Laboratory 7: Active Filters

Concept

Limiting the response of an op amp circuit to a particular frequency range of interest is important for all applications. RC, RL, and LC filters can be used between a signal source and the op amp, but building the feedback circuit with R and C elements has advantages. These laboratory exercises explore the low-pass, high-pass and band-pass configurations in both the time and frequency domains.

Helpful hints and warnings

Operational amplifiers are integrated circuits (consisting of many internal transistor, diodes, resistors and capacitors) which require a bipolar power source. It is imperative that symmetric positive and negative potentials be applied to the + and - power pins, such as 12.0 V or 14.7 V. The power supply should provide 15 V or less. Check the specification sheet for the absolute maximum power supply potential. Unlike the passive devices encountered in previous laboratory experiments, opamps can be destroyed by the application of excessive potential differences. Remember to connect the power supply ground to the oscilloscope ground. Besides the limitation on the power pins, the two signal inputs also have a limitation on the maximum applied potential. Check the specification sheet. The output of an op amp can be sensitive to changes in the potentials provided by the power supply, Vcc . It is generally wise to include 100 nF capacitors between each power supply line and the system ground to dampen any such variations.

When measuring the response or gain function A() for and opamp circuit (both amplitude and phase), one usually triggers the oscilloscope with the input signal. However, when the gain is high, the input signal needs to be small, and triggering can become unreliable. Switching the trigger source from the input to the output signal might make triggering more reliable, but an error can occur in measuring the relative phase when the trigger source is changed. The solution to this problem is to use the pulse or clock or TTL square-wave output of the function generator to trigger the oscilloscope. This signal is usually 0 to 5 V, and should be connected to the external trigger input on the scope. Be sure to set the trigger source switch to external.

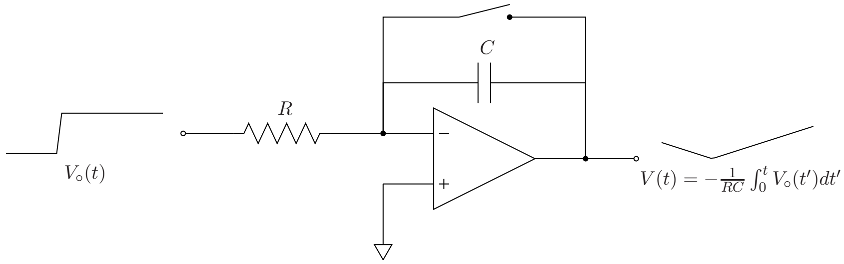
If you need to create an input signal or DC level using a potential divider, be sure that the source resistance of the divider is at least 10 times less than the input resistance of the entire opamp circuit. If this condition is not satisfied, then the source you have created will be distorted by the opamp circuit.

Experiments:

7.1 Integrating or Low-Pass Amplifier

7.1.1 LP Switch

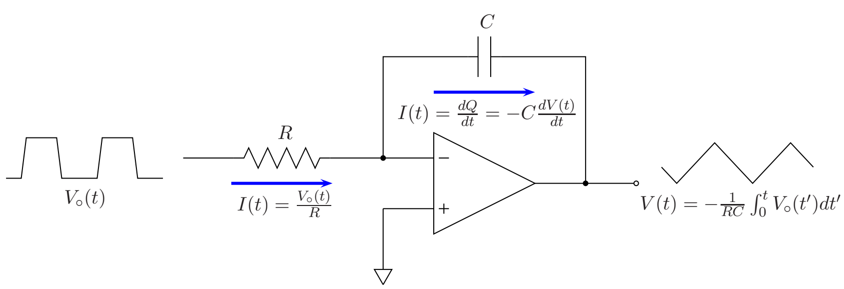
Instructions:
Build the integrating op amp circuit below with a discharge switch (this can just be break in wiring), using $\tau = RC \approx 1$ sec. Because R will need to be large ($\approx 1M\Omega$), you might need to add a resistor to the non-inverting input to negate the input bias current.
Apply a small constant input signal, discharge the capacitor momentarily and observe the rate of change of the output.



Questions to answer:
Does this rate of discharge agree with the theoretical τ, based on your measured values of R and C?

7.1.2 Integrator with Capacitor

Instructions:
Rebuild the circuit, using $\tau = RC \approx 10^{-3}$ sec. Apply a square wave at 50, 100, 200, 500, 1000, and 5000 Hz and record important aspects and data of the observed waveforms in the time domain.

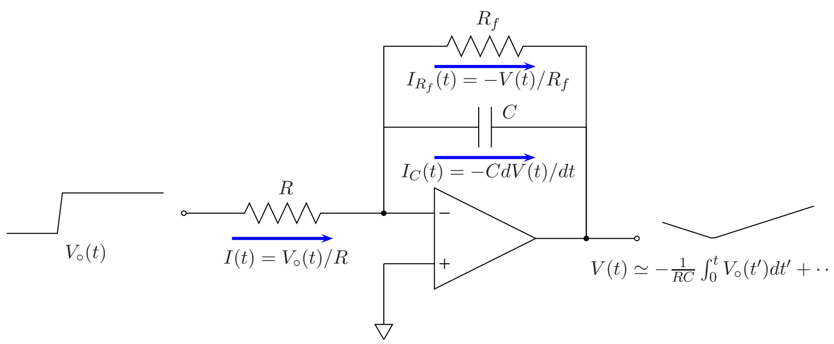


Questions to answer:
Explain the shapes of the waveforms in terms of the theoretical model.
Is there a difference between athe behavior of the passive RC circuit and the behavior of this active RC circuit?

7.1.3 Integrator with Capacitor and R_f

Instructions:

Add a feedback resistor R_f such that $R_f C \approx 1$ sec.
Apply a square wave at 50, 100, 200, 500, 1000, and 5000 Hz and record the output.



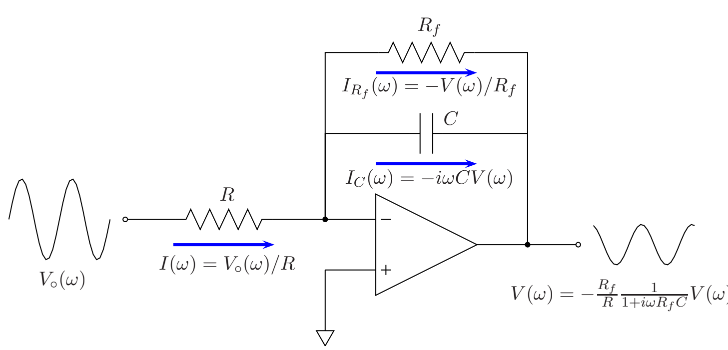
Questions to answer:

Explain the shapes of the waveforms in terms of the theoretical model including R_f.
Is there a reason to include R_f?
Is there a difference between athe behavior of the passive RC circuit and the behavior of this active RC circuit?

7.1.4 Integrator with Capacitor and R_f: Frequency Analysis

Instructions:

Using the same cicuit as above, apply a sine wave at 10 frequencies between 100 Hz and 100 kHz and measure the amplitude and phase transmission functions $[A(\nu), \phi(\nu)]$.



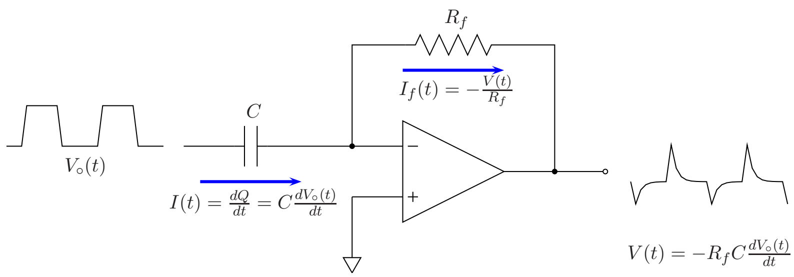
Questions to answer:

Plot both the transmission $|A(\nu)|$ in dB and the phase $\phi(\nu)$ versus log ν.
Compare both to the theoretical behavior for an ideal op amp of infinite frequency response.
Explain the effect of the finite frequency response in this op amp.

7.2 Differentiating or High-Pass Amplifier

7.2.1 Differentiator with a Capacitor and R$_f$

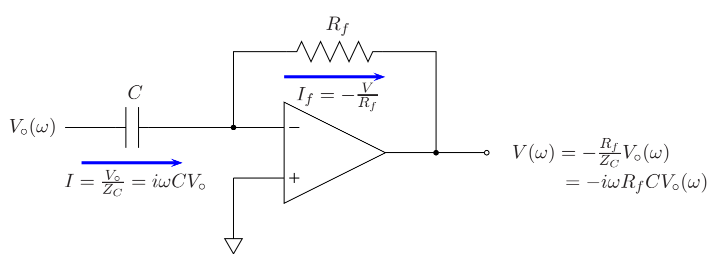
Instructions:
Build a differentiating op amp ciruit using $tau = RC \approx 10^{-3}$ sec.
Apply a square wave at 50, 100, 200, 500, 1000, and 5000 Hz and record the time domain output.



Questions to answer:
Explain the shapes of the waveforms in terms of the theoretical model.
Is there a difference between the behavior of the passive CR circuit (no op-amp) and the behavior of this active CR circuit (with op-amp)?

7.2.2 Differentiator with a Capacitor and R$_f$: Frequency Analysis

Instructions:
Using the same circuit as above, apply sine waves at a minimum of 10 frequencies between 100 Hz and 100 kHz and measure the amplitude and phase transmission functions $[A(\nu), \phi(\nu)]$.

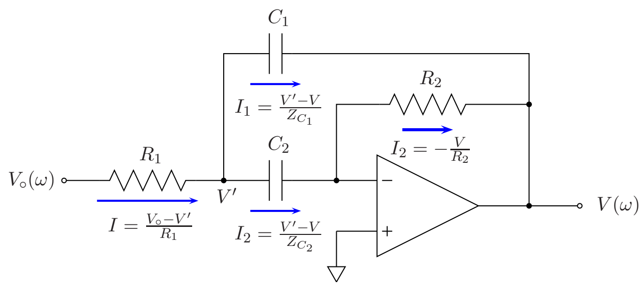


Questions to answer:
Plot both the transmission $|A(\nu)|$ in dB and the phase $\phi(\nu)$ versus log ν.
Compare both to the theoretical behavior for an ideal op amp of infinite frequency response.
Explain the effect of the finite frequency response in this op amp.

7.3 Band-Pass Amplifier

7.3.1 Frequency Analysis of a Band-Pass Amplifier

Instructions:
Build the integrating op amp circuit below, using compenent values provided by the TAs.
Apply a square wave at 50, 100, 200, 500, 1000, and 5000 Hz and record the output.



Questions to answer:
Explain the shapes of the waveforms in terms of the theoretical model.
Is there a difference between the responses of the passive RLC bandpass circuit (no op-amp) and the behavior of this active bandpass circuit (with op-amp)?