

Digital Filtering

TD 6: Digital Crossovers

Antonin NOVAK

Laboratoire d'Acoustique de l'Université du Maine, Le Mans, France



Goal:

Digital Crossovers

- Butterworth filters
- Linkwitz–Riley filters

Crossovers in Sigma Studio

- Load measured data (FRF) of speakers
- Design a 3-way crossover in Sigma Studio for given speakers

Crossover = filter that blocks out unwanted frequencies to a speaker

low-pass for **woofer**

high-pass for **tweeter**

(**band-pass** for **mid-range**)

goal is to smoothly cross over from one frequency range to the next

most common types of filters:

- Butterworth filters
- Linkwitz–Riley filters

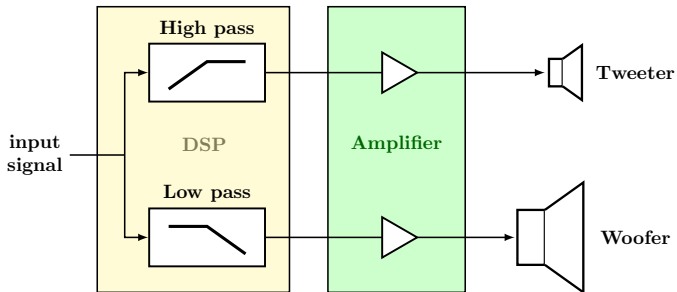


1 2-way Digital Crossovers

3-way Digital Crossovers

Crossovers in Sigma Studio

2-way Digital Crossovers



Work 1: 1st-order Butterworth crossover

Design in Python 1st-order Butterworth 2-way crossover filters
(cut-off frequency $f_c = 1$ kHz, sample rate $f_s = 48$ kHz)

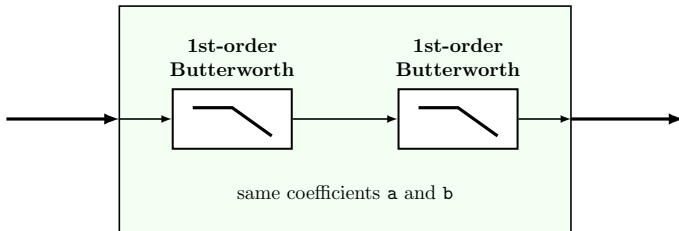
1. get coefficients **a1** and **b1** (1st order Butterworth low-pass filter)
2. get coefficients **a2** and **b2** (1st order Butterworth high-pass filter)
3. plot the FRF (amplitude and phase) of both filters
4. add to the figure the FRF (amplitude and phase) of the sum of both filters
5. answer the following questions:
 - what is the slope (dB/oct) of each filter ?
 - what is the drop (in dB) at cut-off frequency ?
 - is the sum flat ?

Work 2: 2nd-order Butterworth crossover

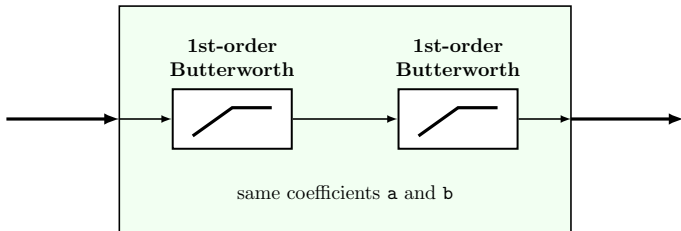
Design in Python 2nd-order Butterworth 2-way crossover filters

1. repeat the previous work for 2nd order Butterworth filters
2. answer the following questions:
 - what is the slope (dB/oct) of each filter ?
 - what is the drop (in dB) at cut-off frequency ?
 - is the sum flat ?
3. think about modifications that need to be done

2nd order Linkwitz–Riley (LR2) low-pass filter



2nd order Linkwitz–Riley (LR2)
high-pass filter

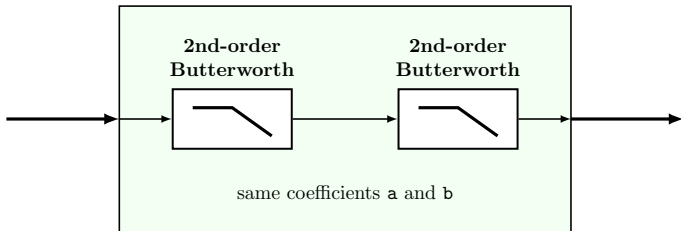


Work 3: 2nd-order Linkwitz–Riley crossover (LR2)

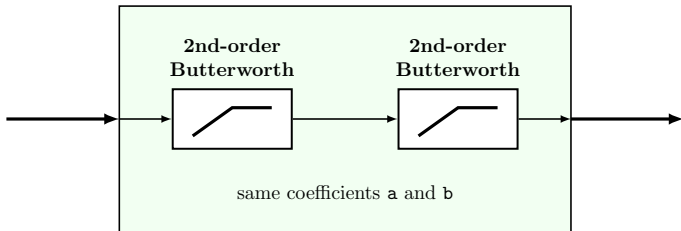
Design in Python 2-way LR2 crossover filters

1. repeat the previous work for LR2
2. answer the following questions:
 - what is the slope (dB/oct) of each filter ?
 - what is the drop (in dB) at cut-off frequency ?
 - is the sum flat ?

4th order Linkwitz–Riley (LR4)
low-pass filter



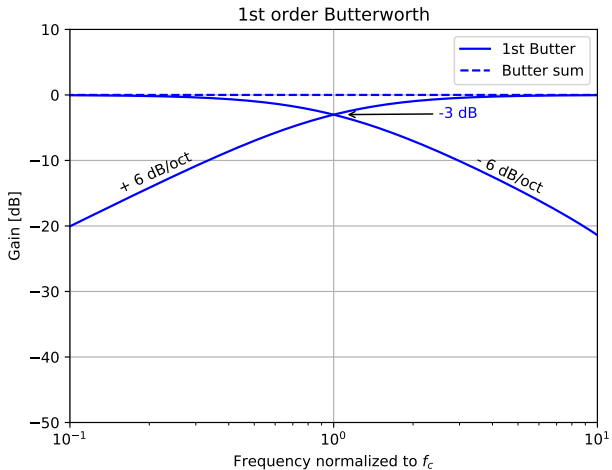
4th order Linkwitz–Riley (LR4)
high-pass filter

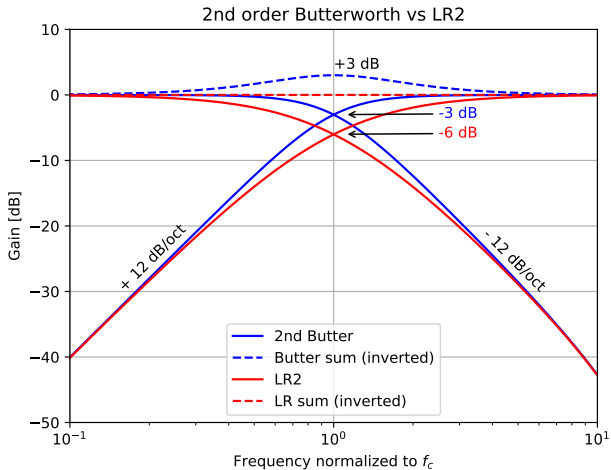


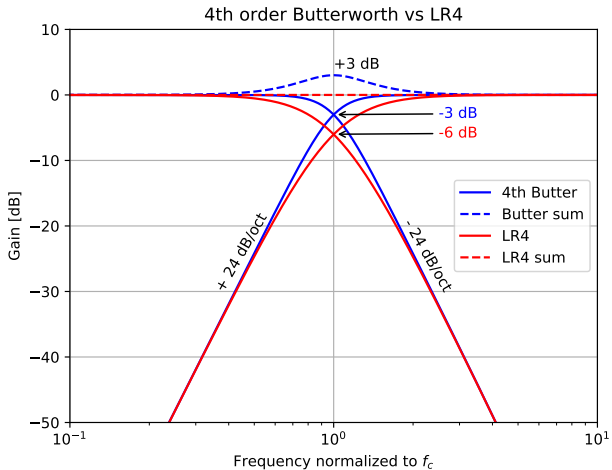
Work 4: 4th-order Linkwitz–Riley crossover (LR4)

Design in Python 2-way LR4 crossover filters

1. repeat the previous work for LR4
2. answer the following questions:
 - what is the slope (dB/oct) of each filter ?
 - what is the drop (in dB) at cut-off frequency ?
 - is the sum flat ?









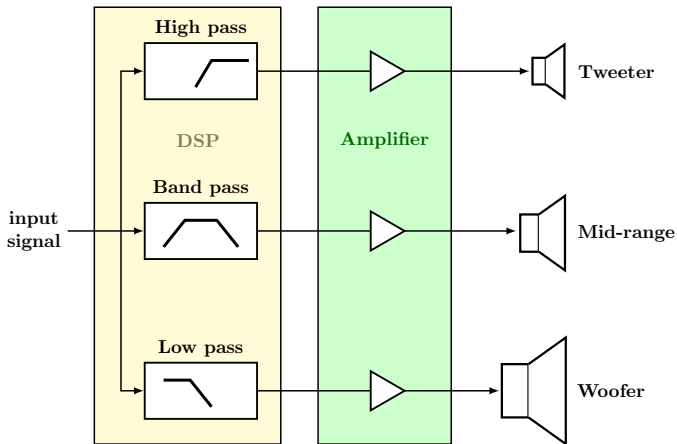
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2-way Digital Crossovers

3-way Digital Crossovers

Crossovers in Sigma Studio

3-way Digital Crossovers



Work 5: 2nd-order Linkwitz–Riley crossover (LR2) for 3-way system

Design in Python 3-way LR2 crossover filters

(cut-off frequencies $f_{c1} = 200$ Hz, $f_{c2} = 2$ kHz, sample rate $f_s = 48$ kHz)

1. design a **low-pass filter** (LR2 @ f_{c1})
2. design a **bandpass filter** (LR2 high-pass @ f_{c1} in series with LR2 low-pass @ f_{c2})
3. design a **high-pass filter** (LR2, f_{c2})
4. plot the FRF of all three filters
5. plot their sum



2-way Digital Crossovers

3-way Digital Crossovers

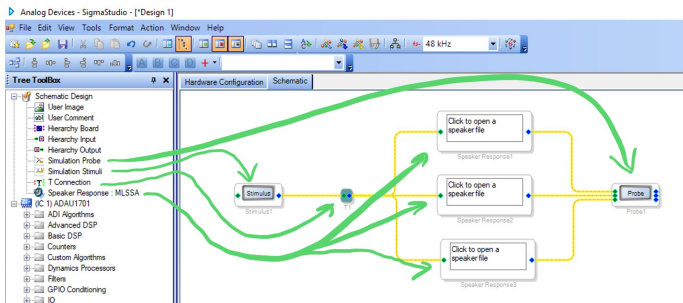
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Crossovers in Sigma Studio

Work 6: Crossovers in Sigma Studio - part 1

Import measured loudspeaker FRF (exported to .txt files) to Sigma Studio

1. Download the data files containing the speaker responses (loudspeakers_01_mlssa.txt, loudspeakers_02_mlssa.txt, and loudspeakers_03_mlssa.txt) from the umtice platform.
2. In Sigma Studio, use 3 blocks of "Speaker Response: MLSSA"

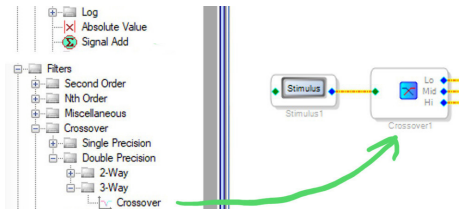


3. Load each speaker response from .txt files
4. Use **Probe** and **Stimulus** to visualize speakers FRFs.

Work 7: Crossovers in Sigma Studio - part 2

Design crossovers filters in Sigma Studio

1. Add, to the previous project, **Crossover** block, and connect it to each speaker



2. Add **Sum** block after Speaker Responses and use another **Probe** to plot the simulated final FRF.
3. Tune the crossovers to find a flat response.

Project

Continue working on the project.
The project assignment is available on
<https://imdea.ant-novak.com/DF>.