Laboratory 4: Differentiators and Integrators

ELEC ENG 2CJ4: Circuits and Systems
Instructor: Prof. Jun Chen

1 Objective

You will learn how to construct differentiators and integrators using Op-Amps.

2 Euqipment

The following equipments are used in this laboratory:

- DC voltage source with positive and negative output($\pm 10V$); Oscilloscope; Function signal generator
- Resistors: $1k\Omega \times 2$, $10k\Omega \times 2$, $100k\Omega \times 2$, $2.2M\Omega \times 1$
- Capacitors: $1nF(102) \times 1$, $100nF(104) \times 1$
- Op-Amp LM358

3 Pre-lab Exercises

A simple differentiator based on the RC Op-Amp circuit can be found in Figure 1. The ideal input-output relationship for this differentiator is given by

$$v_o(t) = -RC\frac{dv_i(t)}{dt}. \tag{1}$$

A simple integrator based on the RC Op-Amp circuit can be found in Figure 2. The ideal input-output relationship for this integrator is given by

$$v_o(t) = -\frac{1}{RC}\int_0^t v_i(x)dx + v_o(0). \tag{2}$$

3.1 Circuit Analysis

3.1.1 Analyze the differentiator

In practice, the output of the differentiator in Figure 1 is quite sensitive to the noise perturbation, especially in the high frequency regime (Can you explain why?). For this reason, we incorporate a series resistor at the input as shown in Figure 3 (Can you explain the role of this resistor).

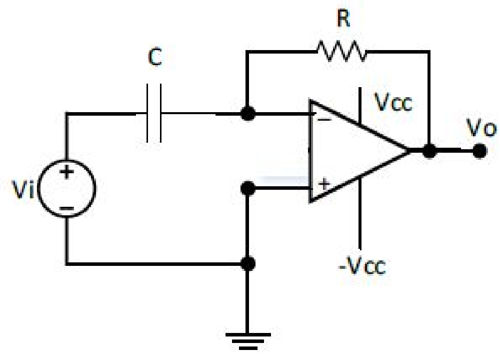

Figure 1: A simple differentiator based on the RC Op-Amp circuit

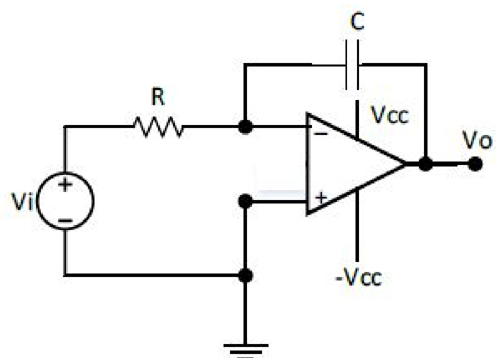

Figure 2: A simple integrator based on the RC Op-Amp circuit

- Assume $R_1 = 10K\Omega$, $R_2 = 1K\Omega$, $C_1 = 1nF(102)$, $V_{cc}+ = +10V$, and $V_{cc}- = -10V$. Consider two types of inputs: 1) the triangle wave, 2) the sine wave (both with frequency= $4KHz$ and peak-to-peak amplitude= $1V$). Analyze and plot the relationship between the input voltage and the output voltage.

3.1.2 Analyze the integrator

In practice, instead of using the integrator in Figure 2, we use the one shown in Figure 4, where a resistor parallelled to the feedback capacitor is added. The value of R_4 is chosen to be large enough so that the bias current going through this branch is negligible.

- Assume $R_3 = 10K\Omega$, $R_4 = 2.2M\Omega$, $C_3 = 100nF(104)$, $V_{cc}+ = +10V$, and $V_{cc}- = -10V$. Consider two types of inputs: 1) the triangle wave, 2) the sine wave (both with frequency= $1KHz$ and peak-to-peak amplitude=

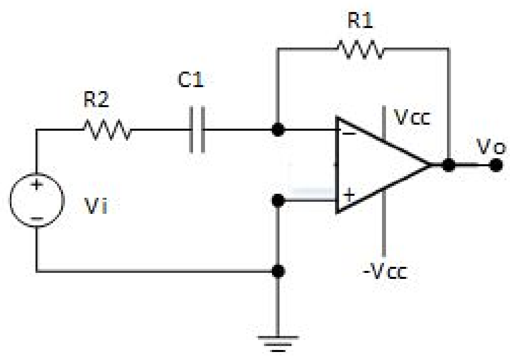

Figure 3: A practical differentiator

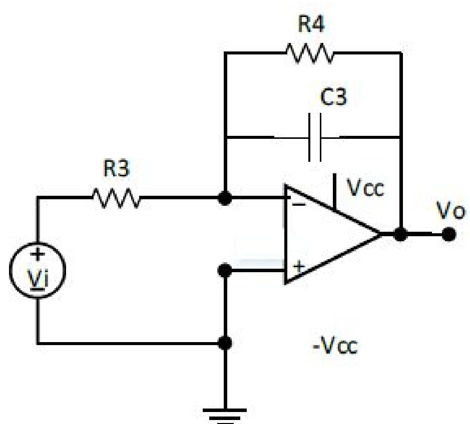

Figure 4: A practical integrator

$2V$). Analyze and plot the relationship between the input voltage and the output voltage.

4 Experiment

4.1 Differentiator

In this experiment, construct the differentiator in Figure 3.

- Use 1) the triangle wave, 2) the sine wave (both with frequency= $4KHz$ and peak-to-peak amplitude= $1V$) as the inputs, and measure the corresponding outputs.
- Compare your theoretical analysis with your measured responses.

- Set the frequency= $10KHz$ or higher. Check whether the differentiator functions properly, and explain your finding.
- Set the frequency= $10Hz$ or lower. Check whether the differentiator functions properly, and explain your finding.
- Include the relevant waveforms in your report.

4.2 Integrator

In this experiment, construct the integrator in Figure 4.

- Use 1) the triangle wave, 2) the sine wave (both with frequency= $1KHz$ and peak-to-peak amplitude= $2V$) as the inputs, and measure the corresponding outputs.
- Compare your theoretical analysis with your measured responses.
- Set the frequency= $10Hz$ or lower. Check whether the integrator functions properly, and explain your finding.
- Include the relevant waveforms in your report.

5 Report

In your write-up, present all the relevant circuits, the theoretical and experimental results as well as your analysis.