Multi-Pole Filters

By: John Getty
Laboratory Director
Engineering Department
University of Denver
Denver, CO

Purpose:
Practice the design of multiple pole and cascade filters.

Equipment Required:
- 1 Agilent 54622A Deep memory Oscilloscope or Agilent 54600B Oscilloscope
- 1 Agilent 34401A Digital Multimeter
- 1 Agilent 33120A Waveform Generator
- 1 Agilent E3631A Power Supply
- 1 Protoboard
- OP AMPs and passive elements as necessary

Prelab:
Review Chapter 15* and read this entire lab.

Prepare a Design

a. Add the last digit of your student number to that of your partner. Determine your design problem from the table "Multiple Filter Design Projects" using the last digit of the sum. Record the members of your design team in your lab journal.

b. Prepare a design that will meet the requirements of your particular filter project specifications. During the design process divide the circuit into stages. For example, the stages in Fig.1 describe the two cascaded OP AMP circuits that make up a third-order Butterworth filter. This piecemeal approach simplifies the design process and makes troubleshooting easier.

Third order normalized Butterworth polynomial

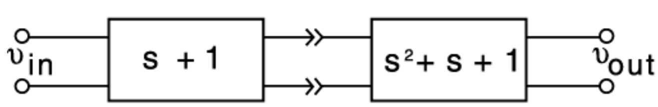

Figure 1

c. Use a CCA to verify that the frequency response of your design meets the design criteria. Print out and tape into your journal the circuit schematic and all pertinent frequency analysis results.

Bonus:
The partnership that designs the least expensive working model for each project will receive a bonus grade on this lab.

Multiple Filter Design Projects
Last digit of the sum of partners' student numbers determine project.

Multiple Filter Design Projects

Last digit of the sym of partners' student numbers determine project

#	Filter Specification **Filter response must be within 10% of the indicated specifications**
0,9	4th order Butterworth low-pass filter, f_c = 1 kHz. Pass B and gain = 3.
1,8	3rd order Butterworth high-pass filter, f_c = 2 kHz. Pass B and gain = 2.
2,3	2nd order (each skirt) bandpass filter with f_{C1} = 500 Hz, f_{C2} = 5 kHz. Pass B and gain = 2.
4,5	2nd order (each skirt) band reject filter with f_{C1} = 500 Hz, f_{C2} = 5 kHz. Lower pass band gain = 5, upper band pass gain > 1.
6,7	A resonant RLC circuit filter with Q > 4 and f_O = 2 kHz. Center frequency gain > 5 (See Sect. 13-6 for details on resonant circuits)

Procedure

1. Build the circuit

   a. Requisition the needed components and construct your circuit. Build each stage separately.

   b. Test each circuit stage and verify that the network gains and critical frequencies are as predicted. Note that the gain and critical frequencies at the output of intermediate stages of a multiple stage design may not be the same as the performance expected from your complete design. Completely document your results, including the results of each stage test.

   c. Combine all the circuit stages and perform a system test. Ask an instructor to perform a critical design and performance review and then sign off in your journal indicating the circuit meets the design specifications.

2. Acquire frequency performance data

   Collect data to completely document your filter performance. Collect at least six points per decade over a frequency range at least two orders of magnitude above and below critical frequency(ies). Collecting more points in the first decade before and after all critical frequencies will better quantify the performance of your filter. If the output is small due to filtering, increase the amplitude of the input voltage so that reliable gain measurements can be made.

Conclusion

1. Document your design

   a. Plot the gain portion of the Bode Plots for your filter circuit.

   b. Describe your filter design in complete detail. Include the cutoff frequency(ies), slope of the frequency response in the stopband(s), and passband gain. Compare the actual performance of your filter to the design specifications.

   c. Perform a cost analysis, based on the prices shown on the "parts order form." Suggest ways to reduce the cost.

2. Create a "Spec-Sheet"

In your lab journal, present a separate onepage "SpecSheet" as if you were to market your filter. Include performance characteristics and a price that will make a profit but will not price you out of the market. Be extra neat and creative.

PARTS ORDER FORM

Multiple-Pole Filter

Partner 1 Name	Number
Partner 2 Name	Number
	Project Number

#	Device Description	Price	Total
	Switch DPDT Toggle	3.20	
	Switch SPST Toggle	0.90	
	Trim Potentiometer: 1 k, 10 k, 100 k ohm	1.50	
	LM741 OP AMP	0.30	
	5 V_{DC} Supply	12.00	
	12 V_{DC} Supply (Dual Independent)	20.00	
	Triple Power Supply	36.00	
	4 Pole DIP Switch	0.90	
	Potentiometer: 1 k, 10 k, 100 k ohm	2.30	
	LED (Red, Green, Yellow)	0.15	
	Standard Capacitor	0.25	
	Standard Inductor	2.99	
	5% Standard Resistor	0.06	
	Total Cost		

* Roland E. Thomas and Albert J. Rosa, The Analysis and Design of Linear Circuits, Prentice Hall, (New Jersey, 1994)