Rev. 2020-11-10/MS

EIT5/CT5: Signal Processing, Lab Session

Exercise: Signal through a Sallen-Key LP-filter

Agenda:

- Brief introduction
- Exercise: Design of a Sallen-Key filter
  - Filter design
  - Component selection, mounting of components
  - Optional simulation in Spice
  - Measurement of filter frequency response (Lab. B1-101) together with me
  - Optional plot of calculated, (simulated) and measured frequency responses
  - Measurement of a signal through the filter (Lab. B1-101) together with me
  - Analysis of the recorded signal with FFT-techniques (The theory will be given later in the course, but you can use my Matlab script to get a plot)

Preparation:

- No new literature but read the exercise description below, and take a look at the Matlab-helpfiles before the lecture.
- Use the files on moodle.

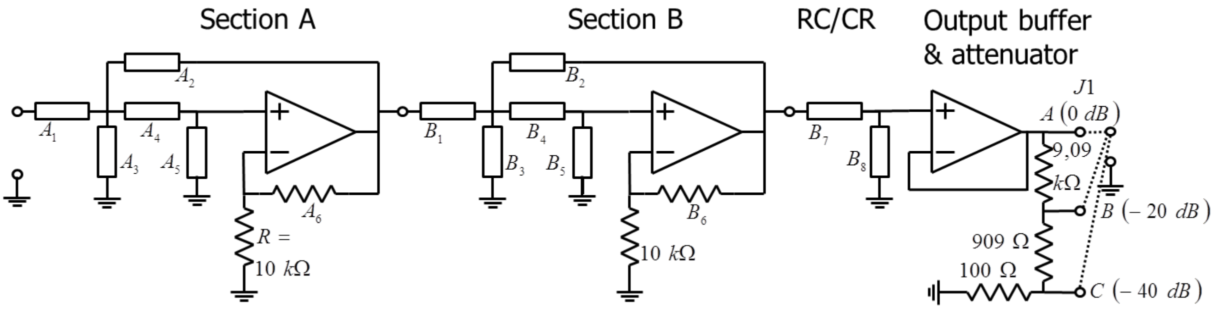
Exercise:

a. The groups are asked to make the following Sallen-Key LP-filters using the techniques from previous lectures:

Chebyshev-filters			
(Groups)/Rooms	**Filter order [-]**	**Ripple [dB]**	**Ripple bandwidth [Hz]**
(5**/5**)	4	0.55	2200
(5**/5**)	4	0.4	2000
(5**/5**)	4	0.3	1800
	5	0.2	2000

Butterworth filters		
Groups	**Filter order [-]**	**-3dB Bandwidth [Hz]**
(5**)	4	1875
(5**)	5	1975
	5	2025

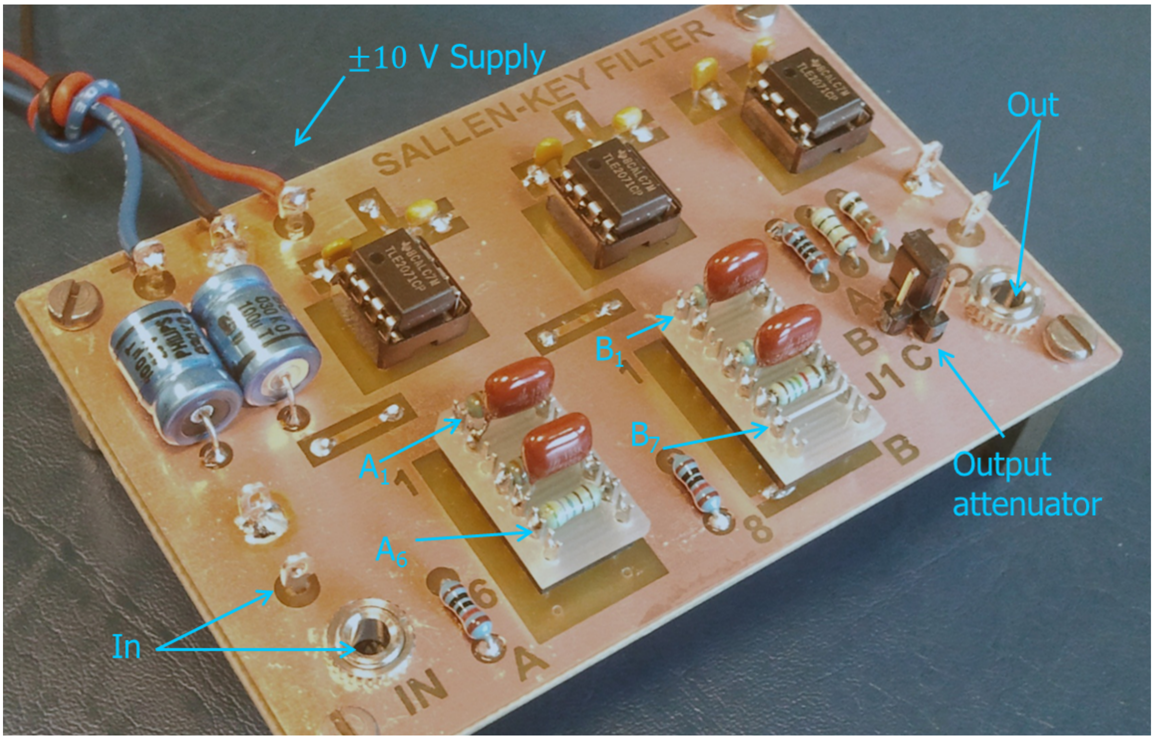
- You can use Matlab to facilitate the work
- There are no restrictions on the filter gain.
- Find the component values $A_1 – A_6$ and $B_1 – B_6$ ($-B_8$).



- You have to make some choices, when you select the components. Resistors are available in the E96-series values, but note that there is a very limited selection of capacitors in the lab, e.g. (Not all values listed):
  - Polyester [nF]: 10, 15, 22, 33, 47, 68, 100,……
  - Styroflex (polystyrene) [nF]: 0.82, 1.5, 1.6, 2, 2.2, 3.3, 3.5, 3.9, 5.6, 10
  - (You may check the accuracy by measuring the capacitance)
- Make a plot of the filter transfer function in Matlab
- Find (Matlab) the attenuation relative to the low frequency gain of the filter at 6.4 kHz.

b. Optional: Make a circuit simulation in Spice of the circuit (In LT-Spice you may use the mathematical opamp-model, "opamp". Remember to include the Spice directive ".lib opamp.sub". You may use "SallenKeyTemplate.asc"). You may export the result for later plot in Matlab. In LT-Spice: Select the plot-window and File → Export.

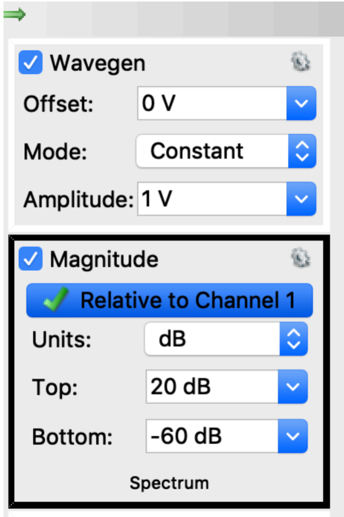
c. Mount the components on component carriers: $A_1 - A_6$ (14 or 16 pin) and $B_1 - B_6$ ($-B_8$) (16 pin).
- Note: If you are not using B_7 you must put a short circuit in its place.
- Mount the component carriers in the sockets of the PCB. When you later on remove the component carriers, use a small screwdriver to lift them from the sockets.



d. Make a measurement of the transfer function using Analog Discovery (recommended.

i. Using Analog Discovery with a laptop and the software Waveforms
- If you are not familiar with this device, take a look at the slides and manual on Moodle
- Suggested settings (not mentioned ⇔ default setting):

- Scale: Logarithmic
- Start frequency: 1k Hz
- Stop frequency: 20k Hz
- Samples: 201
- Amplitude : 1 V
- Adjust the wavegen and magnitude settings based on the need.



ii. Using a PC with an NI-4461-card and the "Swept Sine FRF – VI" (not recommended)
   - If you are not familiar with this equipment, take a look at the slides on moodle
   - Suggested settings (not mentioned ⇔ default setting):
     - AO terminal configuration (excitation channel): Pseudodifferential
     - AI range (stimulus channel) : ±1 V
     - AI terminal configuration (stimulus channel): Default
     - AI range (response channel) : ±10 V
     - AI terminal configuration (response channel): Differential
     - Sampling frequency: 90000 Hz
     - Source amplitude: 0,5 V
     - Start frequency: 20 Hz
     - Stop frequency: 20000 Hz
     - Number of steps: 1000 (you might start with 100 for a fast check)

- Save the measured data or plot on a USB memory stick
- Check the result by a plot in Matlab using *SweptSine.m* (If problems occur, check that the format of the file corresponds to the Matlab script)

e. Make measurements on a signal through the filter:
   - Use the AD2 with Waveforms.
   - Make the connections:
     - Waveform generator 1 pin (yellow)→ filter in
     - Filter out → Scope channel 1 positive (orange)
     - Scope channel 1 negative (orange with white strip) + Ground → Filter ground
     - ±10 V supply for the filter
   - Import and play using AD2:
     - Under the generator function select the file to play: *Signal1.txt* (The program will ask you for the file name). Wait a few seconds until the signal is on the figure. Confirm and continue.
     - Inspect the 1 kHz signals in the beginning and end of the plot (zoom on the plot). If there are problems with clipping etc. try to adjust the *Amplitude* value.
     - If the signal looks OK, save the recorded signal under another Scope in *RecordedSignal1.txt* on a USB memory stick.

- Repeat the procedure above using *Signal2.txt* (And change the recorded file name accordingly). Signal2 is more noisy than Signal1.

f. Analyse the recorded signals *SlidingFFT.m*:
- Try to decode the number.
- Observe the difference in the results of the 4 files.