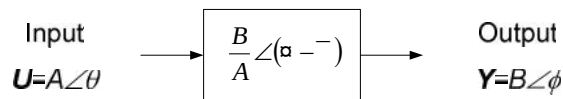
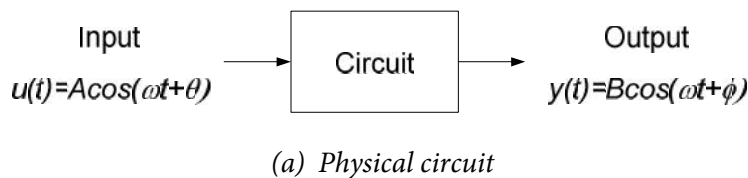


10.6.3: Inverting Voltage Amplifier

Overview:

In this lab assignment, we will be concerned with the steady-state response of electrical circuits to sinusoidal inputs. Figure 1(a) shows a block-diagram representation of the system. The input and output signals both have the same frequency, but the two signals can have different amplitudes and phase angles.

The analysis of the circuit of Figure 1(a) can be simplified by representing the sinusoidal signals as *phasors*. The phasors provide the amplitude and phase information of sinusoidal signals. By comparing the phasors representing the input and output signals, the effect of the circuit can be represented as an amplitude gain between the output and input signals and a phase difference between the output and input signals, as shown in Figure 1(b).



(b) Phasor representation of circuit input-output relationship.

Figure 1. Steady-state sinusoidal circuit analysis

In this lab assignment, we will measure the gain and phase responses of an inverting voltage amplifier circuit and compare these measurements with expectations based on analysis.

Before beginning this lab, you should be able to:

- Represent sinusoidal signals in phasor form
- Represent electrical circuit steady-state sinusoidal responses in phasor form
- Analyze operational amplifier-based circuits

After completing this lab, you should be able to:

- Measure phasor form of circuit steady-state sinusoidal response
- Measure input impedance of electrical circuit

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 this lab assignment, we will measure the frequency domain input-output relation governing the inverting voltage amplifier shown in Figure 1. The frequency domain input-output relation for the circuit of Figure 1 is:

$$\frac{V_{OUT}}{V_{IN}} = -\frac{1}{j\omega RC + 1} \quad (1)$$

So that the amplitude gain between the output and input is:

$$\left| \frac{V_{OUT}}{V_{IN}} \right| = -\frac{1}{\sqrt{(\omega RC)^2 + 1}} \quad (2)$$

and the phase difference between the output and input is:

$$\angle V_{OUT} - \angle V_{IN} = 180^\circ - \tan^{-1}\left(\frac{1}{\omega RC}\right) \quad (3)$$

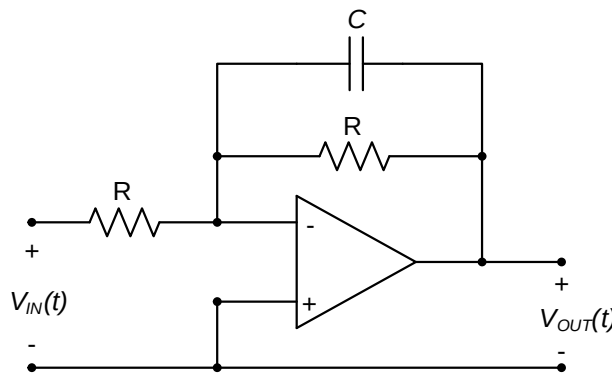


Figure 1. Inverting voltage amplifier.

Pre-lab:

ANALYSIS

- a. Show that equation (1) is the input-output relation for the circuit of Figure 1. Also verify equations (2) and (3) above.

ANALYSIS

- b. Determine the cutoff frequency of the circuit if $R = 10\text{k}\Omega$ and $C = 10\text{nF}$. Also determine the amplitude gain and the phase difference between the circuit's input and output voltages for the circuit¹. Also determine the input impedance for frequencies of:

- $\omega = \omega_c / 10$ (low frequency input)
- $\omega = 10\omega_c$ (high frequency input)
- $\omega = \omega_c$ (corner frequency input)

ANALYSIS

- c. Check your low and high frequency results in part (b) relative to your expectations based on the capacitor's low and high frequency behavior.

Lab Procedures:

Construct the circuit of Figure 2, using $R = 10\text{k}\Omega$ and $C = 10\text{nF}$.

DATA

- a. Use the waveform generator to apply a sinusoidal signal with 2V amplitude and 0V offset to the circuit. Set up the oscilloscope to measure both the input and output voltages. Measure the amplitudes of the input and output voltage signal, and the time delay between the input and output signal for inputs with the following frequencies:

- 100 Hz
- 1 KHz
- 5 KHz

DATA

- b. Record an image of the oscilloscope window, showing the signals $V_{\text{IN}}(t)$ and $V_{\text{OUT}}(t)$, for each of the above frequencies.

ANALYSIS

- c. Use your measurements to calculate the amplitude gain and phase difference of the circuit for the above three frequencies. Compare your measured results with your expectations based on the analysis you did in the pre-lab.

DEMO

- d. Demonstrate operation of your circuit to the TA and have them initial the appropriate page(s) of your lab notebook and the lab worksheet.

Hint:

Be sure to record all necessary data and any calculations you perform to obtain your results in your lab notebook. Appendix A of this lab assignment provides tips relative to gain and phase measurement of sinusoidal signals.

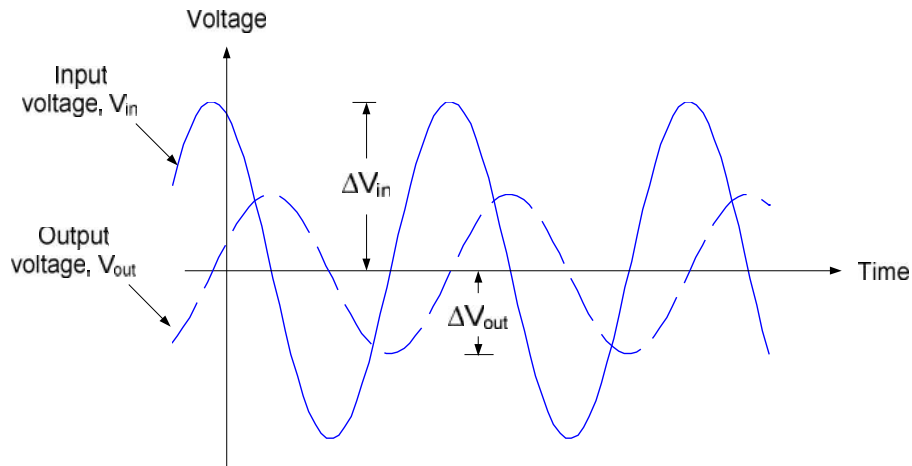
¹ Be sure to use units of radians/second for μ in equations (2) and (3)!

Appendix A – Measuring Gain and Phase:

The gain of a system at a particular frequency is the ratio of the magnitude of the output voltage to the magnitude of the input voltage at that frequency, so that:

$$\text{Gain} = \frac{\Delta V_{out}}{\Delta V_{in}}$$

where ΔV_{out} and ΔV_{in} can be measured from the sinusoidal input and output voltages as shown in the figure below.



The phase of a system at a particular frequency is a measure of the time shift between the output and input voltage at that frequency, so that:

$$\text{Phase} = \frac{\Delta T}{T} \times 360^\circ$$

where ΔT and T can be measured from the sinusoidal input and output voltages as shown in the figure below.

