

7.4.1: Inverting Differentiator

Overview:

In this lab assignment, we will examine the forced response of a circuit which performs a differentiation – that is, the circuit output is the derivative with respect to time of the input to the circuit. We will apply sinusoids of various frequencies to the circuit and compare the output with our expectations based on analysis.

Before beginning this lab, you should be able to:

- Determine the input-output relationship for first order circuits
- Use the Analog Discovery waveform generator to apply a time-varying voltage input to an electrical circuit (Lab 6.2.1)
- Use the Analog Discovery oscilloscope to measure and display time-varying waveforms

After completing this lab, you should be able to:

- Measure the forced response of a circuit which performs a differentiation process

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit

Symbol Key:

	Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
	Analysis; include principle results of analysis in laboratory report.
	Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
	Record data in your lab notebook.

General Discussion:

The circuit we will be concerned with in this assignment is shown in Figure 1. The output of the circuit, $V_{OUT}(t)$, is proportional to the inverse of the derivative of the input voltage, $V_{IN}(t)$. The constant of proportionality is determined by the values of the resistance and capacitance in the circuit. In this assignment, we will analytically estimate the relationship between the circuit's input and output and compare this with measured input and output signals.

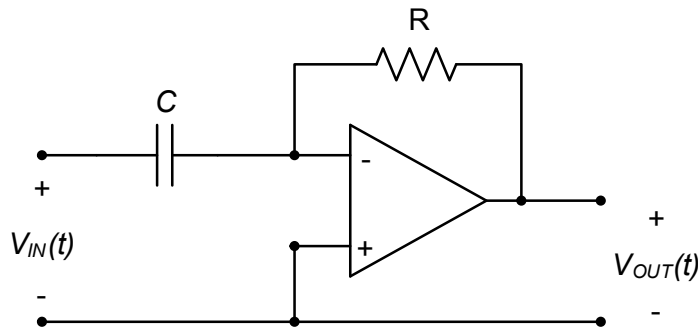


Figure 1. Differentiating circuit.

Pre-lab:

ANALYSIS

Determine the circuit output $V_{OUT}(t)$ as a function of the circuit input, $V_{IN}(t)$. (This is the circuit's input-output relationship.) Your relationship will be a function of the resistance, R , and the capacitance, C .

ANALYSIS

If the input function is a sinusoid of the form

$$V_{IN}(t) = A \cos(\omega t)$$

determine the output function. (Your solution will be a function of R , C , A , and ω .)

Note:

The argument in the cosine function has units of radians. Thus, ω has units of radians/second. This is different from the units of Hertz (cycles/second) that are used by most waveform generators. The conversion between Hz and radians/second is:

$$\omega = 2\pi f$$

where the frequency f has units of Hz. The above conversion is essential, if you want to compare calculations with data.

Lab Procedures:

DATA

- a. Construct the circuit shown in Figure 1, using $R=1.5k\Omega$ and $C = 100nF$. Use $V+$ and $V-$ as the positive and negative power supplies of the operational amplifier. Use the oscilloscope to measure both the input and output voltages $V_{IN}(t)$ and $V_{OUT}(t)$. Set the oscilloscope measurements to provide at least the amplitude of each of these waveforms. (As always, measure the actual resistance value; measure the capacitance value if you have the appropriated instrument – some DMMs have a capacitance meter – otherwise, assume that the nominal capacitance value is correct.)

DATA

- i. Apply a sinusoidal input voltage with frequency = 1kHz, amplitude = 1V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to $V_{IN}(t)$ and $V_{OUT}(t)$; measurement window displaying amplitudes of $V_{IN}(t)$ and $V_{OUT}(t)$). Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes.

DATA

- ii. Apply a sinusoidal input voltage with frequency = 2kHz, amplitude = 1V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to $V_{IN}(t)$ and $V_{OUT}(t)$; measurement window displaying amplitudes of $V_{IN}(t)$ and $V_{OUT}(t)$). Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes.

DATA

- iii. Apply a sinusoidal input voltage with frequency = 500Hz, amplitude = 1V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to $V_{IN}(t)$ and $V_{OUT}(t)$; measurement window displaying amplitudes of $V_{IN}(t)$ and $V_{OUT}(t)$). Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes.

DEMO

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

Post-lab Exercises:

ANALYSIS

For the three cases in the lab procedures (1kHz sinusoid, 2kHz sinusoid, 500Hz sinusoid), calculate the expected output voltage based on your pre-lab analysis. Make a table comparing listing the measured and expected amplitudes of the output voltage, and the percent difference between the measured and expected amplitudes.

ANALYSIS

Comment briefly on the overall shapes of the expected vs. measured waveforms. Is the phase difference (the time delay between the input and output sinusoids) of the measured voltages consistent with what you would expect from your pre-lab analysis?