Reverb Projects

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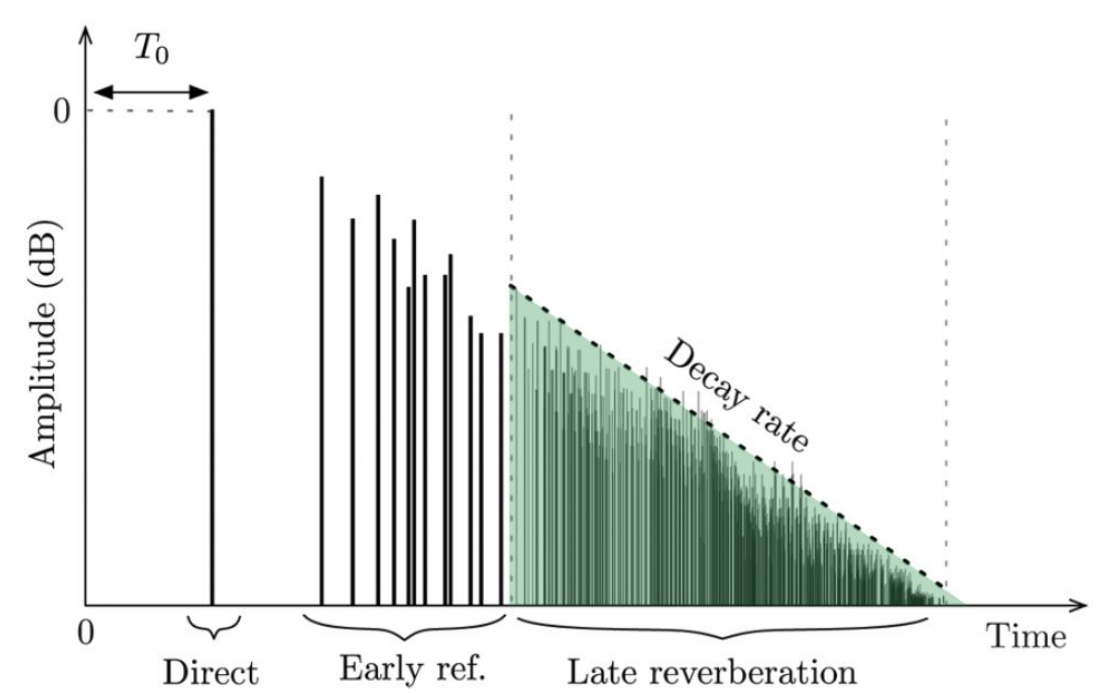
TU Berlin
Audio Communication Group

Introduction

Room Impulse Response



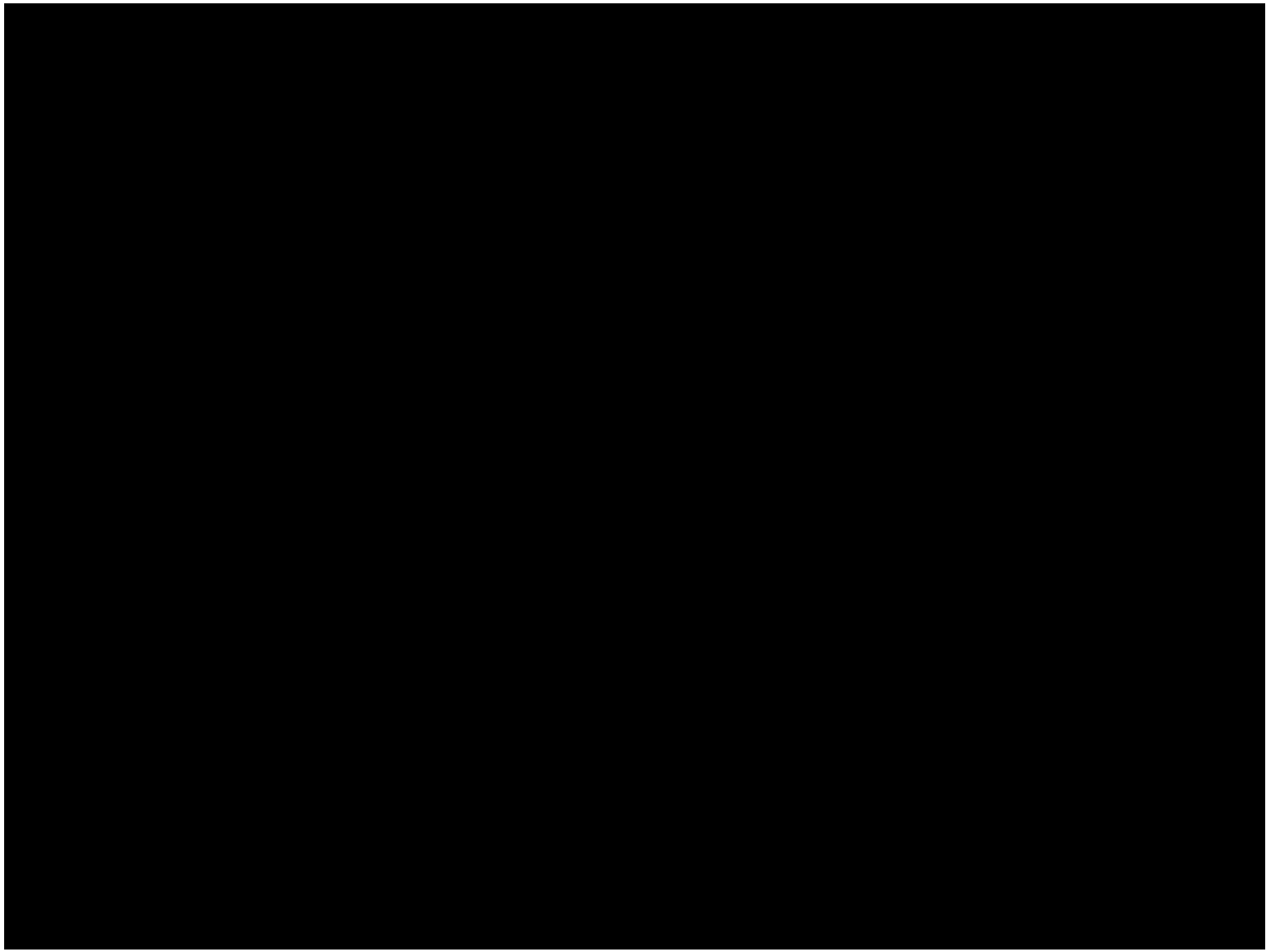
Direct sound
- Direction of arrival
- Sound color

Early reflections
- Source width
- Envelopment
- Direction of arrival
- Sound color

Late reverberation
- Envelopment
- Source distance (Direct-to-Reverberant Ratio - DRR)
- Room Properties (dry/wet, small/large)

Image: Välimäki at al. “Fifty years of artificial reverberation.” *IEEE Trans. Audio, Speech & Language Processing*. 2015.

Introduction

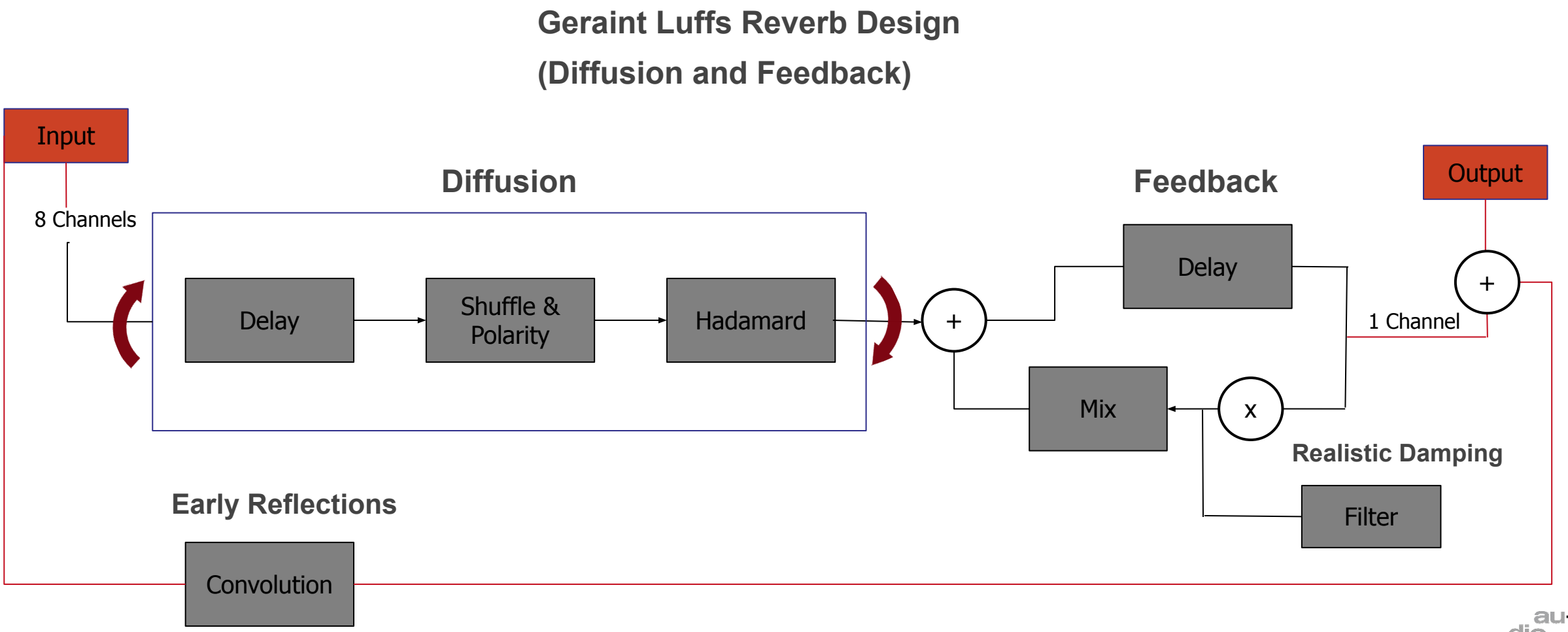


Idea

- **4 different Reverbs Designs based on feedback delay networks**

- **Listening comparison with musical sources as input**

Design



[7] ADC conference 2021 - Geraint Luff

Implementation

C++/JUCE

- **Realisation as Real Time Plugin**
- **Convolution with cropped IR (to get ER)**

Shelf Filter

- **3 IIR Filter with decreasing gain (0.7, 0.5, 0.3)**
- **Filter quality of 0.71 so energy sums up to 1**
- **Center frequencies at 400Hz, 2000Hz and 6000Hz**

[6] JUCE Framework

[10] Database of Omnidirectional and B-Format Impulse Responses

Implementation

C++/JUCE

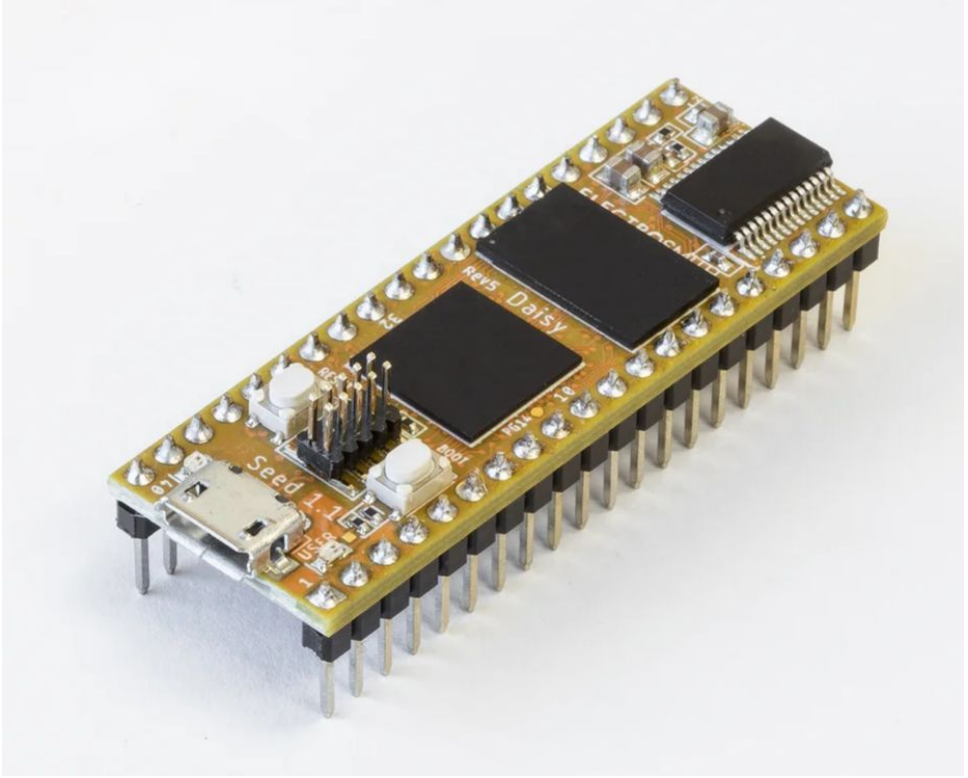
- **4 controllable Parameter (dry mix, wet mix, early reflections mix, decay)**

Conclusions

- **Still optimisation to do: CPU usage is rather high**
- **Modulation can be added for more realism**
- **Variety of controls can be improved**

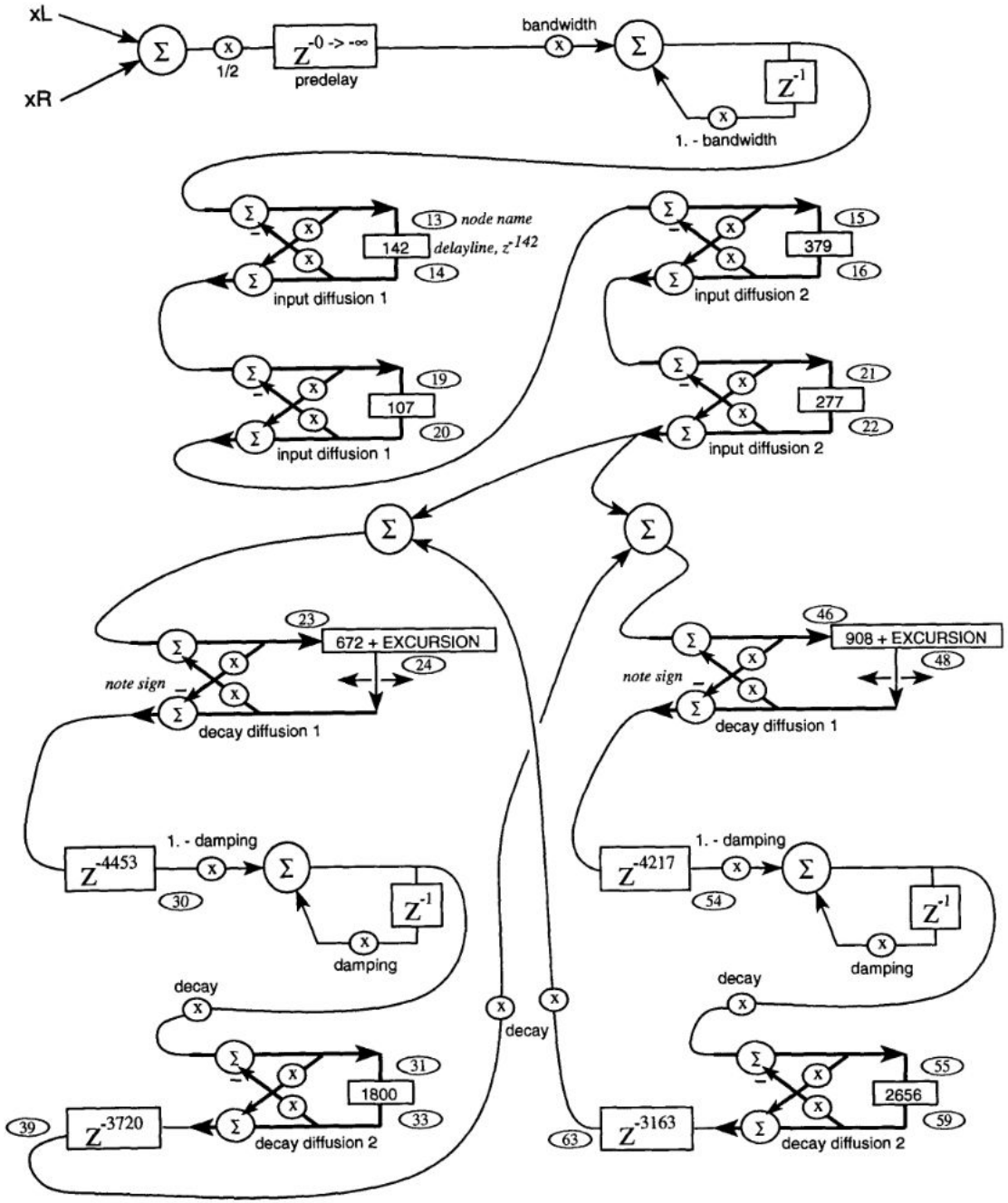
Lexicon - Reverb

Lexicon 224 (1978)



Daisy Seed

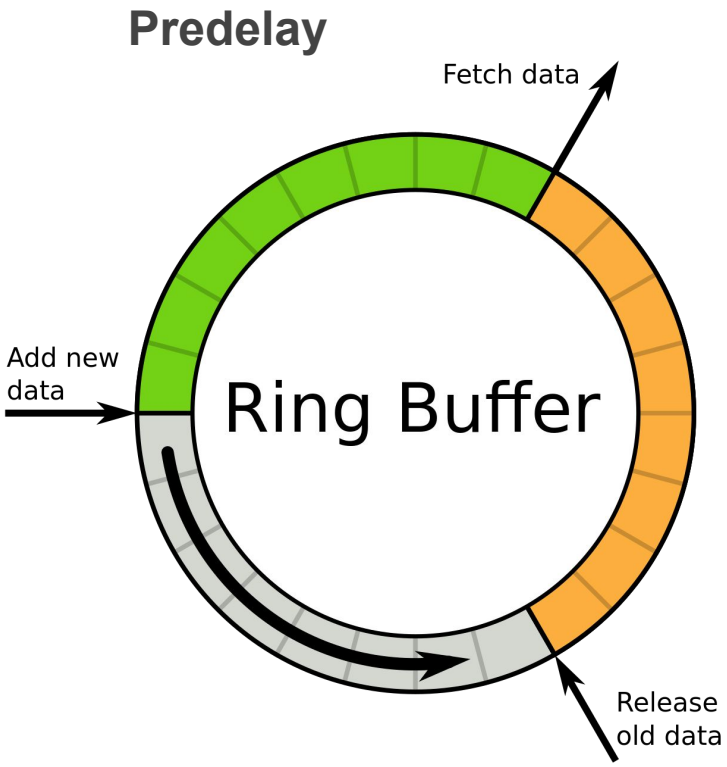
Lexicon - Reverb

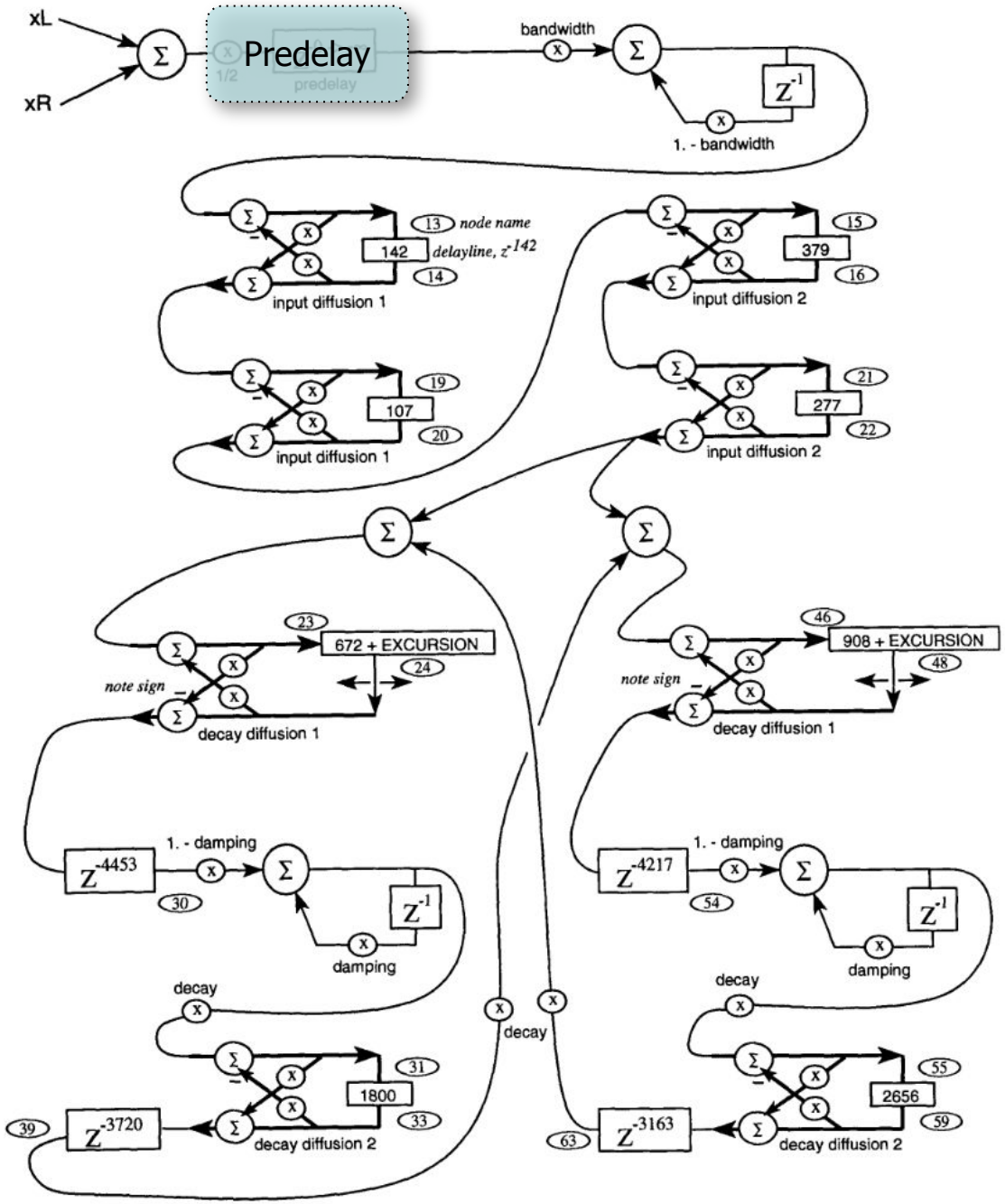


Lexicon style reverb block diagram

[1] Dattorro, J. (1997).

Lexicon - Reverb





Lexicon style reverb block diagram

[1] Dattorro, J. (1997).

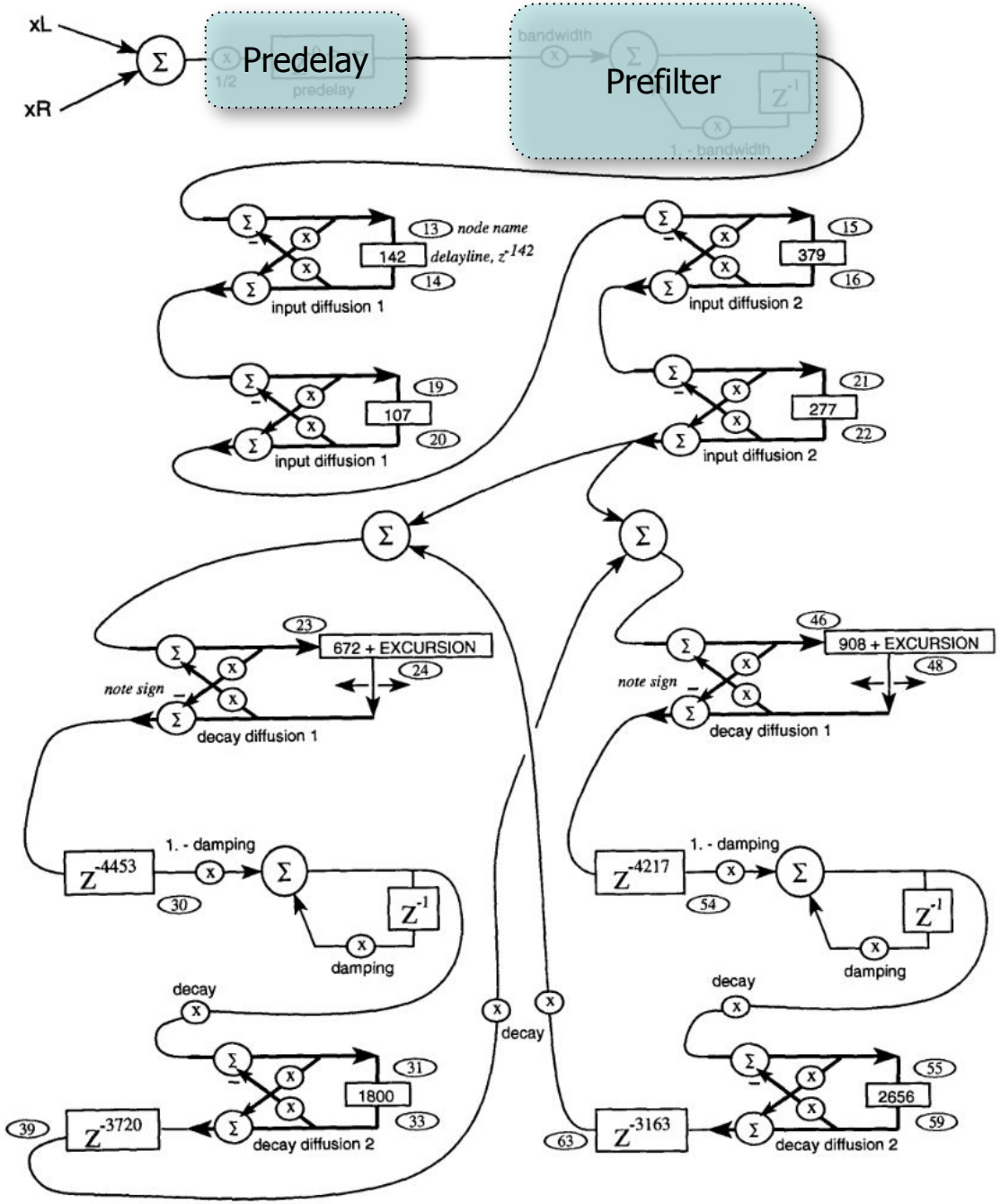
Lexicon - Reverb

Prefilter

2 Pole Lowpass

```
float process(float in, int TYPE = LOWPASS)
{
  outLP = in * a0 + outLP * b1;
```

(x2)



Lexicon style reverb block diagram

[1] Dattorro, J. (1997).

Lexicon - Reverb

Input Diffusion

→ scramble phases

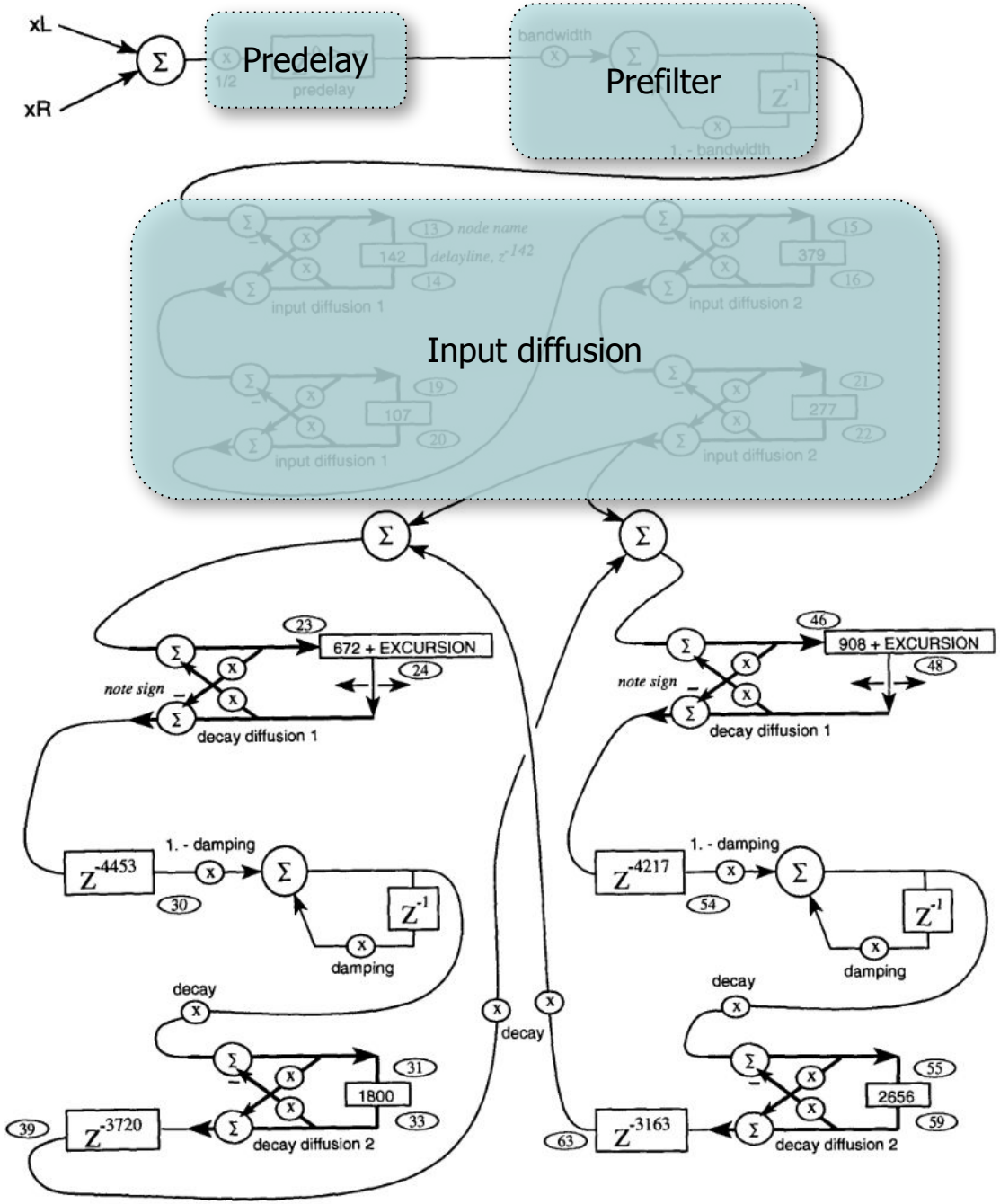
4 serial allpasses

different coefficients

using ringbuffer

```
float Process(float input){
    float bufferOut = buffer.readBuffer(time_ms_);
    float mix = input + bufferOut * gain_;
    buffer.writeBuffer(mix);
    float output = mix * (-1 * gain_) + bufferOut;

    return output;
}
```



Lexicon style reverb block diagram

[1] Dattorro, J. (1997).

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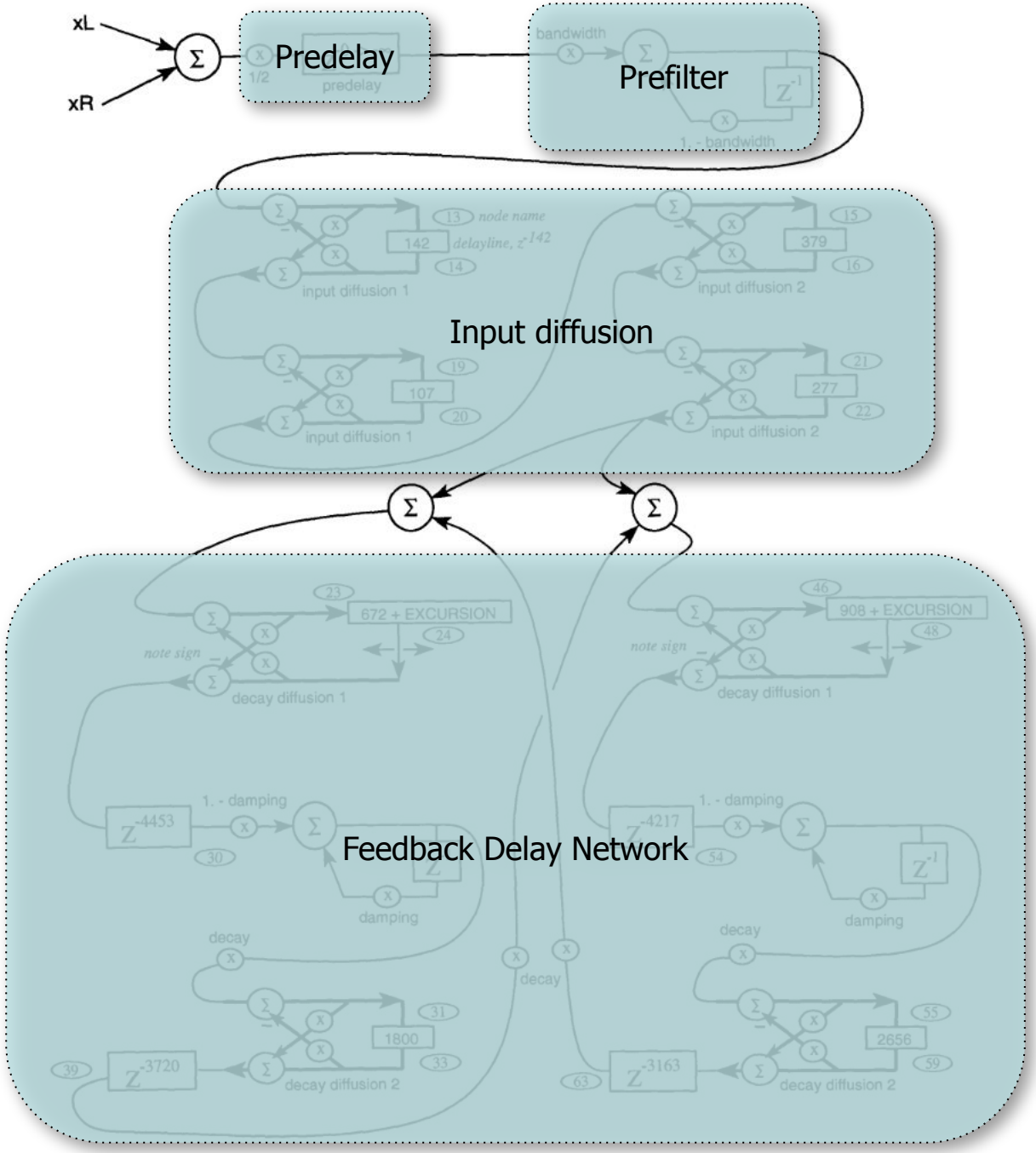
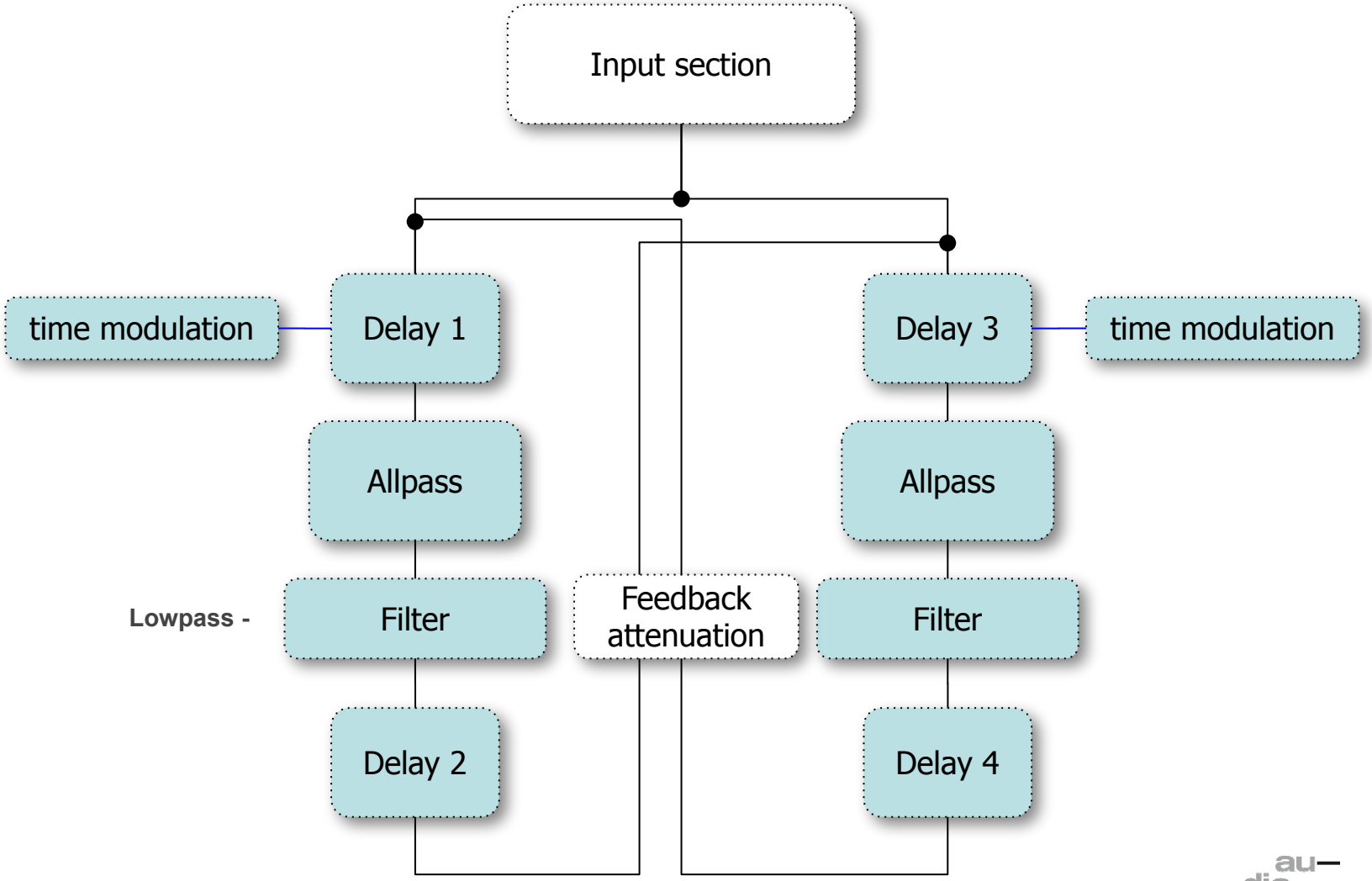


Lexicon style reverb block diagram

[1] Dattorro, J. (1997).

Lexicon - Reverb

Feedback Delay Network



time modulation
→ less resonance

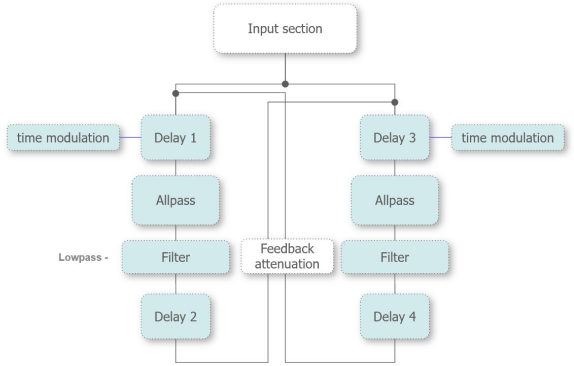
very performant

only 4 delay lines
(easy on RAM)

Filter → longer reverb time for lower frequencies

Lexicon - Reverb

reminder:

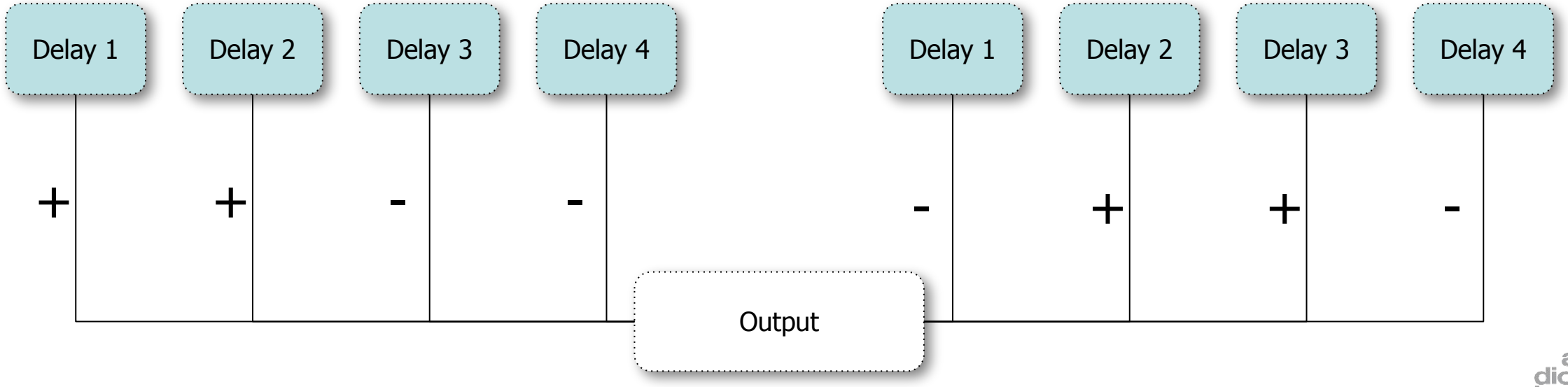


Output stage + early reflections

signs → energy neutral addition (s. Hardamat)

4 Early reflections from delay lines

→ phases get more and more scrambled by FDN allpass



Lexicon - Reverb

Chris Moor inspired FDN in MAX/MSP

Chris Moor - Ursa Major Spacestation

Pros:

- Reverb-Tail klingt verträumt und nostalgisch
- funktioniert gut für atmosphärische Sounds
- Delay Settings sind gut

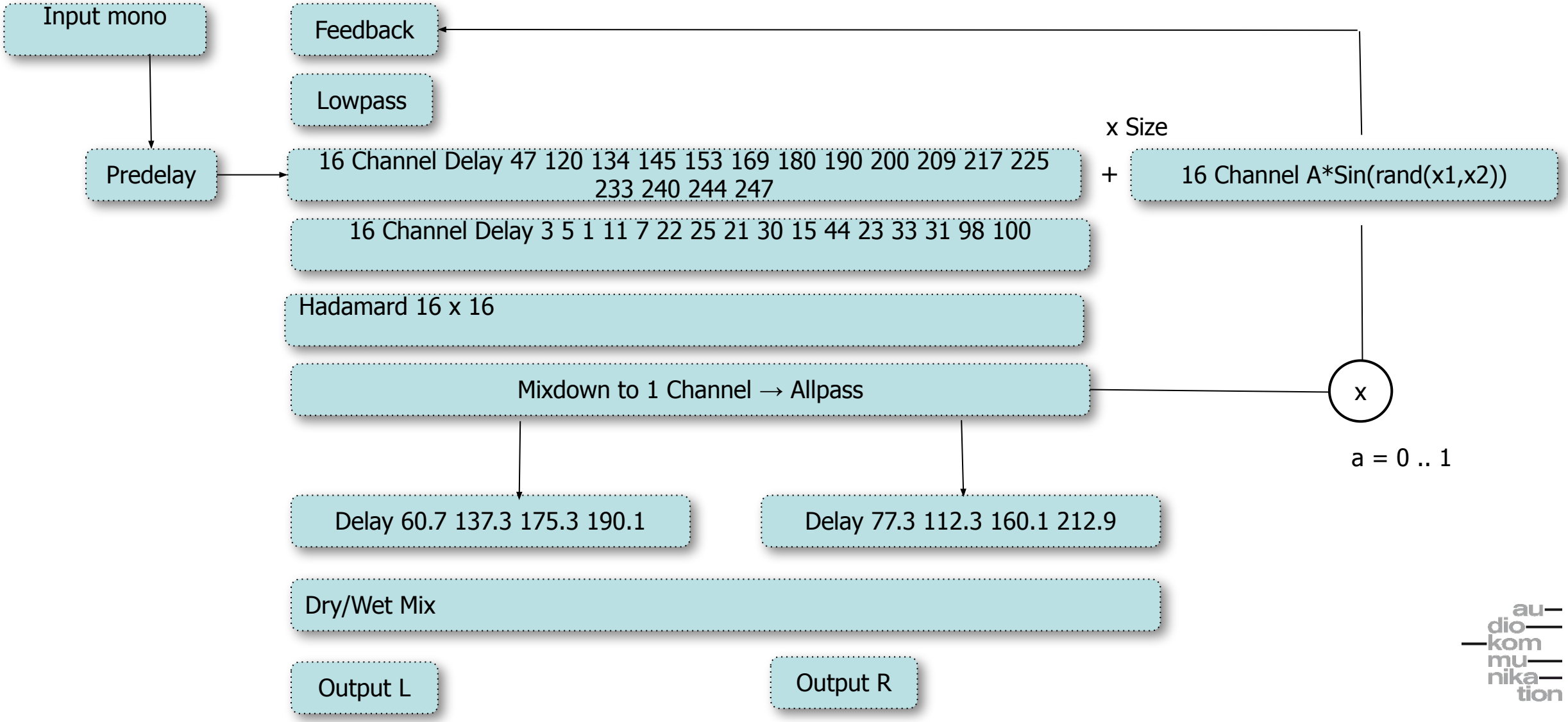
Cons:

- es klingt Teilweise noch wie ein “Cluster-Delay” und nicht diffus genug
- Scheint nicht für Drums zu funktionieren da die early Reflections sehr nach Delay klingen
- Chorus ist zwar einstellbar aber notwendig um wohlklang zu erreichen

Ausblick: FDN kann durch moderne Methoden erweitert werden.
Faltung mit Impulsantworten, separierte Stereo-Verarbeitung
Diffusor/Shuffler/Polarity-Flipper

[2]**Tom Erbe/Soundhack "Designing the Make Noise Erbe-Verb**

Chris Moor inspired FDN



Max/MSP für Reverbs

Pros:

- "schnelles Prototyping"
- es wurden 3-4 unterschiedliche Reverb Ideen ausprobiert
- Multi-Channel
- große Sammlung an Objekten usw.
- Tool in Ableton

Cons:

- Hadamard ist tricky
- Dokumentation ist sehr untechnisch
- bug fixing ist kompliziert
- wird schnell sehr unübersichtlich
- manche Objekte sind nicht "wertig" genug

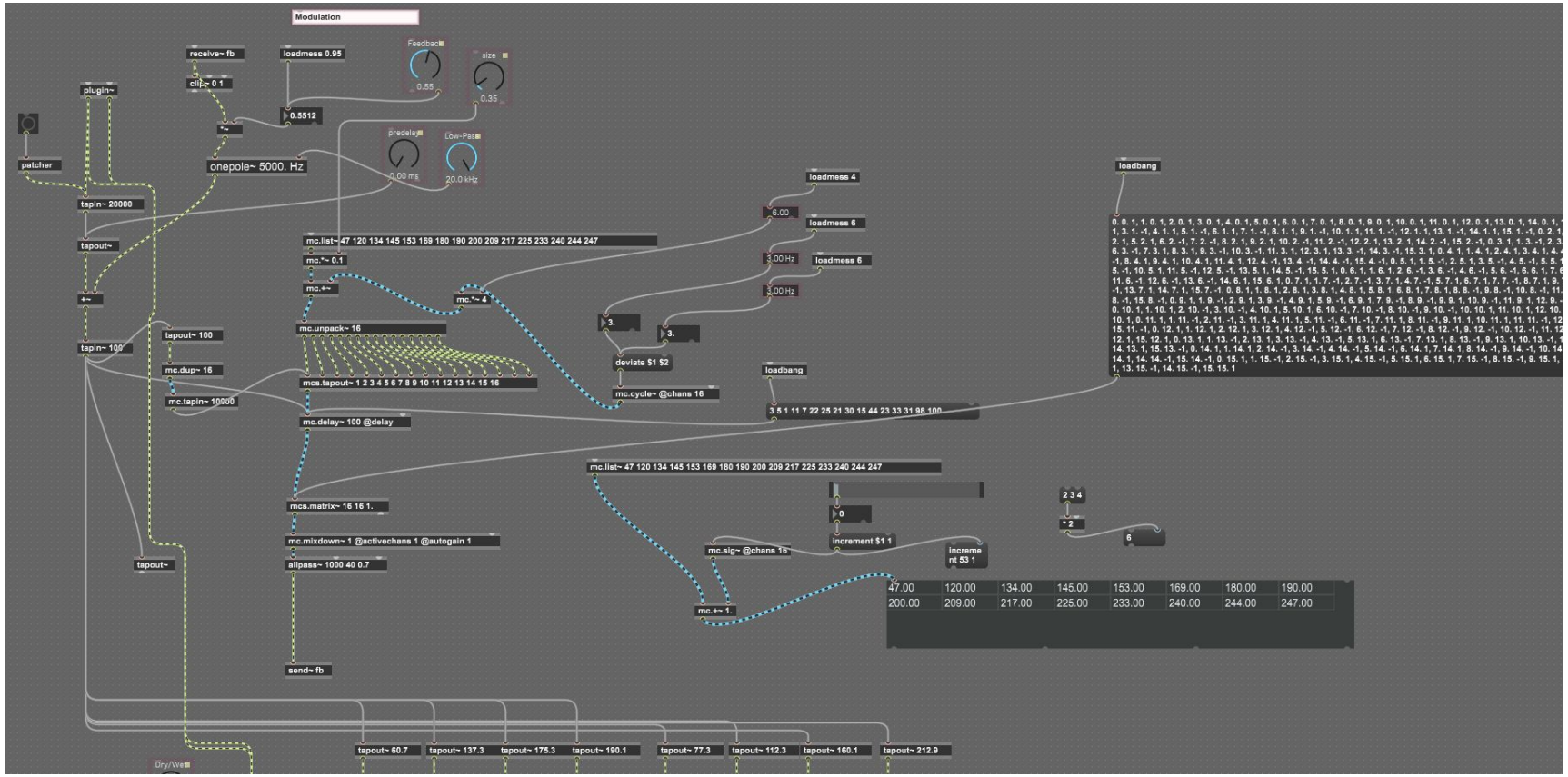
Learnings :

-Hadamard = energy preserving = infinite sustain

→ kein Raum für Fehler

Random Orthogonal Matrix = decay ist viel stärker

→ Raum für experimente z.B. Pitchshifter



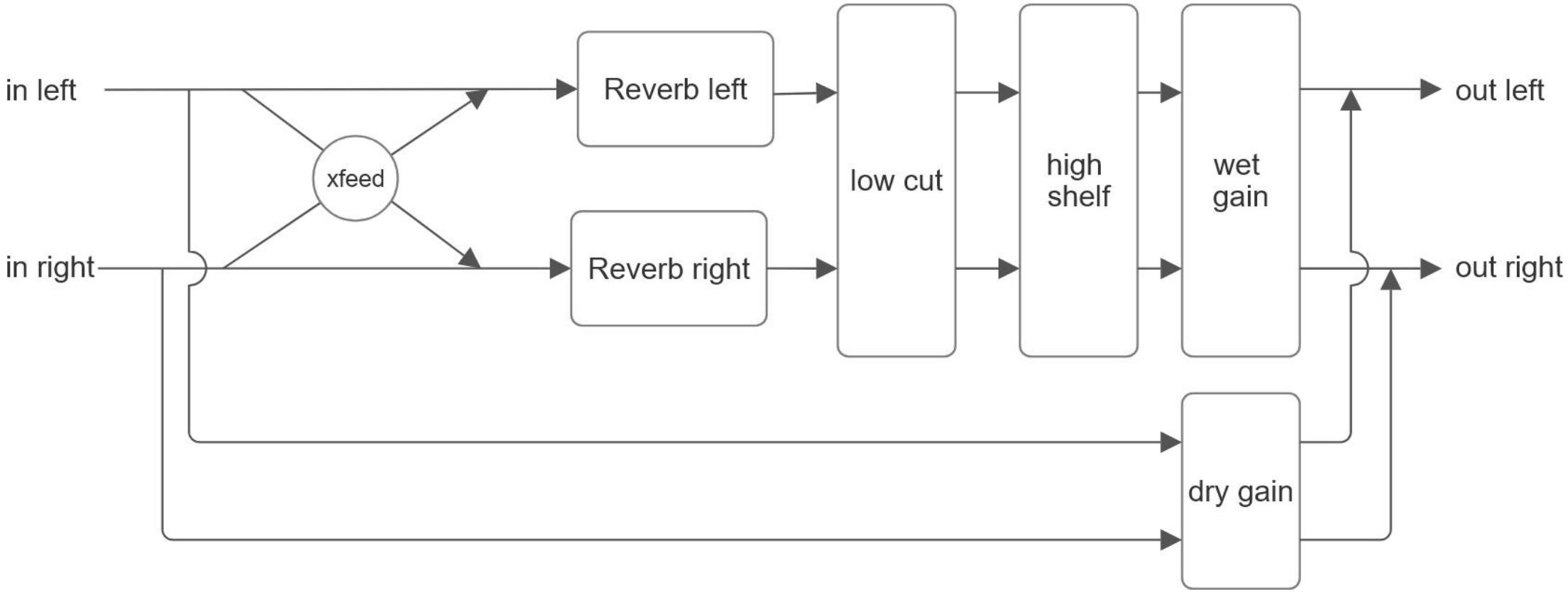
[3] Sebastian Schlecht - FDN Matlab Toolbox

DFDN reverb

DFDN: differential feedback delay network

[8] Dal Santo, G., Prawda, K., Schlecht, S., & Välimäki, V. (2023). **Differentiable Feedback Delay Network For Colorless Reverberation**. In F. Fontana, & S. Willemsen (Eds.), Proceedings of the 26th International Conference on Digital Audio Effects (DAFx23) (pp. 244-251)

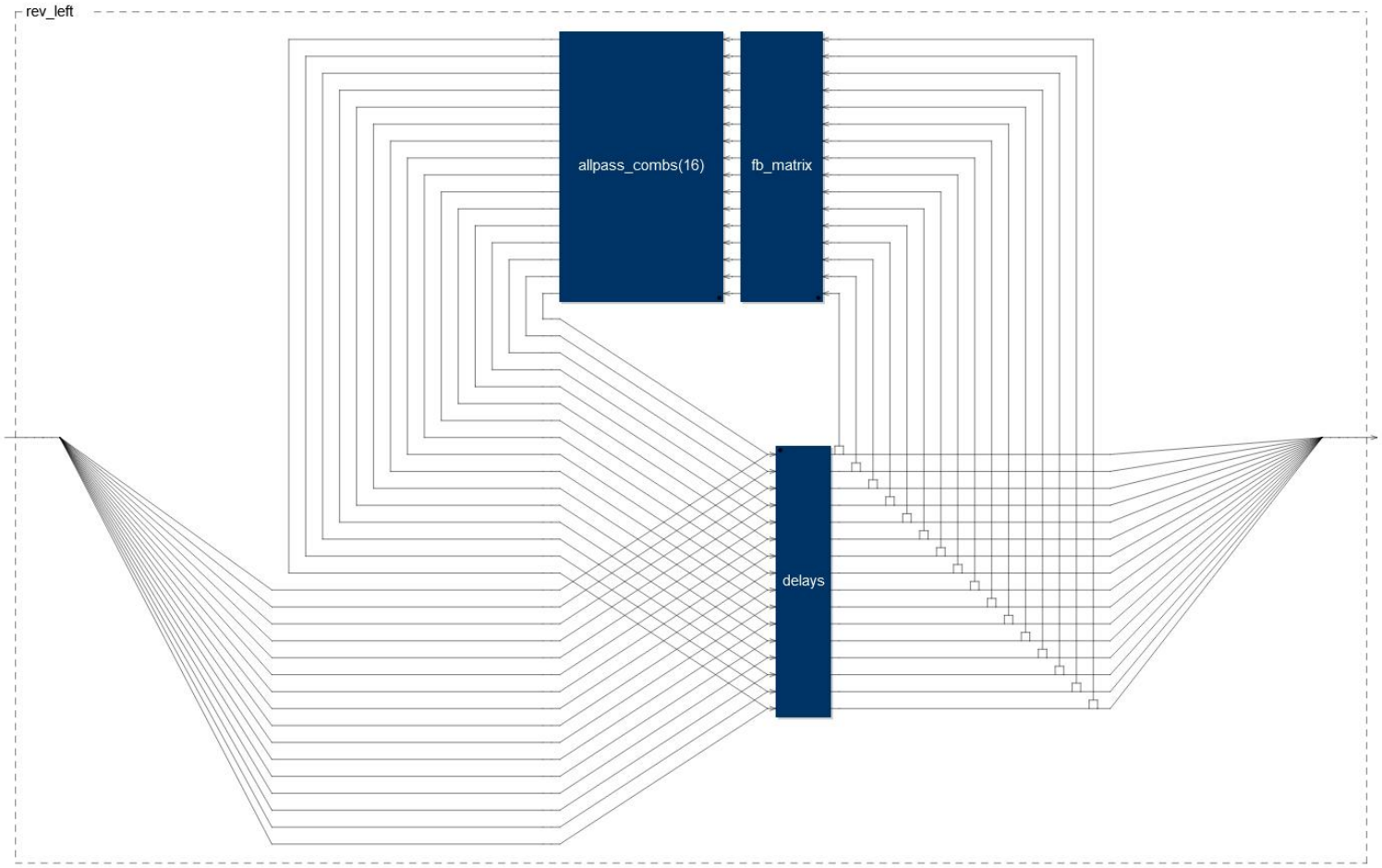
Reverb design:



DFDN reverb

- idea: colorless reverb
- 16 delay lines per channel
- 16x16 feedback matrix
- matrix gain values optimized with FDN Matlab Toolbox by Sebastian Schlecht

  https://www.sebastianjiroschlecht.com/project/fdntb/
- diffusion with allpass filters

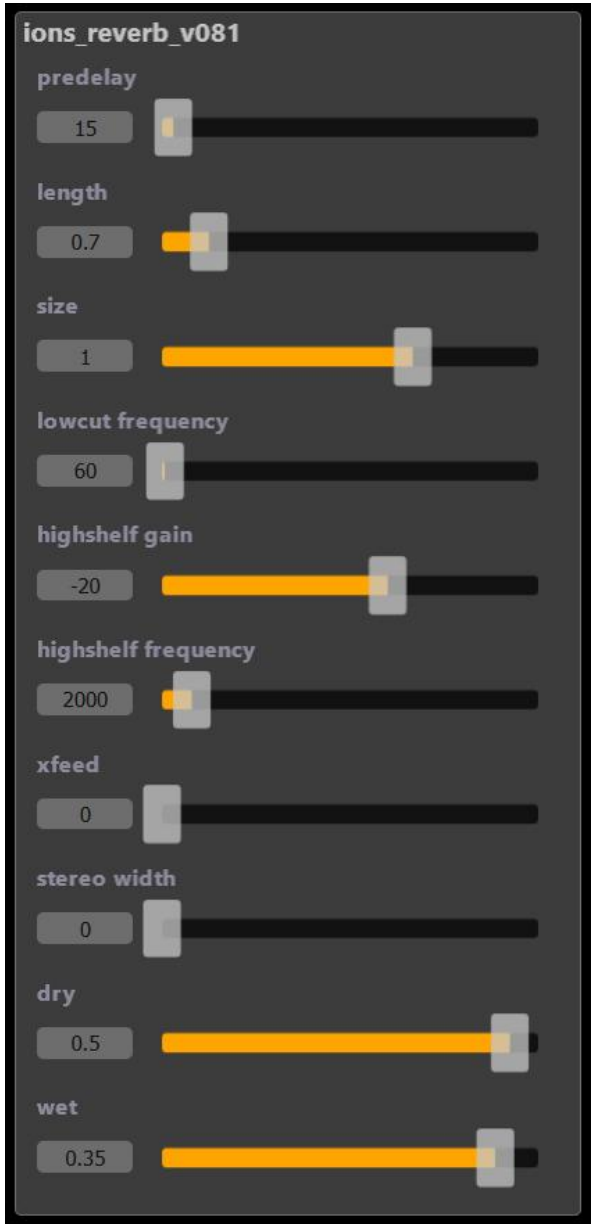


Reverb left

DFDN reverb

- implementation in Faust (Functional Audio Stream) [5]
  https://faustide.grame.fr/
- standalone app and vst3 Plugin with JUCE [6]

- pro: sound
- con: processor load, RAM usage
- to-do: adjustable sample-rate, GUI
- outlook: ambisonics routing



GUI in Faust Web IDE

Sources

[1] Dattorro, J. (1997). Effect design: Reverberator and other filters. Journal of the Audio Engineering Society, 45(9).

[2] Tom Erbe/Soundhack "Designing the Make Noise Erbe-Verb" Reverb Design Lecture (Remastered)

https://www.youtube.com/watch?v=Il_qdtQKnqk vom 2024.06.17

[3] Feedback Delay Networks for Artificial Reverberation - Sebastian Schlecht

https://www.youtube.com/watch?v=gRiZX7C6zJo, https://www.sebastianjiroschlecht.com/

[4] Pytagoras v.S. (560 v.Chr). Berechnung von Winkeln durch gegebene Seitenlängen eines Triangels. Journal of Philosophy and Geometry, 61(2)

[5] Faust https://faust.grame.fr/

[6] JUCE https://juce.com/

[7] Geraint Luff - Let's Write a Reverb - ADC21 https://youtu.be/6ZK2Goiyotk?si=ZKnUK5h3LWqT8w4v

[8] Dal Santo, G., Prawda, K., Schlecht, S., & Välimäki, V. (2023). **Differentiable Feedback Delay Network For Colorless Reverberation**. In F. Fontana, & S. Willemsen (Eds.), Proceedings of the 26th International Conference on Digital Audio Effects (DAFx23) (pp. 244-251)

[9] Stewart, Rebecca and Sandler, Mark. "Database of Omnidirectional and B-Format Impulse Responses", in Proc. of IEEE Int. Conf. on Acoustics, Speech, and Signal Processing (ICASSP 2010), Dallas, Texas, March 2010

Sean Costello (Valhalla DSP) on reverb design, March 2019

https://www.youtube.com/watch?v=aJLhqfHrwsw

Let's Write a Reverb - Geraint Luff - ADC21

https://www.youtube.com/watch?v=6ZK2Goiyotk