

# EECE 2510 - Circuits and Signals: Biomedical Applications

## Sec 2

### Lab 10, Spice Analysis of Active Filters

#### Introduction:

As discussed in class, Op-amps are useful building blocks in many sensing and measurement applications. To measure the EKG signal, we will be using them to amplify small signals, to reject common-mode signals, and to filter out unwanted low and high-frequency noise and interference.

#### Prelab (DiMarzio Section Only)

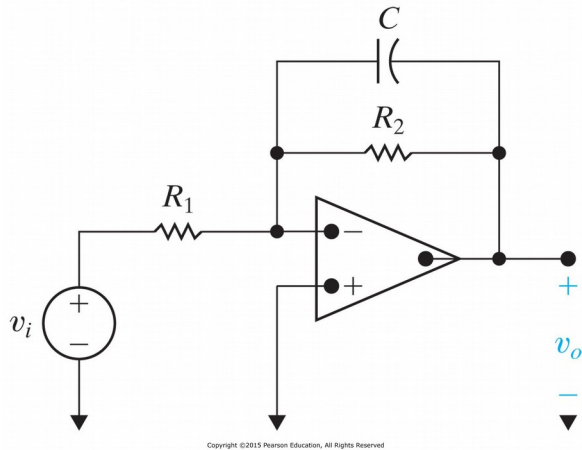
##### In Class:

Determine the transfer function of the circuit analytically.

At home: Do the same for the second circuit.

#### Part 1: Spice Modeling of Op Amp Circuits

- 1.1 In PSpice, use the **741 op-amp model in the Eval library** (note, this is listed as UA741 and is at the end of the Eval list) to build an active **low pass** filter. (If you want to put the inverting input at the top of the diagram as shown below, you can right click and chose “mirror vertically”.) Use  **$R_2 = 100 \text{ k}\Omega$ ,  $C = 10 \text{ nF}$ , and  $R_1 = 20 \text{ k}\Omega$** . Use **+/- 10V DC** power supplies for the op-amp and use an **AC source** (VAC in PSpice) to the input of the filter. Give the filter a **1k $\Omega$  load** (meaning, connect a 1k resistor from the output of the op-amp to ground).



### Some reminders on starting/using PSpice:

1. Run Cadence OrCAD Capture CIS Lite
  2. New Project
  3. Analog or Mixed A/D
  4. Location – somewhere you have permission to write (desktop, for example).
  5. OK
  6. Create a blank project
  7. OK
  8. Special note: m is  $10^{-3}$ , M is also  $10^{-3}$ , Meg is  $10^6$ , meg is also  $10^6$  or 1e6 is  $10^6$ . This is a legacy of the original code being written in the 1960s when it was customary or necessary to program using case-insensitive text!!!
- 1.2 Using the AC Sweep/Noise analysis mode with a logarithmic frequency sweep, test the amplifier with an **AC input** with 0.1V amplitude and create a semilog plot of the response from 1 Hz to 1 MHz using the AC Sweep/Noise analysis mode with a logarithmic frequency sweep (hint – use a voltage probe at the output of the op-amp). **Q1: What is the cutoff frequency,  $f_c$ , (the half power point, or where the voltage is 0.707 times the maximum output voltage)? Is this what you expect, considering the value of the RC time constant?**
- 1.3 **Q2: What happens if you make your input sinusoid have an amplitude of 0.5 V?**
- 1.4 Now use a pulsed source to produce a **200 Hz square wave** with **0.5V** amplitude and connect this to the filter input. Using the Transient (Time Domain) Analysis function plot both the input and output voltages. Use the FFT function to display the frequency components for both the input and output waves.

Source notes:

V1 is one of the two voltages, and would be -0.25V for a 0.5V p-p square wave.  
 V2 is the other voltage, + 0.25 for a 0.5V p-p square wave with no DC component.

TD is the time delay from the start, which can be set to zero.

TR and TF are the rise and fall times of the pulse, which should be significantly smaller than the period, perhaps 1-10 microseconds. If they are too small, PSpice could take a long time to compute the answer, or it might not find a solution.

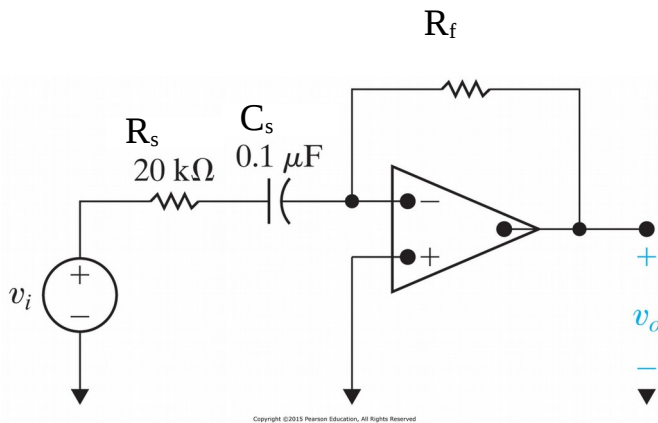
PW is the pulse width, or the time the pulse spends at V2.

PER is the total period of the pulse, which should be double the value of PW for a square wave that has equal times spent in the high and low voltage states.

**Q3: What do you measure at the output? Save/print the output or sketch it in your lab-book and try to explain why the output wave looks as it does, rather than just being a square wave. Try thinking in both the time and frequency domains when coming up with your answer. Note that you should have both time and frequency domain plots – the output as a function of time, and the FFT, which gives the magnitude of the frequency components.**

**Hint – it may help you see what is happening if you try inputting square waves with higher and lower frequencies to see what the filter does (10x to 100x higher or lower, maybe).**

- 1.5 Now, change your circuit so that it is an active high pass filter with  $R_s = 100 \text{ k}\Omega$ ,  $C_s = 10 \text{ nF}$ ,  $R_f = 200 \text{ k}\Omega$  and plot the filter response to an AC input from 1 Hz to 1 MHz. **Q4: What are the in-band gain and  $f_c$  of the circuit? Q5: Why does the output roll off at high frequencies, if this is a high-pass filter??**



- 1.6 Now use a pulsed source to produce a **50 Hz square wave** with **0.5V** amplitude and connect this to the filter input. Plot both the input and output voltages, both as a function of time, and as a function of frequency (using the FFT function). **Q6: What do you measure at the output? Save the output plot or sketch it in your lab-book and try to explain why the output wave looks as it does, again thinking in both the time and frequency domains.**

**Hint – again it may help you see what is happening if you try inputting square waves with higher and lower frequencies (10x to 100x higher or lower, maybe).**

#### **Part 4 – Instructions For the Write-Up...**

Your lab reflection for this lab does not need to include the answers to the questions, just your responses to the general lab reflection questions posted on Blackboard.

**DiMarzio Section Only: No “reflection.”**

#### **IMPORTANT: BEFORE YOU LEAVE THE LAB:**

- (a) Place all of the components that your removed from the red tool box back in that box and return it to the cabinet that houses them**
- (b) Collect all used components and wires from your bench and place them in your group’s reusable plastic container. If you are not going to use these components or wires again please discard them in the trash bin.**
- (c) Turn off all of the equipment you have used on your workbench.**
- (d) Make sure you return your protoboard, the equipment wires and your reusable container to the front window.**
- (e) Make sure to have your notebook signed by an instructor before you leave the lab.**

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Last updated: 10/29/16 D. Brooks, 10/24/16, N. McGruer, 120 minutes; 9/30/14 M.

Niedre and D. Brooks; 9/30/12, D. Erdogmus and N. McGruer