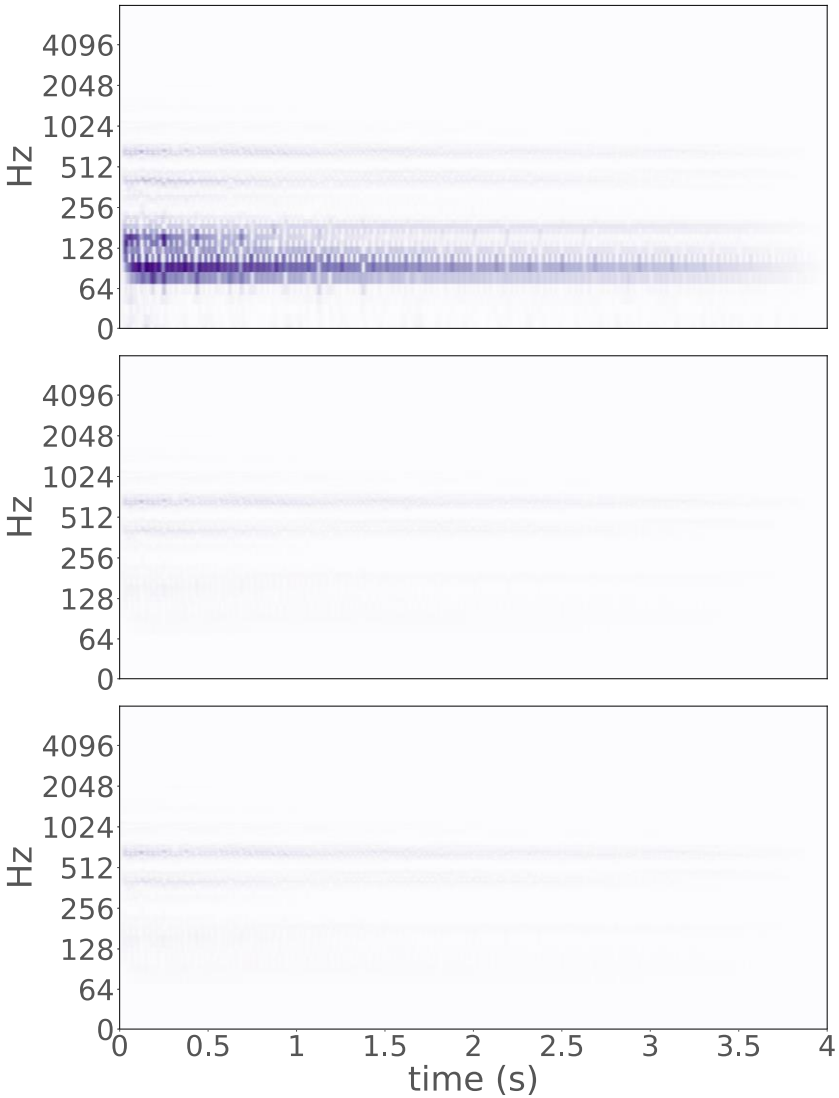
Highpass



Input

Target

Output



Future work

- Style-learning of a specific sound engineer.
- Model much more complex audio effects.
- Generalization capability.