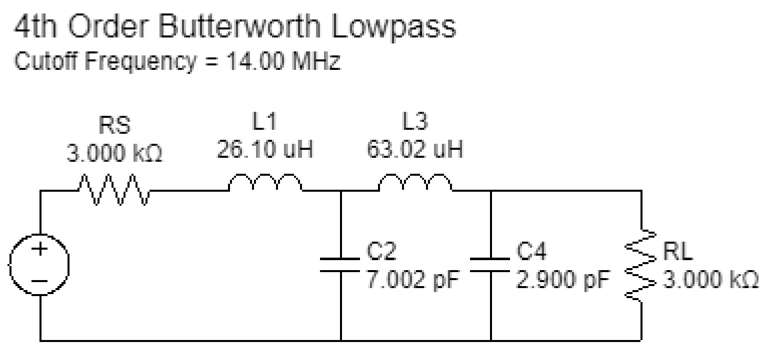
EECS 290C: Advanced circuit design for wireless
Homework # 5

Q1. In this homework, we will design a dual-band lowpass filter for WiFi 11g system. The filter needs to have a 14MHz and 28MHz corner frequency to support 20MHz and 40MHz 11g RF channels in a direct-conversion receiver.

a. Tools such as FilterSolutions (or any other tool) is used get the equivalent LC circuit of a 4^{th} order Butterworth filter whose bandwidth is 14MHz/28MHz (see figure below).
b. Replace the LC filter with an active opamp-RC filter. You can chose the cascade method with two biquads and you can chose any biquad topology you want. You can also mix and match the two biquads as they do not have to have the same topology. For example you can use Thomas-Tow II for the first biquad and MFB single-opamp for the second biquad, etc. Alternatively, you can use the SFG to build a ladder opamp-RC filter. I need only one implementation, either cascade or ladder. For the opamps, use an ideal opamp using ideal VCVS (voltage controlled voltage source) from the analoglib with 60dB gain. Assume the filter is voltage driven from an ideal voltage source as seen in the figure.
c. Create a differential version of the filter you created in “b”
d. Plot for both the LC filter and its differential opamp-RC implementation in “c”:
    a. the magnitude AC response in dB
    b. passband group delay and passband magnitude ripple. Assume passband of 10MHz.
    c. filter step response

Superimpose plots of the two filters (LC and opamp-RC) to compare both filters closely to realize how faithful your implementation is. Make this a habit whenever you design filters.

e. Assume noiseless opamps, scale the filter capacitors (and so resistors in opposite direction) of the implementation in ‘c” to bring the filter output referred passband noise to >15nV/rt(Hz) without affecting its AC magnitude response.
f. Implement the 28MHz bandwidth mode by slicing all capacitors in the filter you did in “e” by half (use MOS switches to switch capacitors in and out for the dual-band filter implementation). Plot AC response in dB and plot output passband noise. Compare noise to that in”e”. Make sure you size switches so as not to impact the filter AC response.
g. Repeat “f” but this time use resistors of the filter to implement the 28MHz band by cutting resistor values of the filter in “e” by half. Plot the AC response in dB and plot the output passband noise. Compare noise to that in “f”.
h. This is a BONOS step. If you have access to an opamp macromodel, you can replace the ideal opamps with that macromodel and add a GBW number to the macro model to see what is the minimum GBW needed to have the AC response of the opamp within 2% of the ideal case (meaning for same resistors and capacitor values, the filter bandwidth changes by only 2% when adding the GBW).



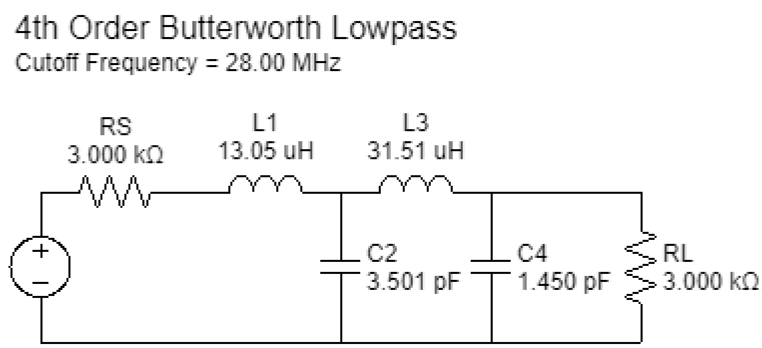


Fig. 4th order 14/28MHz Butterworth lowpass filter

$$H(s) = \frac{1}{(s^2 + 0.765s + 1)} \frac{1}{(s^2 + 1.848s + 1)}$$

Replace "s" with s/ω0, where ω0=2πf and f is the filter corner frequency (14MHz or 28MHz)