Advanced Analog Integrated Circuit Design

FINAL PROJECT – FILTER DESIGN

(Due by 11:59 PM via Canvas on ***May 29)***

1. Project Description

In this project, you are to design and simulate an active filter for use as an IF channel-select filter either in a direction-conversion radio-frequency identification (RFID) reader as specified in Table 1 or in a direction-conversion ultra-wideband (UWB) receiver as specified in Table 2.

The lower cut-off frequency, designed to reject the dc offset and interference, can be simply implemented by a high-pass filter using an ac coupling capacitor, and as a result, the channel-selection filter can simply be a low-pass filter. The requirements of having variable gain and variable upper cut-off frequency as specified are only optional for extra credits.

As always, to give you more motivation, you are also welcome to choose to design a filter with your own specifications or to design an analog-to-digital converter (ADC) or a digital-to-analog converter (DAC) instead, but you would need to *submit a proposal together with detailed specifications for approval by* ***April 24***.

You are to work in groups of two or three, and only one report is required from each group. You are free to implement the filter using either continuous-time or switched-capacitance technique. However, you should justify your design choice. On the other hand, designs of tuning circuits or anti-aliasing filters are not required.

Table 1 Specifications for the channel-selection filter for an UHF RFID reader

Parameters	RFID Specifications
Characteristic	Low-pass
Passband Gain	4 – 30 dB
Passband Ripple	<= 1 dB
Clock Frequency f_s	< = 200 MHz
Lower -3 dB Frequency	8 KHz
Upper -3 dB Frequency f_{up}	50 KHz - 1.28 MHz
Lower Corner Channel Attenuation	> 20 dBc @ dc
Adjacent Channel Attenuation	> 30 dBc @ 2 * f_{up}
Alternating Channel Attenuation	> 50 dBc @ 3 * f_{up}
Source Resistor	10 KΩ
Load Resistor	2 KΩ

Table 2 Specifications for the channel-selection filter for an UWB receiver

Parameters	UWB Specifications
Characteristic	Low-pass
Passband Gain	0 – 10 dB
Passband Ripple	<= 1 dB
Clock Frequency f_s	< = 200 MHz
Lower -3 dB Frequency	5KHz < f_{lo} < 2 MHz
Upper -3 dB Frequency f_{up}	253 MHz < f_{up} < 264 MHz
Lower Corner Channel Attenuation	> 15 dBc @ dc
Adjacent Channel Attenuation	> 12 dBc @ 500 MHz
Alternating Channel Attenuation	> 30 dBc @ 792 MHz
Source Resistor	1 KΩ
Load Resistor	200 Ω

If you choose to design a continuous-time filter, use a voltage-control current source with finite bandwidth and output impedance and limited linearity to model the transconductance amplifiers. You can and probably should use Matlab and HSPICE for your simulations.

For switched-capacitor design, your are to use a voltage-controlled voltage source with finite gain and bandwidth to model the operational amplifiers. You can assume that the maximum clock frequency is about 200 MHz.

2. Design Procedure

    a. Determine which attenuation specification is the most stringent

    b. Figure out the filter type and the minimum filter order to achieve the specifications

    c. Select appropriate implementation for the filter

    d. Design all the required component values

    e. Perform optimization on design

    f. Run simulations to verify your design and iterate if necessary

    g. Investigate the effects of component non-idealities and mismatches.

Please refer to the compliment note on "Instructions on Filter Design Tools" for the tools that are available for your design in addition to Matlab and HSPICE

3. Project Report

In addition to those specified in the project report outline, make sure to include the following

    a. Detailed filter specifications and discussion on how they were derived

    b. Justify your design choice of the filter type (advantages and disadvantages)

    c. Step-by-step design procedure

    d. Schematic diagram of your filter with all important information clearly specified (clock phases, values, etc.)

e. Simulation results (Matlab, HSPICE plots) with comment and discussion. Make sure to include a large-scale plot to show stopband performance and a small-scale plot to show passband performance

f. Discussion on how your design was optimized and how it could be further optimized. For switched-capacitance design, scaling for optimum dynamic range and minimum capacitance spread should be done and described

g. Comparison of the filter performance for ideal and non-ideal components. For continuous-time filters, include the effects of finite bandwidth and limited linearity of the transconductance amplifiers. For switched-capacitor filters, include the effects of the capacitor mismatches and the effects of finite gain and bandwidth of the amplifiers.

4. Extra Credits

For extra credits, you can include the variable gain and the variable cut-off frequency as specified in the tables.

You can also receive extra credits for the project if you include a real amplifier (preferably the one you designed for the midterm project) and simulate the whole filter at the transistor level to see how it affects the filter performance. You would need to repeat *behavioral simulations of the filter with the actual parameters extracted* from the midterm project amplifier *before* doing the *circuit simulations with the real transistor-level amplifier* for comparison.

Note: As your midterm project amplifier has a very high output resistance, it is inherently a good trans-conductance amplifier for a Gm-C filter design. However, if you want to use it for a switched-capacitor filter design, it is necessary to add a buffer (a source follower or an ideal unity-gain voltage-controlled voltage source with low output resistance or) to the output of your midterm project amplifier.

5. Useful References

You may find one of the following books useful for the project.

a. A. Zverev, *Handbook of Filter Synthesis*, Wiley, 1967.

b. A. Williams, and F. Taylor, *Electronic Filter Design Handbook*, McGraw-Hill, 1988.

c. A. Zverev, and H. Blinchikoff, *Filtering in the Time and Frequency Domains*, Wiley, 1976 (reprinted by Robert Krieger Publishing, 1987).

d. D. Johnson, *Introduction to Filter Theory*, Prentice-Hall, 1976.

e. R. Gregorian, and G. Temes, *Analog MOS Integrated Circuits for Signal Processing*, Wiley, 1986.

f. Y. Tsividis, and J. Voorman, *Integrated Continuous-Time Filters: Principles, Design, and Applications*, New York, IEEE Press, 1993.

g. C. Bowick, *RF Circuit Design,* Indianapolis, Sams, 1982.

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