7.5.3: Active RC Circuit Step Response

Overview:

In lab assignments 7.5.1 and 7.5.2, we examined the response of passive first order circuits. These circuits can be very useful, for example, in signal conditioning. However, passive first order circuits have similar drawbacks to passive resistive circuits. One major problem is that the addition of a load to the circuit can significantly modify the circuit's behavior, which may necessitate a re-design of the circuit anytime a different load is applied to the circuit. Another drawback is the inability to amplify any input signal – the energy out of a passive circuit cannot exceed the energy provided to the circuit.

Active circuits can resolve these issues. Active circuits, since the power they supply comes from external sources, are somewhat immune to loading effects. The external sources of an active circuit also allow these circuits to amplify input signals – the output from these circuits can contain considerably more energy than is being provided by the input signal. In this lab assignment, we construct an active RC circuit and note that loading of the circuit – unlike loading of the circuit of lab 7.5.1 – does not significantly affect the circuit's behavior.

Before beginning this lab, you should be able to:

- Analyze, design, and build operational amplifier-based circuits
- State voltage-current relationships for inductors and capacitors
- Determine the natural and step responses of active first order circuits
- State the potential effects of loading on passive first order circuits (Labs 7.5.1, 7.5.2)

After completing this lab, you should be able to:

- Use a function generator to apply a square wave voltage input to an electrical circuit.
- Measure the time constant and steady-state response of first order active electrical circuits

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit
- Digital multimeter (optional)

Symbol Key:

DEMO — Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.

ANALYSIS — Analysis; include principle results of analysis in laboratory report.

SIM — Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.

DATA — Record data in your lab notebook.

General Discussion:

In lab assignment 7.5.1, we (hopefully) noted that loading passive circuits can have a significant effect on their response. Active circuits tend to be less susceptible to loading effects. In this part of the assignment, we construct an active RC circuit with the same time constant as the circuit of lab 7.5.1. We then apply the load of lab 7.5.1 to this active circuit and observe the response.

The circuit shown in Figure 1 has an input-output relationship:

$$\frac{dV_{OUT}(t)}{dt} + \frac{1}{RC} V_{OUT}(t) = -\frac{1}{RC} V_{IN}(t)$$

which, with the exception of a sign change, is the same as that of the circuit of Figure 1(a) of Lab 7.5.1. Thus, the response of the circuit of Figure 1 will have the same time constant and steady state gain as the circuit of lab 7.5.1, but will be of opposite sign.

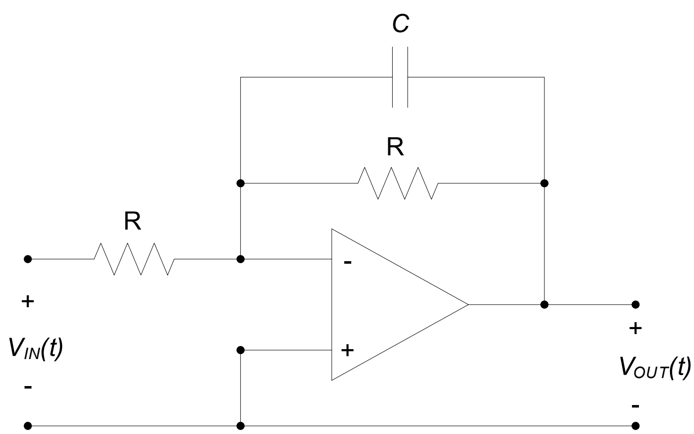

Figure 1. (Inverting) active RC circuit.

Pre-lab:

None

Lab Procedures:

DATA

a. Construct the circuit shown in Figure 1, using R=470 Ω, and C = 1μF (As always, measure the actual resistance and capacitance values (if possible) and record them in your lab notebook.)

DATA

i. Apply a 4V peak-to-peak square wave input with period = 10 ms (frequency = 100Hz) as shown in Figure 2 to the circuit. (Make sure the supply voltage ranges applied to the operational amplifier are adequate to provide the full range of output voltage.) Measure both $V_{IN}(t)$ and $V_{OUT}(t)$; record an image of the oscilloscope window, showing the waveforms.

ANALYSIS

ii. Calculate the time constant and steady state output voltage. Compare your results with your results from lab 7.5.1 and comment on any differences.

DEMO

iii. Demonstrate operation of your circuit to a teaching assistant and have them initial your lab notebook and the lab checklist.

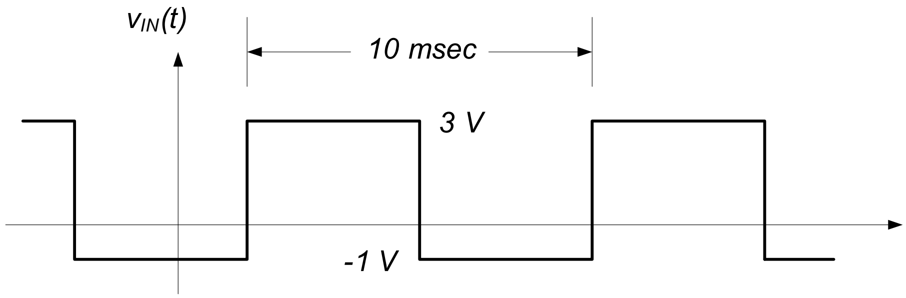

Figure 2. Input voltage signal.

b. Gradually increase the frequency of the input square wave and note the output voltage response.

DATA

i. Tabulate the peak-to-peak input and output voltages for (at least) frequencies of 300Hz, 500Hz, 1000Hz, and 2000Hz. Comment on the trends between the peak-to-peak input and output voltages and the input frequency. Comment on the reasons for this behavior. (Hint: as the input function changes faster than the circuit time constant, the capacitor in the circuit does not have time to fully charge or discharge before the input voltage changes.)

DEMO

ii. Demonstrate operation of your circuit to a teaching assistant and have them initial your lab notebook and the lab checklist.

c. Apply a load to the RC circuit of Figure 1 by constructing the circuit shown in Figure 2. Use R = R_L = 470 Ω.

DATA

i. Measure the V_{IN} and V_{OUT}, for the input voltage shown in Figure 2. Record an image of the oscilloscope window, showing the waveforms.

ANALYSIS

ii. Determine a time constant and steady state response from your measured data. How do these parameters compare with those of the unloaded circuit of part (a) of Lab 7.5.1? How do they agree with the loaded passive circuit of part (c) of Lab 7.5.1?

DEMO

iii. Demonstrate operation of your circuit to a teaching assistant and have them initial your lab notebook and the lab checklist.

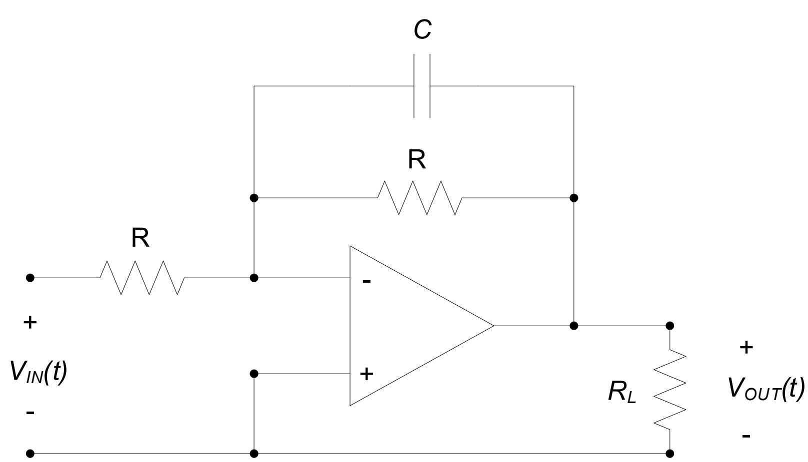

Figure 3. Loaded active RC circuit.