ECE 332 Lab 20d

Filter Product

Design a filter. OK, but why? Up to this point, we've been designing circuits, including filters because we.... Because we what? Because we were told to. Because we had to solve a problem. Because we had a homework assignment. Because we...

Until now, the because has not been, 'because we need to make a filter board as part of a product.' We haven't designed a circuit where the cost of making it has been included. While we have thought a little about parts counts and the like, we haven't considered the cost of manufacturing the circuit on a circuit board. We haven't included the cost of designing the board's layout, the cost of the real estate the circuit required on the board, or even the costs of the individual parts.

In this lab, cost is the primary outcome. The measure of how good the design is will be in dollars. Of course, the circuit must meet specifications, too, but if it does, the quality of the design will be determined by its cost.

Goal

The goal of this lab is very easy to state: We want:

- An active low-pass filter.
- A passband gain of 20 ± 2 dB.
- A cutoff frequency $f_c = 900$ Hz.
- More than 30 dB below the passband gain for $f > 2.5$ kHz.
- Assume a source impedance of 0.
- Minimal cost to design and manufacture
- Standard commercially-available parts only.

For filters that meet these specifications, the design that achieves the lowest cost will receive the best grade.

Introduction

A filter that meets the stated specifications can be done with any of the available common filters: Butterworth, Chebychev, cascaded first-order, Sallen-Key, and so on. It is likely one or more of these designs will achieve the goal of minimal cost.

Tables on the next page list the common commercially-available parts and their costs in the quantities you'll be using. Another table lists costs associated with making the circuit board, including the up-front layout cost, the cost of making the board itself, and the cost of drilling holes in the board.

Academic Direction

- This is individual effort. You may NOT seek assistance from other cadets. You may only reference your course textbook and other course materials.
- You may question any DFEC instructor or technician when doing your work.

Procedure

Design the filter! But while you are doing this, keep in mind the manufacturing costs are all affected by the number of parts and the space they take on the board. So it perhaps seems wise to minimize the number of parts first.

Once you have a design, simulate it to show that it meets specifications. There is little benefit in calculating costs if you don't know that your filter works. Note you don't have to test the design in great detail. Let Multisim give you a Bode plot to see if you are within $\pm$ 2 dB of 20 dB in the pass band and at least 30 dB below the pass band at 2.5 kHz. Enlarge the Multisim plot and use cursors to determine these gains. If these tests show you meet specifications, you have an acceptable filter.

Next, check you have used acceptable parts in your design. If, for example, you have specified 5% resistors and require 2.1 kΩ, you can't manufacture your filter. You can either shift the resistor to a standard 5% value (2.0 or 2.2 kΩ) or specify a more expensive 1% resistor (you'll need to look these up on the Internet).

Finally, calculate the cost, including everything needed to make 500 copies of the circuit board.

Report

Submit a brief report consisting of an Excel spreadsheet tabulating all costs and the total cost of manufacturing 500 board and a Multisim file (.ms13) to demonstrate your design meets specifications. Your instructor may provide a standard Excel spreadsheet.

Note there is a **5% bonus** for a working filter (with real parts). If you choose to implement, include a copy of your myDAQ-generated Bode plot.

The End

Grades will be determined by cost. The least expensive circuit that meets specifications with standard parts will get 100. More expensive filters will receive grades linearly dispersed downward. All filters meeting specifications will get at least 80. A filter failing to meet specifications but otherwise working will get 70 if cost calculations are correct. There will be no credit for any lesser work.

Parts and work costs

Op-amp LM741 or LF351	\$0.25 each
Op-amp LM747 (dual 741)	\$0.40 each
Any other op-amp	\$0.60 each
Resistors, 1% (values on internet)	\$0.04 each
Resistors, 5% (see table)	\$0.02 each
Capacitors (see table)	\$0.12 each
Board layout (one-time up front)	\$90 per sq in
Board build (one-sided, per board)	\$0.40 per sq in
Thru holes	\$0.50 per hole

Board Space and Holes

An op-amp with related resistors and capacitors requires 3 sq.in. of board space (so a 747 needs 6 sq.in.). Devices must have as many holes as they have terminals, so an LM741 requires 8 holes, an LM747 requires 14, and all resistors and capacitors require 2 each. Assume no jumpers and therefore no extra holes are needed. (This circuit can be done without jumpers.)

Available Resistors (5%)

1.0	2.0	3.9	7.5
1.1	2.2	4.3	8.2
1.2	2.4	4.7	9.1
1.3	2.7	5.1	10.0
1.5	3.0	5.6	
1.6	3.3	6.2	
1.8	3.6	6.8	

Resistors are available with any multiplier from $1 - 10^6$ i.e. the values 2.4, 24 and 240 Ω; 2.4, 24, and 240 kΩ; and 2.4 MΩ. However, generally do not specify resistors in op-amp circuits less than 1 kΩ or greater than 1 MΩ.

Available Capacitors

1.8 pF	27 pF	0.001 μF	0.1 μF
2.2	33	0.0015	0.22
5.0	47	0.0022	0.33
7.5	68	0.0047	0.47
10	100	0.01	1.0
12	220	0.022	
18	330	0.033	
22	470	0.047	

You may also use any capacitor on the course parts list.

Pin Diagrams

Note the $+V_{CC}$ pins on the LM747 are internally connected.

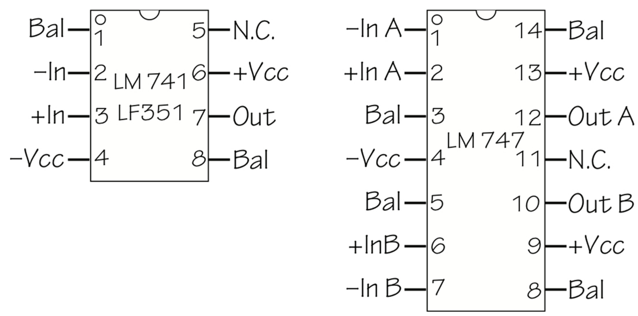

Figure 1: Pin Outs