

## Characterizing Multiple-Pole Filters

### Purpose

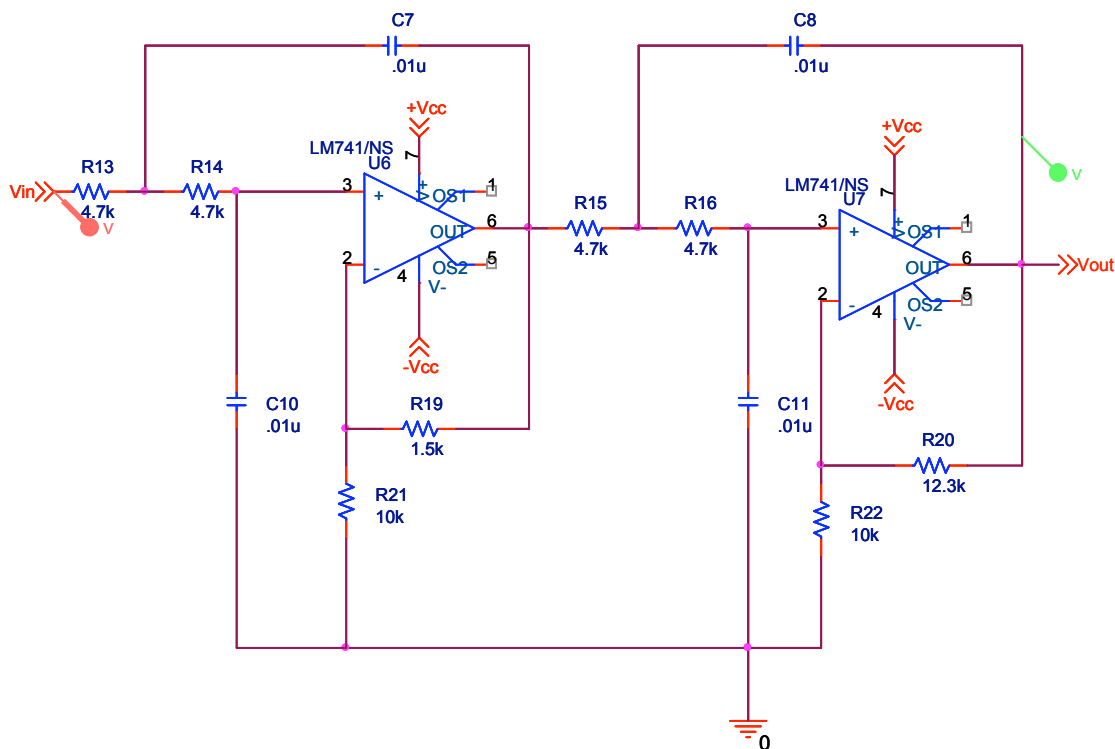
Explore time and frequency response of multi-pole filter circuits in PSpice and in the laboratory.

### Equipment Required

- 1 - Oscilloscope
  - 1 - Function Generator
  - 1 - Dual Power Supply ( $\pm 15\text{Vdc}$ )
  - 1 - Digital Multimeter (to check circuit if needed)
  - 1 - Protoboard
- Components as required for the schematics below.

### Prelab:

1. Reread lab scoring rubric (copy is on web page).
2. Read whole lab before starting the pre-lab. Record your pre-lab in your lab book!!!
3. What kind of filter is in the following low pass filter circuit (type and order)? Verify that it follows the design rules as outlined in H&H section 5.07 or in class notes. Show your work in your lab book. What is  $f_0$  for the circuit? What is total gain of two-stage filter? What kind of frequency and time response to expect from this circuit (sketch in your notebook)?
4. Describe how to convert the filter below to a high pass filter with same  $f_0$ , using the same components. Sketch design of your high pass filter with sufficient detail so you can build it.
5. Set up an excel table for the experimental frequency response data discussed in lab, including all the planned frequency points included in your table.



**Lab:**

1. Enter the low pass filter circuit above and the high pass filter you designed into PSpice. Run PSpice frequency analysis (6 per decade from  $f_0/100$  to  $1000f_0$ ) on both filters. Don't forget proper sources and probes. Export gain and phase data for both filters to Excel. Make one gain plot and one phase plot with both filters on each plot.
2. Run a time domain PSpice analysis of the two filter circuits. Run for pulse width  $\sim 20x$  response time and run time  $40x$  response time (so oscillations in the final values have decayed to  $<1\%$ ). Include a probe of the source voltage. Export data to Excel and plot time response to rising and falling edges for both filters (all on one graph).
3. Build the low pass circuit. Measure the gain and phase of the output of the circuit with respect to the input. Measure for frequencies from  $f_0/100$  to  $1000f_0$  at 3 points per decade (1, 2, 5 convention) and add at least 4 extra frequency measurement points around the cut-off frequency for finer (6 per decade) resolution. Record all values and plot in Excel.
4. Set up oscilloscope to measure and record the time response of the low pass filter. Include the input pulse as a trace. Make the pulse width is  $\sim 20x$  response time and only record response to a rising edge. Use cursors to measure and record the delay (edge to 90% response), rise time (10% to 90% response), and voltage overshoot of response (See H&H page 269). Set cursors for 10% to 90% measurement and print oscilloscope window.
5. TA check. TA will check set-up. Neatness of your circuits is worth 1 lab point.

**Data Analysis**

1. Measure and record the frequency characteristics (BPG,  $f_c$  (at -3dB), slopes, phase at cut-off) of both filters analyzed in PSpice.
2. Measure and record the frequency characteristics (BPG,  $f_c$  (at -3dB), slopes, phase at cut-off) of the experimental low pass filter that you build in lab.
3. For the low-pass filter, measure and record the delay (to 90%), rise time (10% to 90%), and voltage overshoot from your PSpice time response data.
4. Make sure all traces in all graphs are clearly labeled and that each graph is clearly labeled with a title that clearly describes the graph. Make sure all plots are neatly taped in context into your lab book. Mark and label accurately on all plots the important characteristics of the filters (names and values).

**Conclusion**

1. Contrast and compare (qualitatively AND quantitatively) the frequency response of your low pass filter to those predicted by PSpice and discussed in lectures.
2. Contrast and compare (qualitatively AND quantitatively) the transient response parameters of your experimental low pass filter to those predicted by PSpice AND to those listed in Table 5.1 in H&H (page 273 in 2<sup>nd</sup> edition). Explain any errors or inconsistencies.
3. Compare and contrast the rising versus falling edge time response of each filter.
4. Explain the time response of high pass filter (qualitatively AND quantitatively) that was observed in your PSpice analysis. Connect time response to frequency response.