

# EE431 Lab 4

## Frequency Filters

Dec. 27, 2014

For this laboratory exercise the student designs a low-pass filter to given specifications. The student then builds and tests the filter.

Design a fourth order low-pass filter with a cutoff frequency of 500 Hz using the Butterworth implementation. Implement the filter using two cascaded Sallen-Key low-pass circuits. Your report should show the complete design calculations documented in logical order that can be easily followed (that is something that would be expected on a job so that someone else could check your work).

You are encouraged to use the spreadsheets on the class website to check your work but those are not a substitute for showing the details. Printouts of those spreadsheets can be included as an appendix. Be sure to take into account available parts in laboratory stock when determining components. Because a number of choices are involved it is expected that coincidence of multiple students making the identical choices would be rare. Your report should briefly discuss the limits (the math and instructors guidelines) of a choice and what parts were available for that choice and then the part you chose. You do not have to justify why you chose a particular part other than the limits of choice.

After you have completed the design your report should show an analysis that proves that the design works – i.e. check each Sallen-Key circuit for correct natural frequency and damping. You should then compare your analysis with the design requirements. It is improbable that there would be an exact match because of rounding but differences of more than a few percent raise questions as to why. Do not build the circuit until there is agreement between design and analysis. Use the frs.xls spreadsheet or on the class website or SPICE to make a frequency response plot of your design and include this in your report.

After you have built the filter do a quick test using your theoretical frequency response plot to determine if your filter appears to be working. Apply a 10 volt peak-peak sine wave at the various frequencies. The measured response at 80% of the cutoff frequency should agree reasonably close. The measured response at double the cutoff frequency should agree reasonably close. The measure response at ten times the cutoff frequency should agree reasonably close – this point is subject to a variety of measurement error sources in your crude lab setup so use a broad tolerance of around  $\pm 30$  percent. If any of these tests fail then try to determine what is wrong. The most common problems are missed connections and wrong component values.

Collect data to plot the actual frequency response of your filter by applying a 10 volt peak-peak sine wave over frequencies from one tenth the cutoff to ten times the cutoff. The spacing of the frequency samples should be exponential (often erroneously referred

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to as logarithmic because data is shown on a plot with a logarithmic axis) with 12 points per decade except that finer spacing should be used in the region from about 80% of cutoff to about 150% of cutoff for better resolution. The student should work the simple algebra to determine the factor for the 12 points per decade (if you need help then study the frequency axis calculation of frs.xls). The actual frequencies used do not have to be the exact per the calculation. They only need to be convenient rounded values as it makes no difference as to the exact frequency but only to the extent that there is sufficient coverage of the range. You should have approximately 30 points total. Enter the actual frequencies and measured response data into an Excel spreadsheet and plot the result and include in the report. Your plot should resemble (i.e. both axis logarithmic) that used in frs.xls. It takes a little bit of skill to format an Excel plot to be very presentable and the student should use this as an opportunity. Use the generic sample in Figure 1 as a guide.

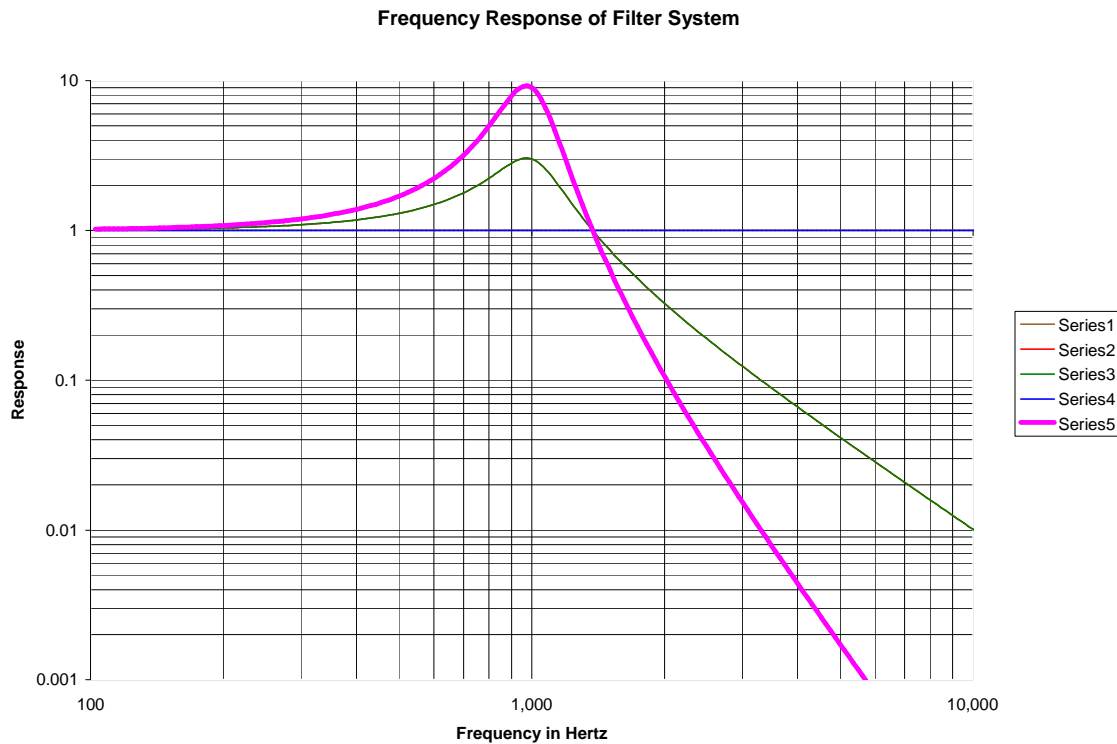


Figure 1: Generic Sample of a Frequency Response Plot done with Excel  
Note the log-log axis