Moog
Ladder Filter

Februrary 2, 2024

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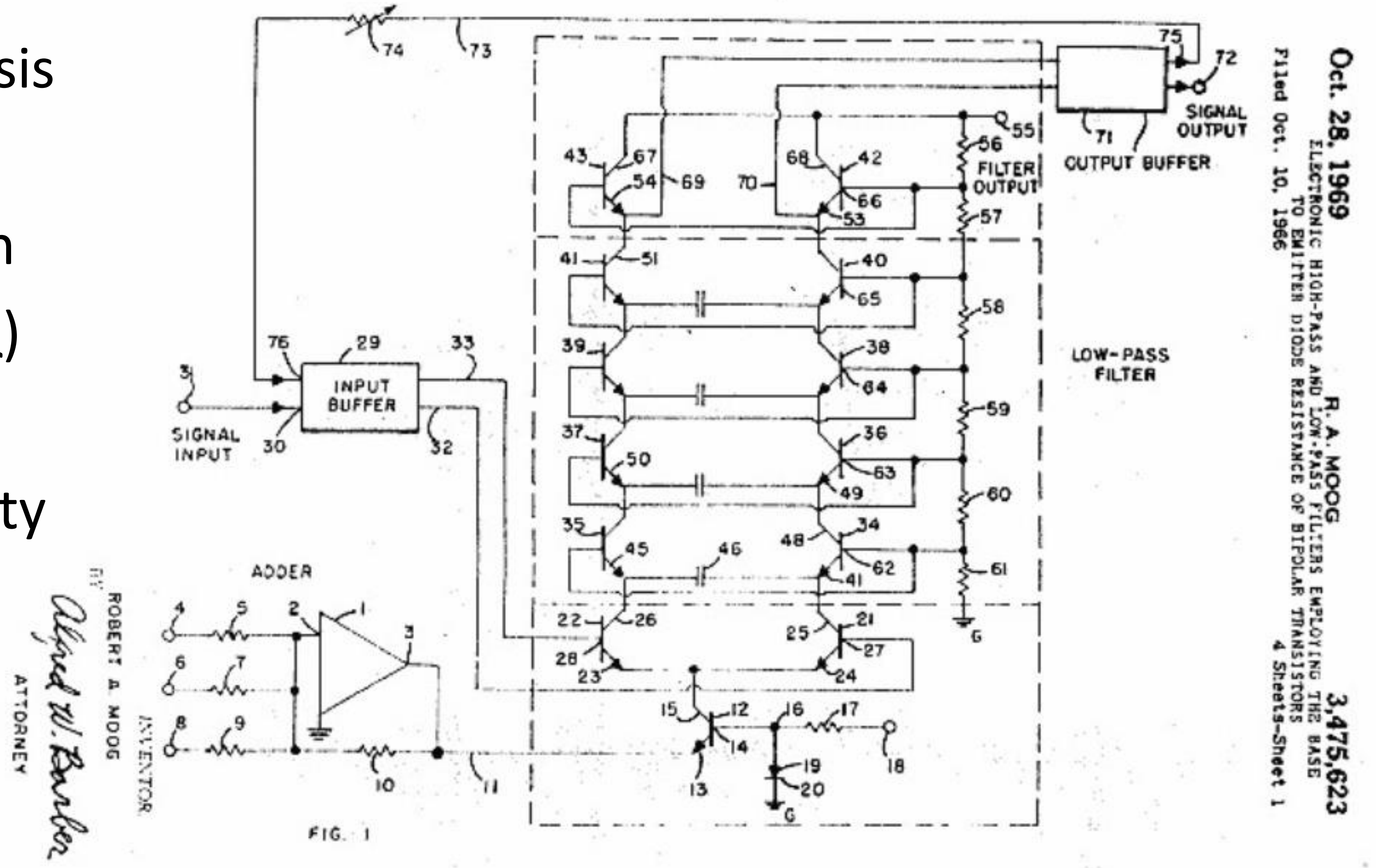
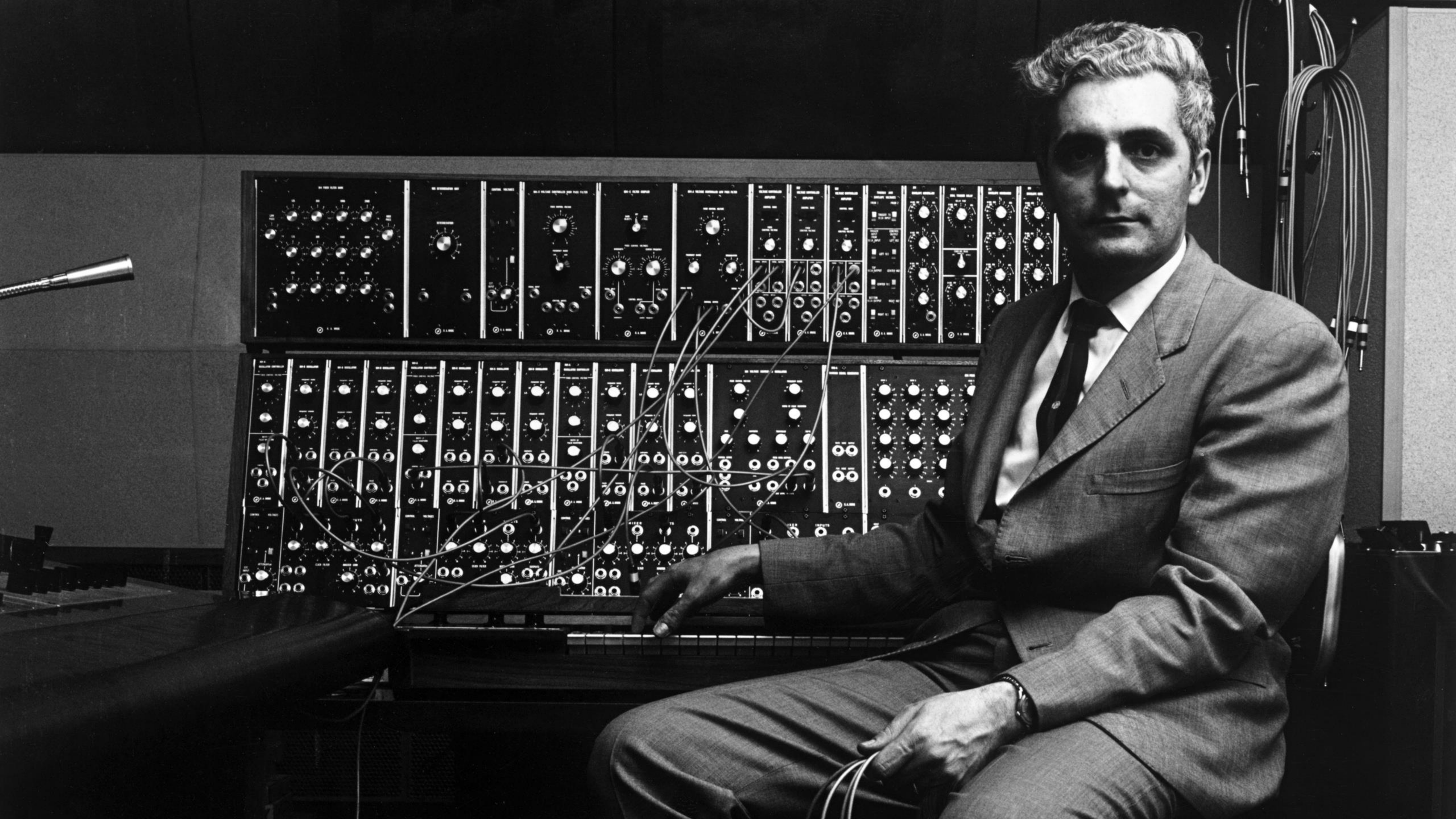


https://www.uaudio.com/blog/moog-ladder-filter/

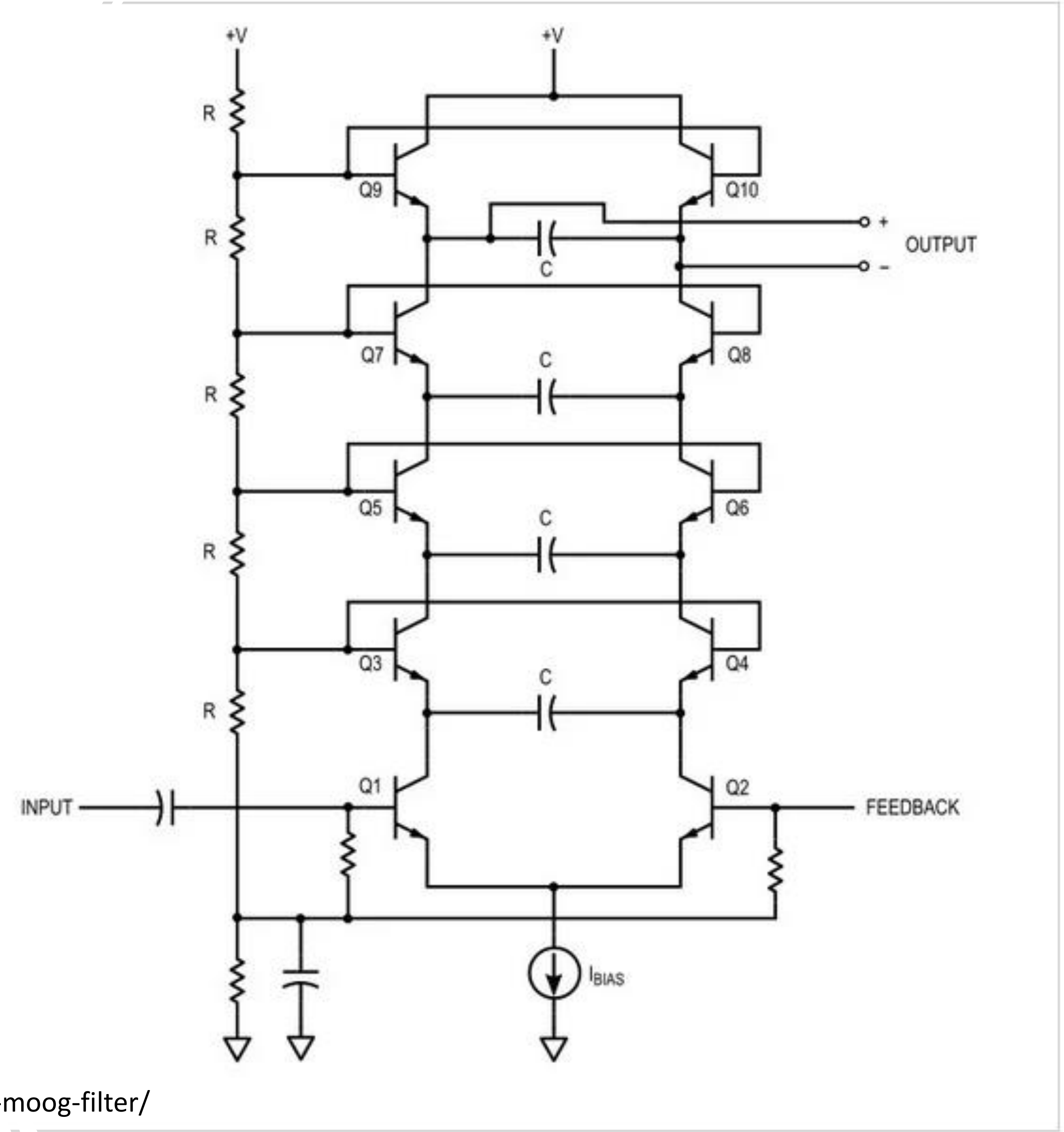


Early Modular Synthesis

- the 904A
- modular approach to sound synthesis, allowing musicians to connect various components to create complex and customizable soundscapes
- the 900 series prices in 1969 ranged from $125 for an envelope generator to $1,225 for a sequencer [1]

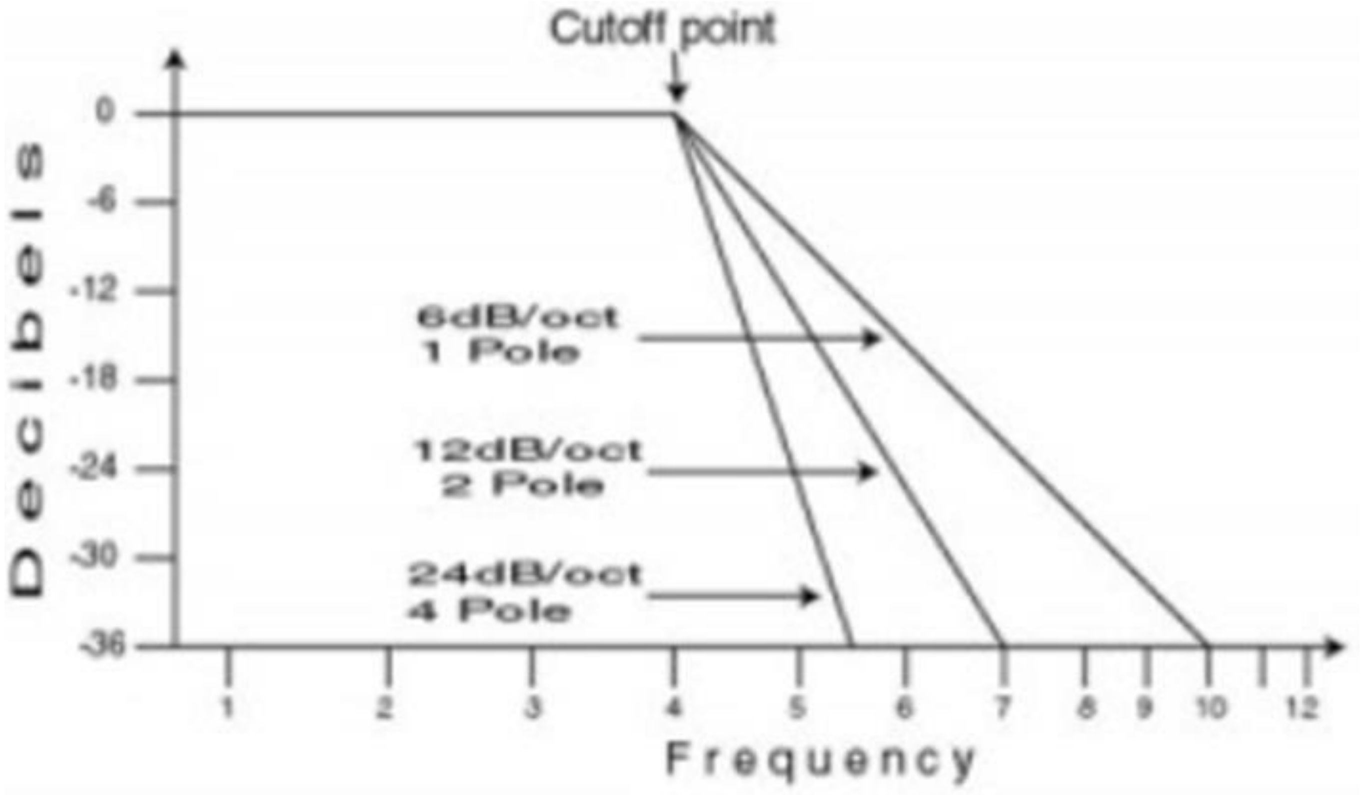
The Filter Schematic

- four one-pole filters in cascade and a global negative feedback loop
- transistor choices define influencing the filter's response characteristics
- integration of op-amps in the circuitry allows for the fine-tuning of the filter’s parameters
- feedback loop - resonance contribute to the filter's ability to produce the characteristic resonant peak



https://www.allaboutcircuits.com/technical-articles/analyzing-the-moog-filter/

Slope and Attenuation



original

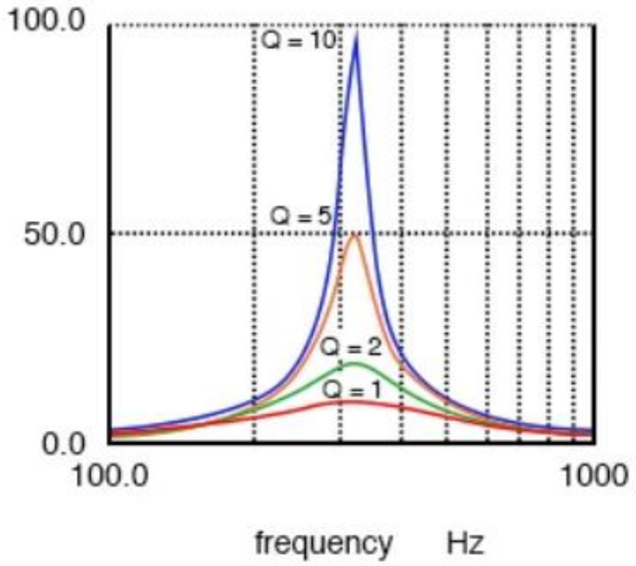
6 dB/oct

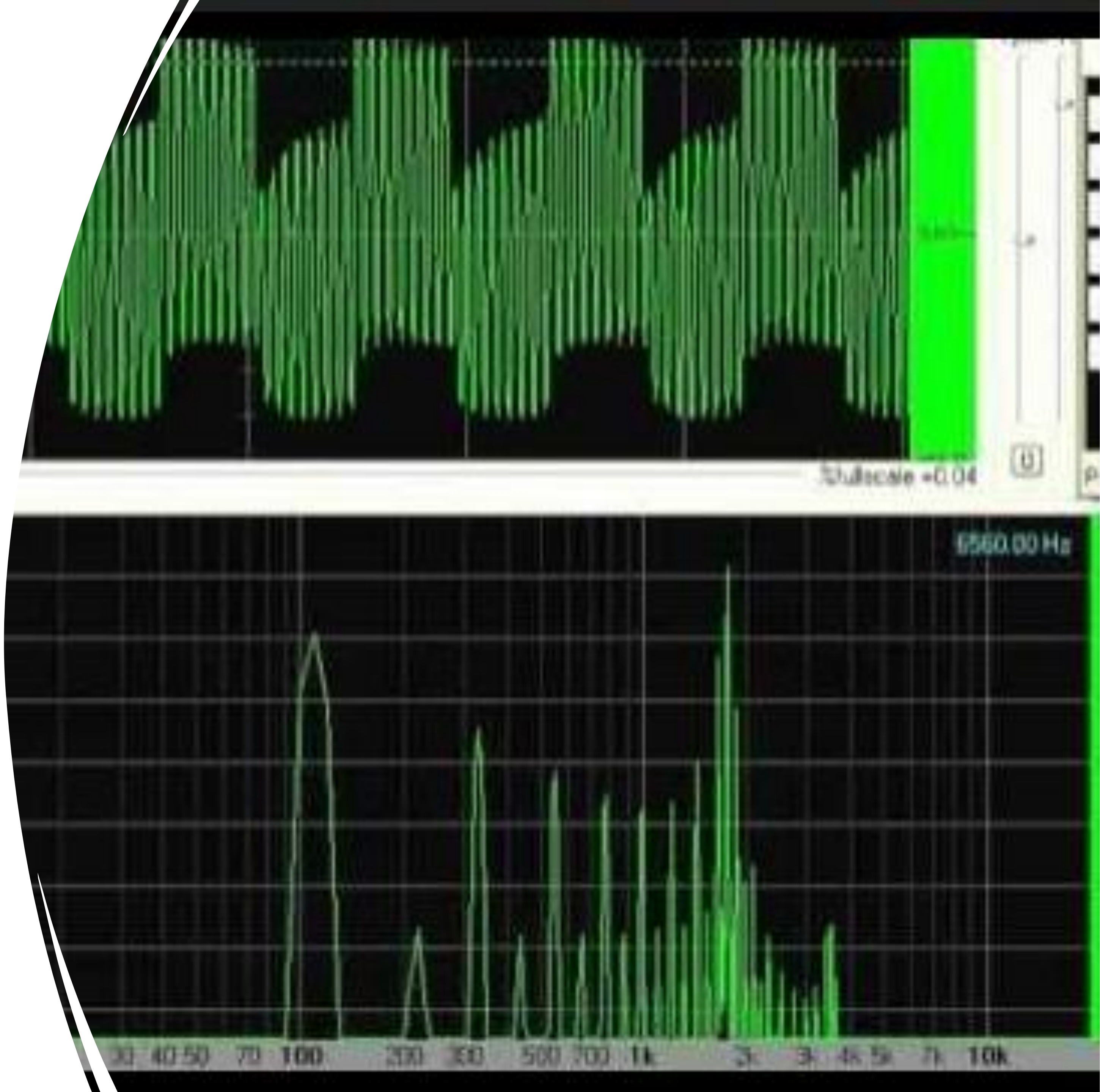
12 dB/oct

24 dB/oct

Resonance control (Q)

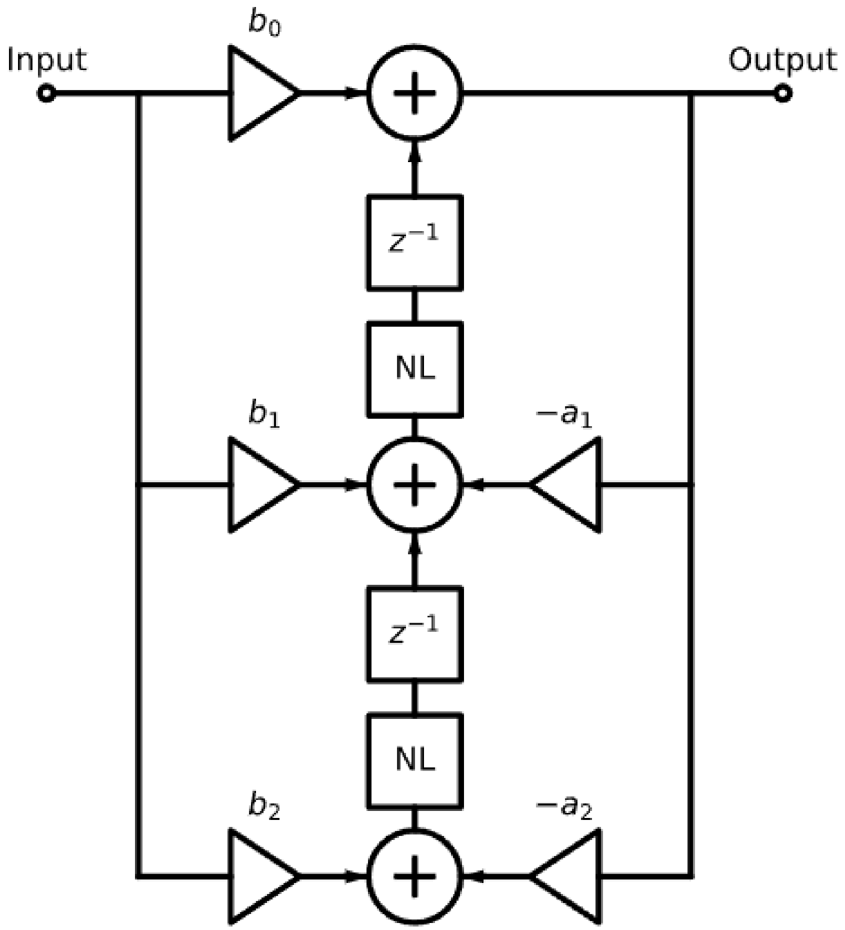
- the resonant peak near the cut-off frequency adjustable by the feedback gain - flat up to the cut-off frequency for Q = 1/sqrt(2)





Virtual Analog Filters

- analog filters used in music technology produce distortion at high signal levels, making them not strictly linear (e.g. transistors softly saturating the signal)
- modeling nonlinearity with saturating functions
  (fc = 1000 Hz; 24dB/oct; Q = 10;)



original

biquad
(no saturation)

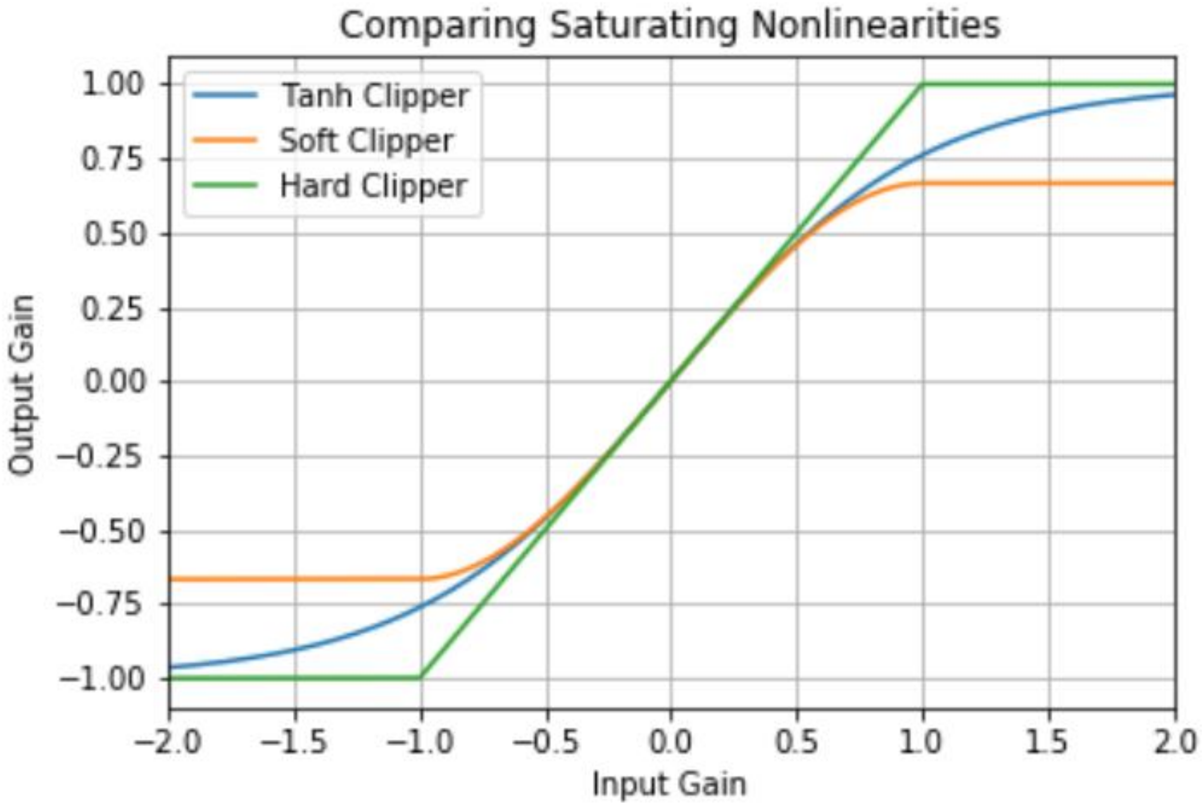
hardclip

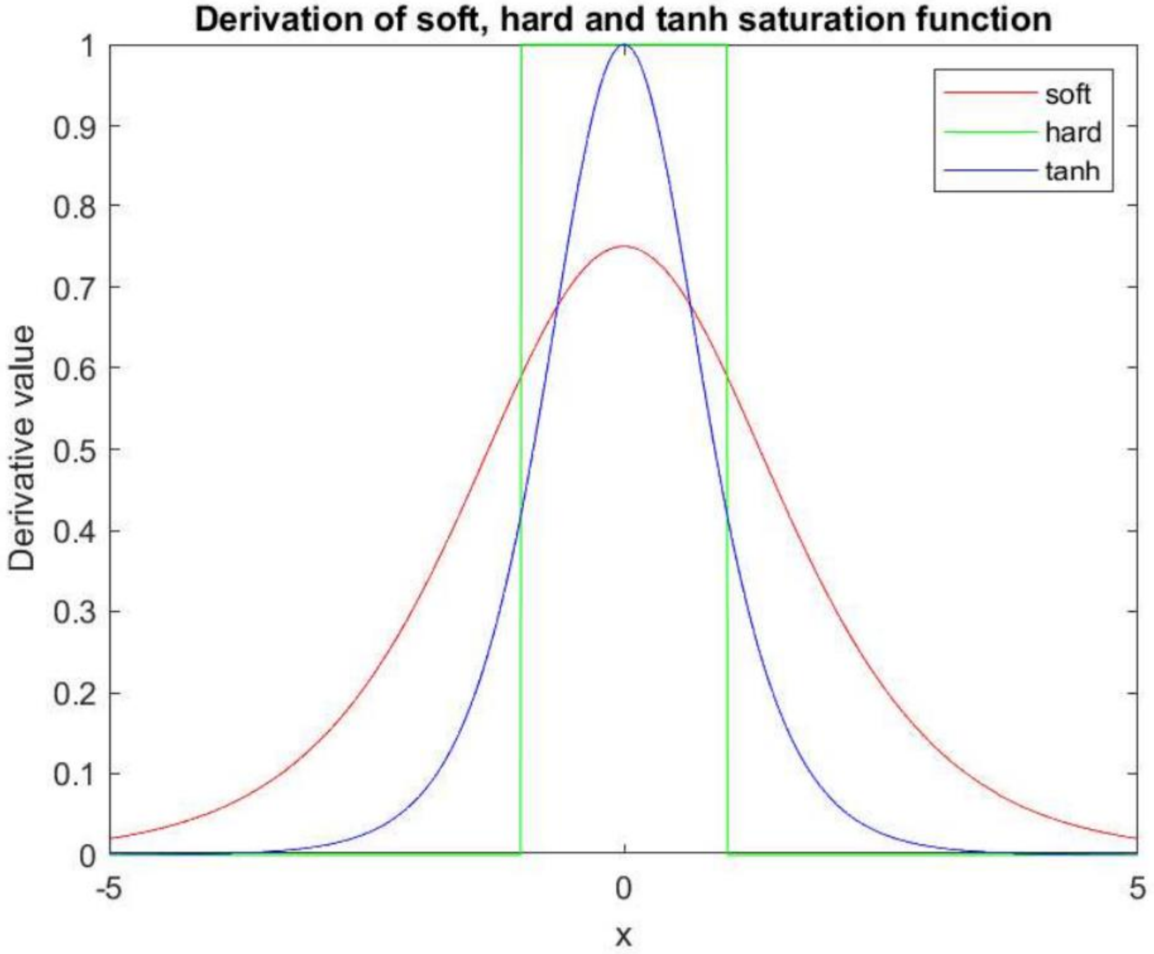
softclip

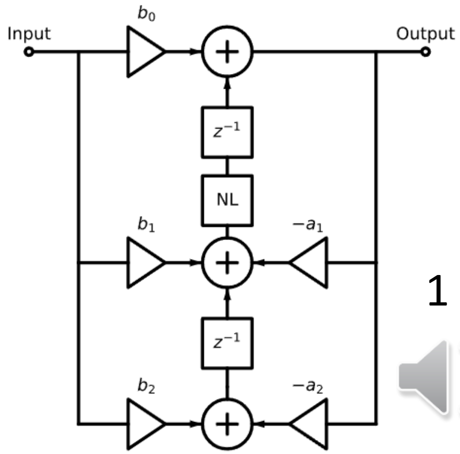
tanh

Stability Test

Assuming that the corresponding linear filter is stable, the nonlinear feedback filter will be stable provided the absolute value of the derivative of the saturation function is always less than or equal to 1. [2]







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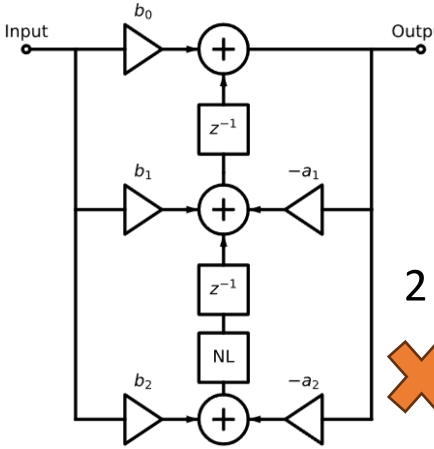

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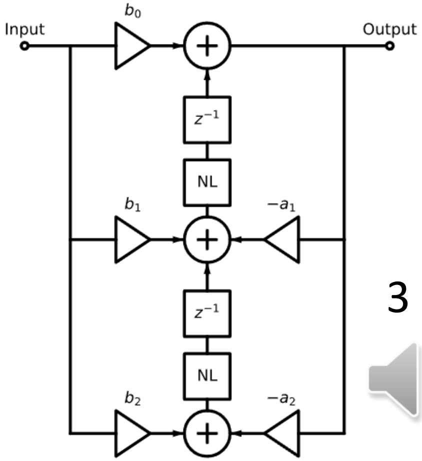

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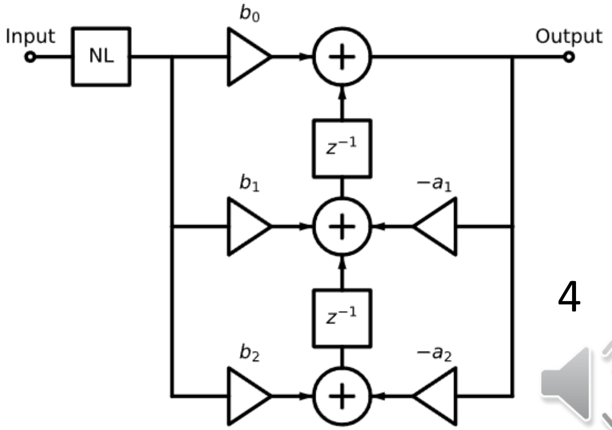

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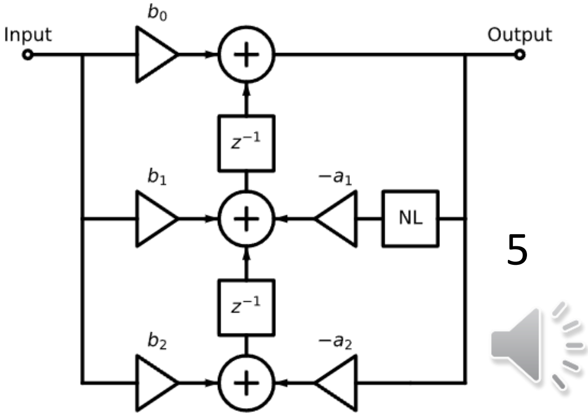

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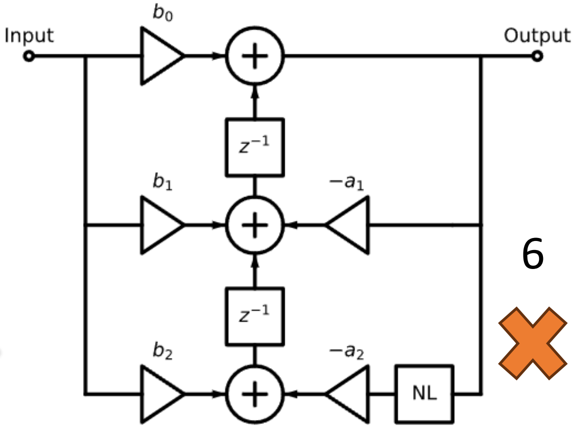

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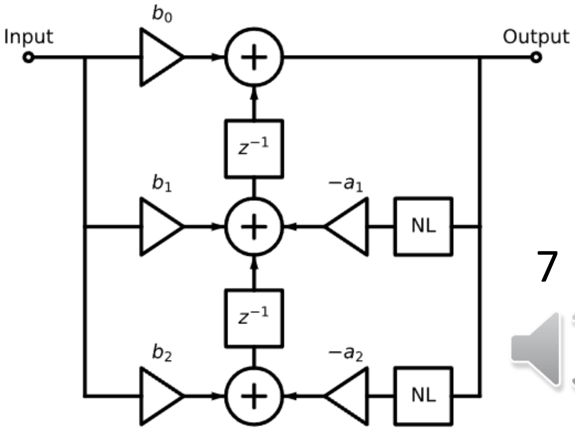

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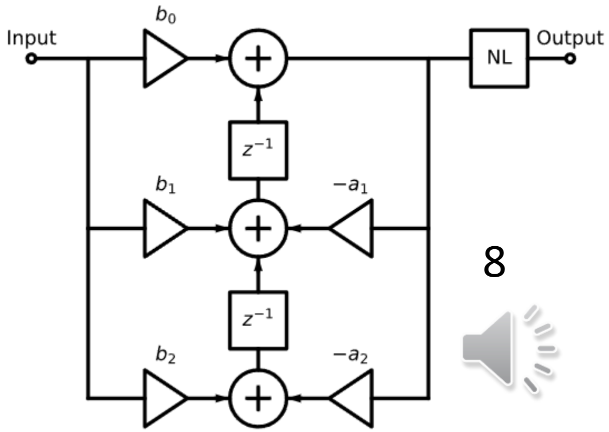

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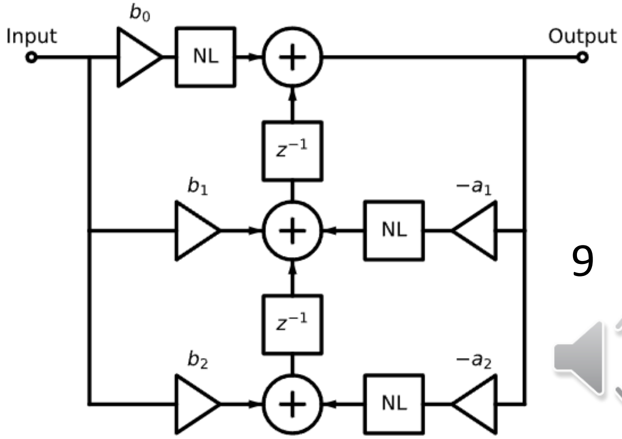
Parameters:

- tanh clipper
- cutoff at 1000 Hz
- 24dB/oct
- Q = 10



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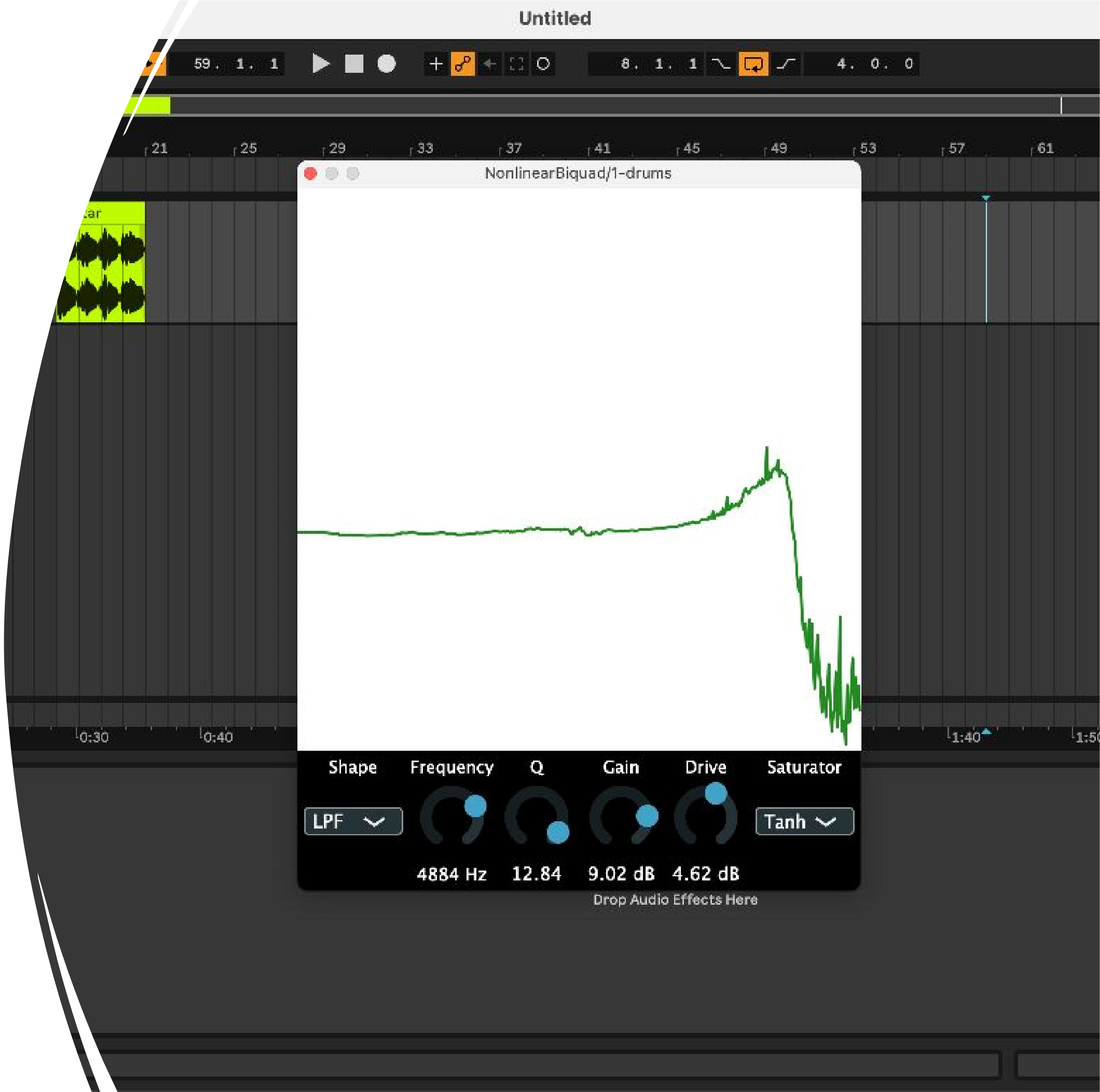
Plugin Demo

- https://github.com/jatinchowdhury18/ComplexNonlinearities
  repository containing recent research exploring purely digital complex nonlinear signal processing
- https://juce.com
  framework for audio application and plug-in development
- https://www.ableton.com
  Ableton Live DAW



Resources

- [1] https://www.uaudio.com/blog/moog-ladder-filter/
- [2] J. Chowdhury, “STABLE STRUCTURES FOR NONLINEAR BIQUAD FILTERS,” *Proceedings of the 23rd International Conference on Digital Audio Effects (DAFx-20), Vienna, Austria, September 8–12, 202*
- *DAFX : digital audio effects*. Chichester, West Sussex, England: Wiley, 2011
- https://120years.net/moog-synthesisersrobert-moogusa1963-2
- https://www.allaboutcircuits.com/technical-articles/analyzing-the-moog-filter/
- https://github.com/jatinchowdhury18/ComplexNonlinearities
- https://juce.com
- https://www.ableton.com/en/live/