Design of an Active Low Pass Filter

The circuit shown in figure 1 below is an example of an RC active low pass filter. Filters are circuits that block or pass signals based on their frequency. Most electrical systems contain some type of filter circuit. Generally, they are used to eliminate unwanted signals while allowing the desired signals to get through.

![Figure 1. RC Active Low Pass Filter](image)

This particular filter is referred to as an active filter because it contains an op amp. It is a “low pass” filter because it lets low frequencies through but blocks higher frequencies. In EE 110 you will study filter circuits in a lot of detail.

The filter circuit in figure 1 is a first order circuit. Thus, we know that the output, $v_o(t)$, can be expressed as:

$$v_o(t) = v_{o, transient} + v_{o, steady state}$$

We know that the transient part of the solution is independent of the input signal $v_i(t)$ and that it dies out after about five time constants. The steady state part of the solution depends on the input signal. In this project you are only going to be concerned with the steady state part of the solution.

Part 1. Find the differential equation for the output, $v_o(t)$.

Part 2. Assume that the input signal is a sinusoid of the form:

$$v_i(t) = \cos \omega_0 t$$

Solve for the steady state (particular) solution of the differential equation found in part 1. Note that this solution will be in terms of the component values $R_1$, $R_2$, $C$ and the frequency of the input, $\omega_0$. 
Part 3. For very low frequencies, you would like for the output signal to have a peak amplitude that is “K” times that of the input signal. In your design, “K” is equal to the 8th digit in your student ID number (note: if this number is zero, use 5 instead). Select values of $R_1$ and $R_2$ to give you this output. Use resistors between 1KΩ and 100KΩ. Since you are designing for low frequencies assume that $\omega_o = 0$ for this part of the design. Recall from trigonometry that a sinusoid of the form:

$$A \cos \omega_o t + B \sin \omega_o t$$

has a peak amplitude of:

$$\sqrt{A^2 + B^2}$$

Part 4. Verify that the values you selected in part 3 work by simulating your circuit on PSPICE. Use a uA 741 op amp. Apply an input sinusoid with a very low frequency (0.001 Hz). Recall that $\omega = 2\pi f$. Use a value of $C = 1\mu F$. Be sure to begin the display of your output after the transient part has died out by setting a value for TSTART in the simulation. Check that the peak amplitude of your output is equal to “K” (5% error allowed).

Part 5. In this part you will select the value of $C$ needed to block the specified high frequencies. Use your results from part 2 to select $C$ so that the amplitude of the output drops down to 10% of “K” when the frequency, $L$, is equal 10000 Hz times the 9th digit of your student ID number (use 5 if this digit is zero). Keep the resistance values the same as those selected in part 3. Show how you calculate $C$.

Part 6. Verify that the value of $C$ you selected in part 5 is correct by simulating your circuit again on PSPICE. Check that the peak amplitude of your output is equal to 0.1K at the frequency $L$. Again, 5% error is allowed.

In order to get full credit for this project it must be written up so that your procedure and results are clear to the person grading it. Be sure to include the PSPICE schematics and relevant output graphs.