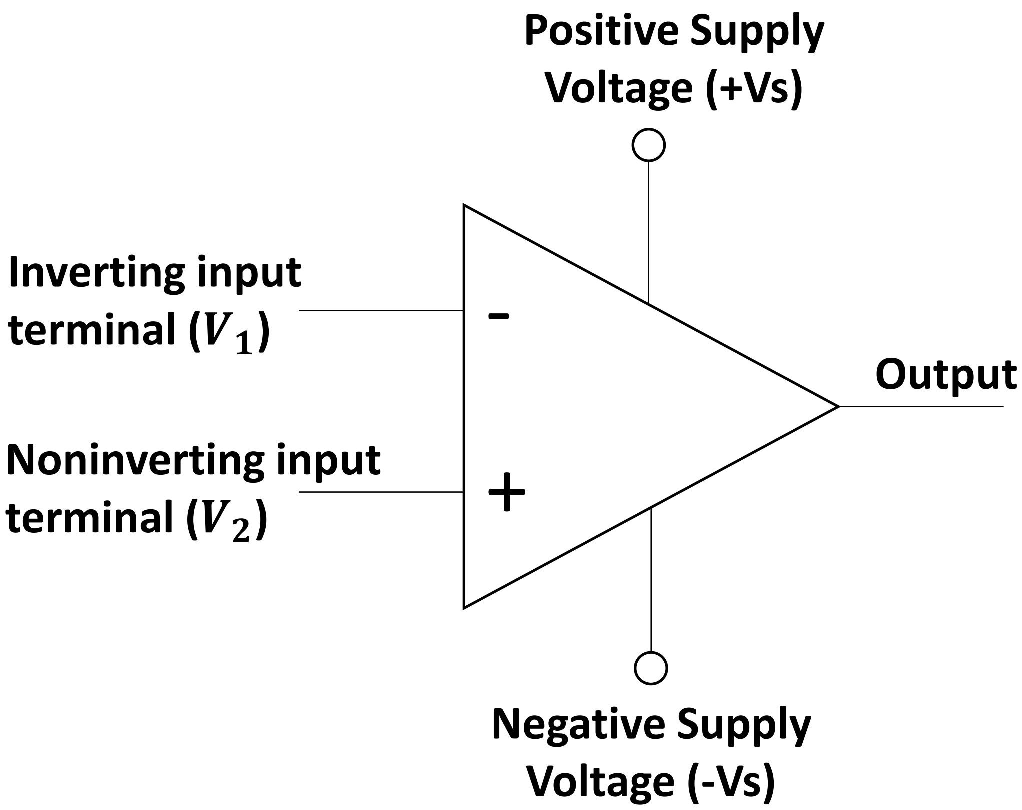
Lab 2: Inverting and Noninverting OP-Amp Circuits

EE316-08 Spring 2021

- **Purpose:** The goal of this laboratory is to examine inverting and noninverting Op-Amp configurations for both DC and AC inputs.

Operational Amplifier (Op-amp)



- A typical op-amp consists of an inverting input, a noninverting input, two dc power supply leads (positive and negative), and the output.
- Generally, dc power supply leads are not included in circuit schematics, but we assume that they are being used.

'Ideal' Operational Amplifier

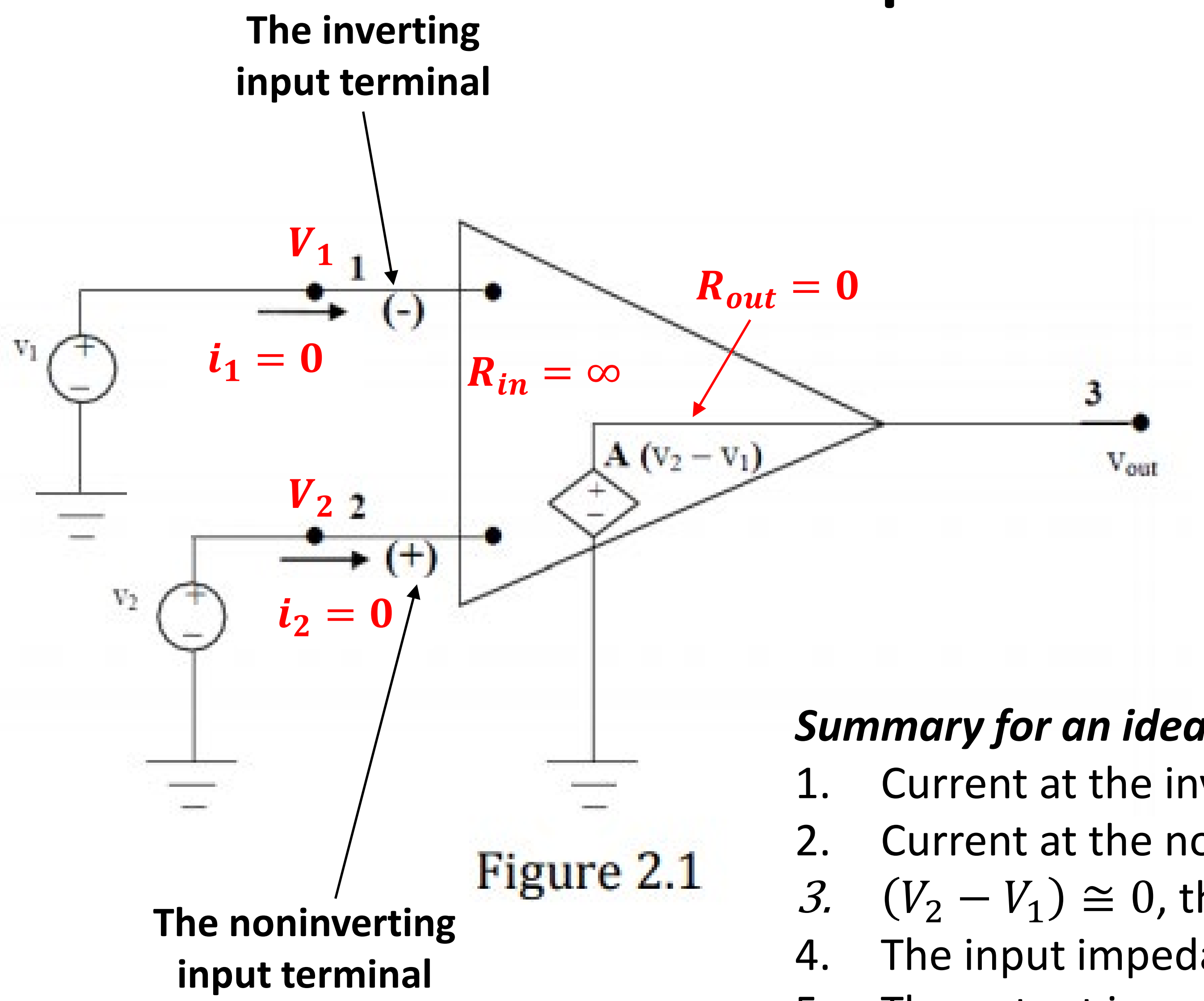


Figure 2.1

$$V_{out} = A(V_2 - V_1)$$

where:

- A is a constant called the open-loop gain

<u>** For an **ideal amplifier,** A is infinite*</u>

$$(V_2 - V_1) = \frac{V_{out}}{A}$$

$$(V_2 - V_1) \cong 0$$

$$V_2 = V_1$$

Summary for an ideal op-amp:

1. Current at the inverting input terminal is equal to zero ($i_1 = 0$)
2. Current at the noninverting input terminal is equal to zero ($i_2 = 0$)
3. $(V_2 - V_1) \cong 0$, therefore, $V_2 = V_1$
4. The input impedance of an ideal op-amp is infinite ($R_{in} = \infty$)
5. The output impedance of an ideal op-amp is zero ($R_{out} = 0$)

Inverting Amplifier

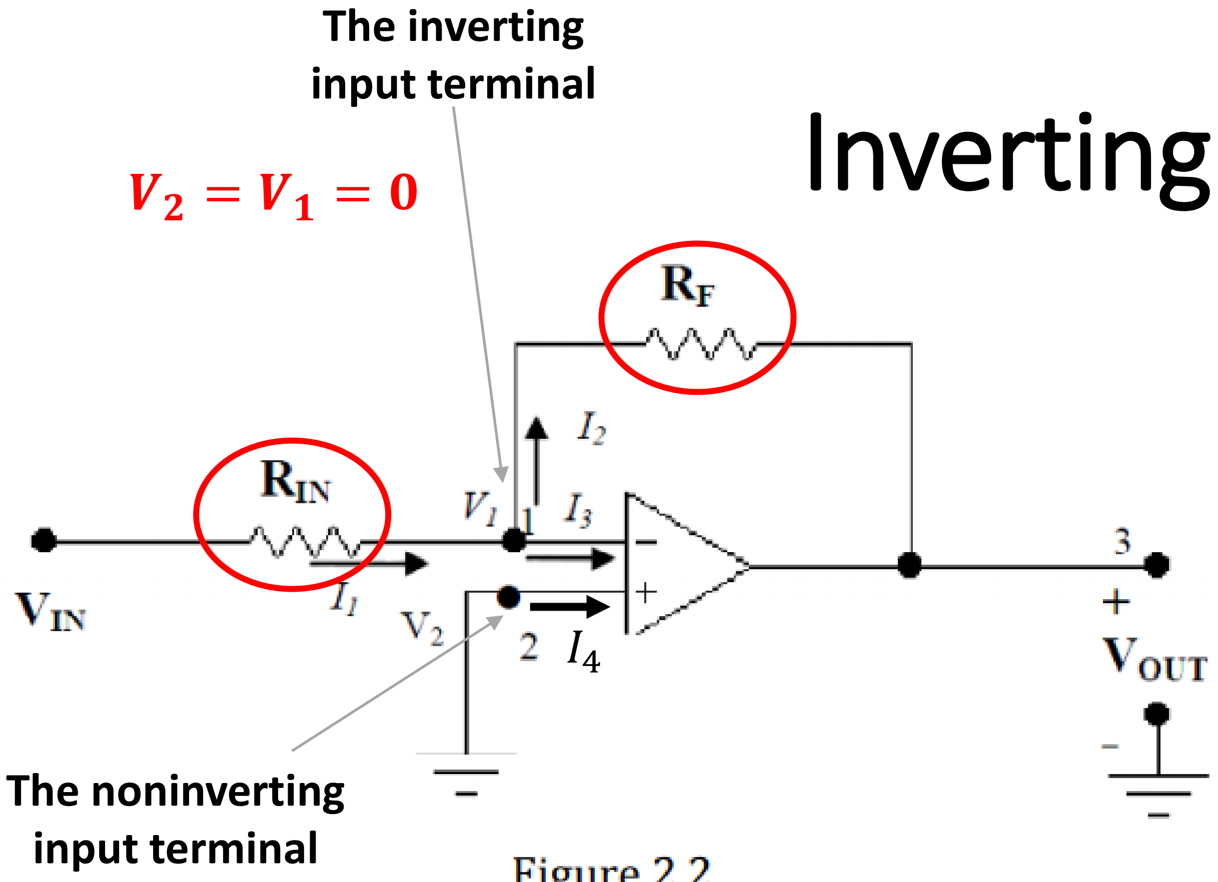


Figure 2.2

$$G = \frac{V_{out}}{V_{in}}$$

where:

- G is a constant called the closed-loop gain

KCL at node 1: $I_1 = I_2 + I_3$

$$\frac{V_{IN} - V_1}{R_{IN}} = \frac{V_1 - V_{OUT}}{R_F} + 0$$

$$\frac{V_{IN}}{R_{IN}} = \frac{-V_{OUT}}{R_F}$$

$$\frac{V_{OUT}}{V_{IN}} = \frac{-R_F}{R_{IN}} = G$$

Summary for an ideal op-amp:

1. Current at the inverting input terminal is equal to zero ($I_3 = 0$)
2. Current at the noninverting input terminal is equal to zero ($I_4 = 0$)
3. $(V_2 - V_1) \cong 0$, therefore, $V_2 = V_1$
4. The input impedance of an ideal op-amp is infinite ($R_{in} = \infty$)
5. The output impedance of an ideal op-amp is zero ($R_{out} = 0$)

Inverting Amplifier

$$V_2 = V_1 = 0$$

$$\frac{V_{OUT}}{V_{IN}} = \frac{-R_F}{R_{IN}} = G$$

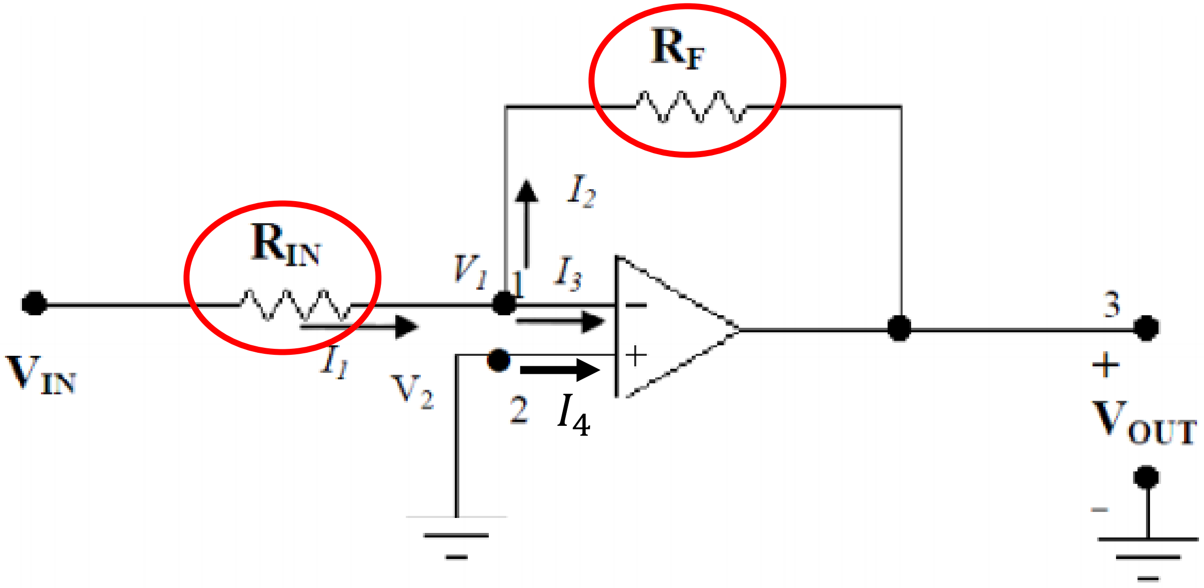
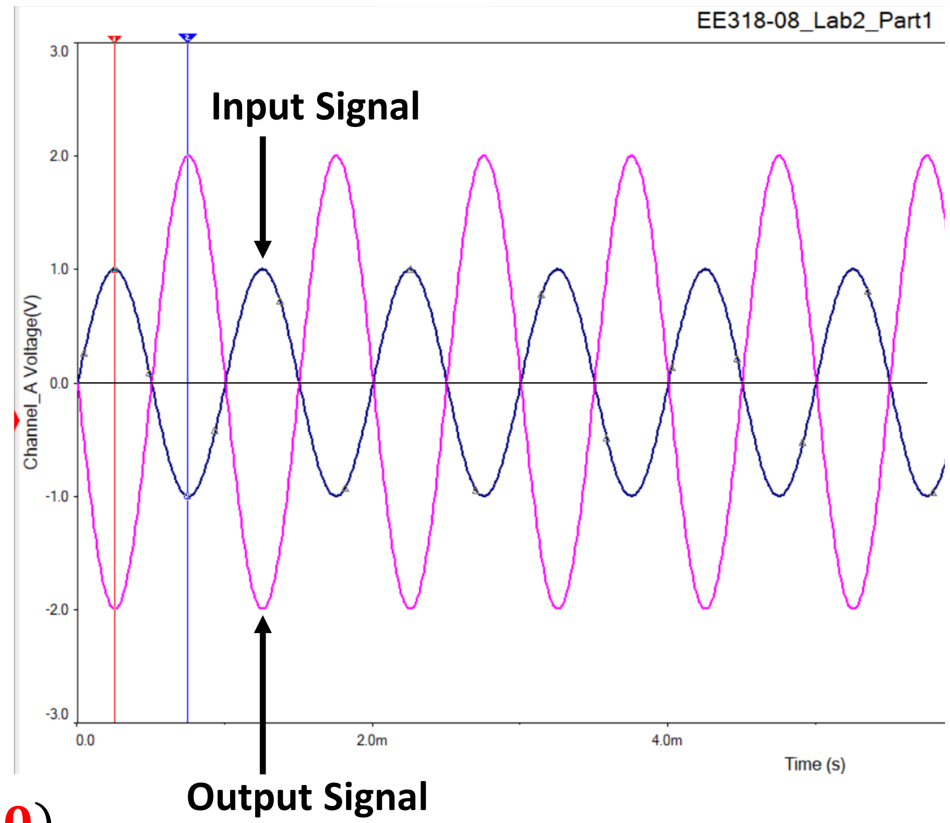


Figure 2.2



*** Output signal is completely out of phase with respect to the input signal. ***

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Non-Inverting Amplifier

$\boldsymbol{V_2 = V_{IN} = V_1}$

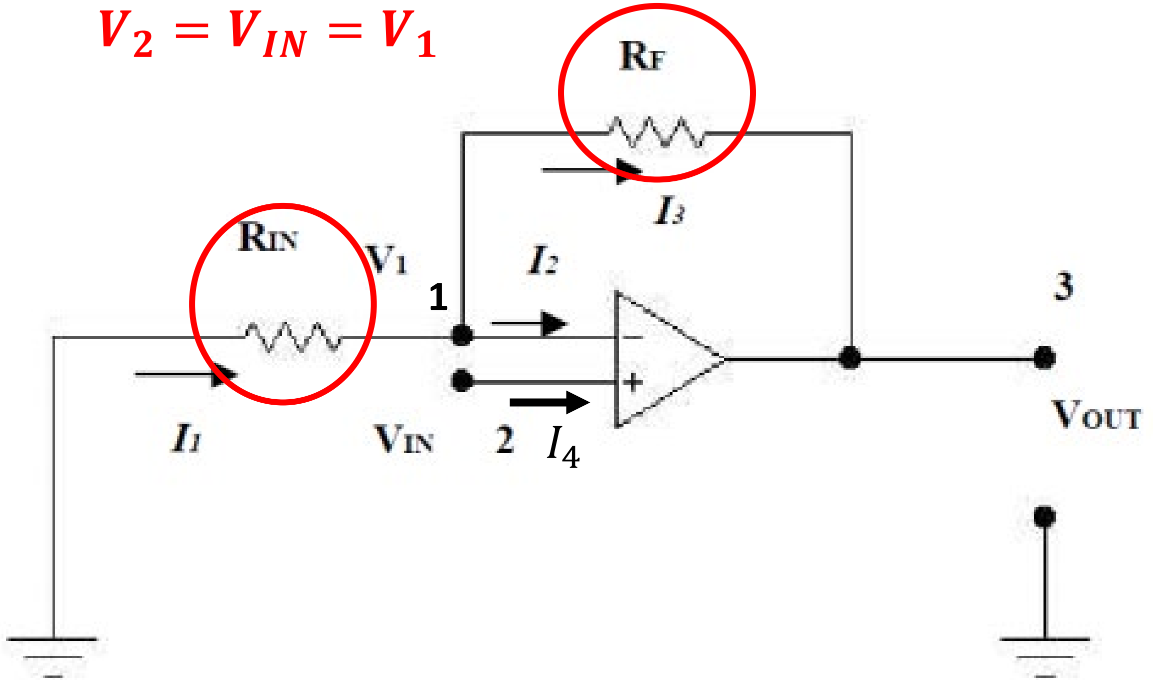

Figure 2.3

Recall, $\quad \boldsymbol{G = \frac{V_{out}}{V_{in}}}$

KCL at node 1: $\quad I_1 = I_2 + I_3$

$$\frac{0 - V_1}{R_{IN}} = 0 + \frac{V_1 - V_{OUT}}{R_F}$$

$$\frac{-V_{IN}}{R_{IN}} = \frac{V_{IN} - V_{OUT}}{R_F}$$

$$\frac{V_{OUT}}{R_F} = V_{IN}\left(\frac{R_{IN} + R_F}{R_F \cdot R_{IN}}\right)$$

$$\boldsymbol{\frac{V_{OUT}}{V_{IN}} = \frac{R_{IN} + R_F}{R_{IN}} = 1 + \frac{R_F}{R_{IN}} = G}$$

Summary for an ideal op-amp:

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2. Current at the noninverting input terminal is equal to zero ($\boldsymbol{I_4 = 0}$)
3. $(V_2 - V_1) \cong 0$, therefore, $V_2 = V_1$
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5. The output impedance of an ideal op-amp is zero ($\boldsymbol{R_{out} = 0}$)

Non-Inverting Amplifier

$$\frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_{IN}} = G$$

$V_2 = V_{IN} = V_1$

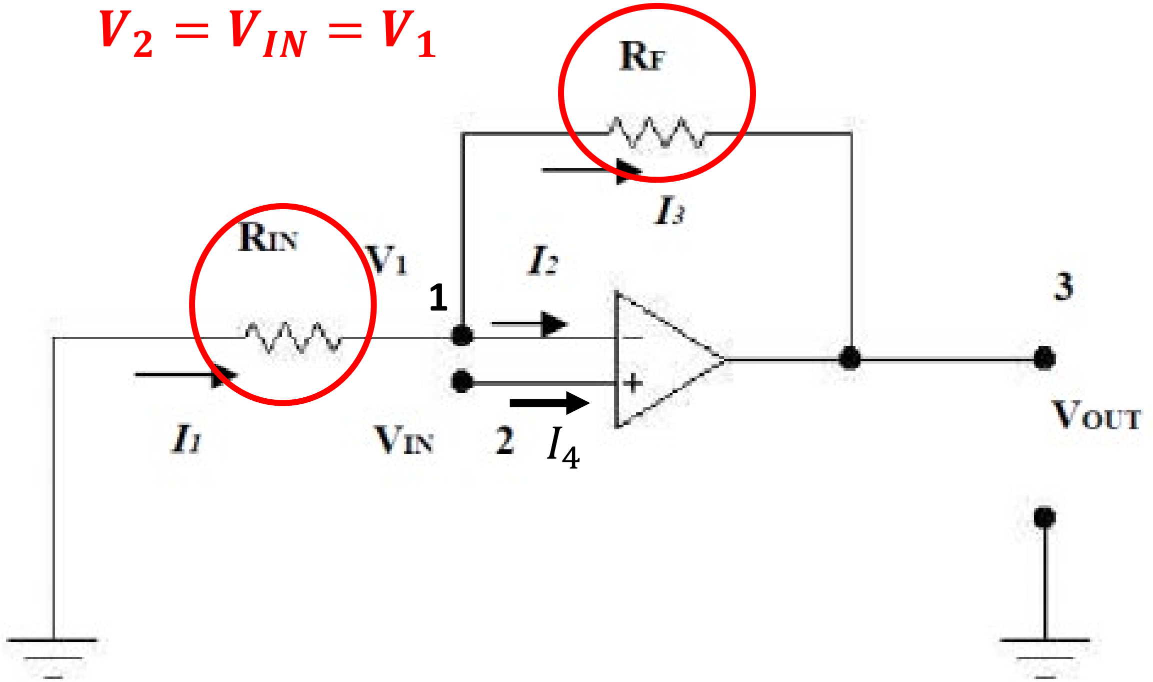
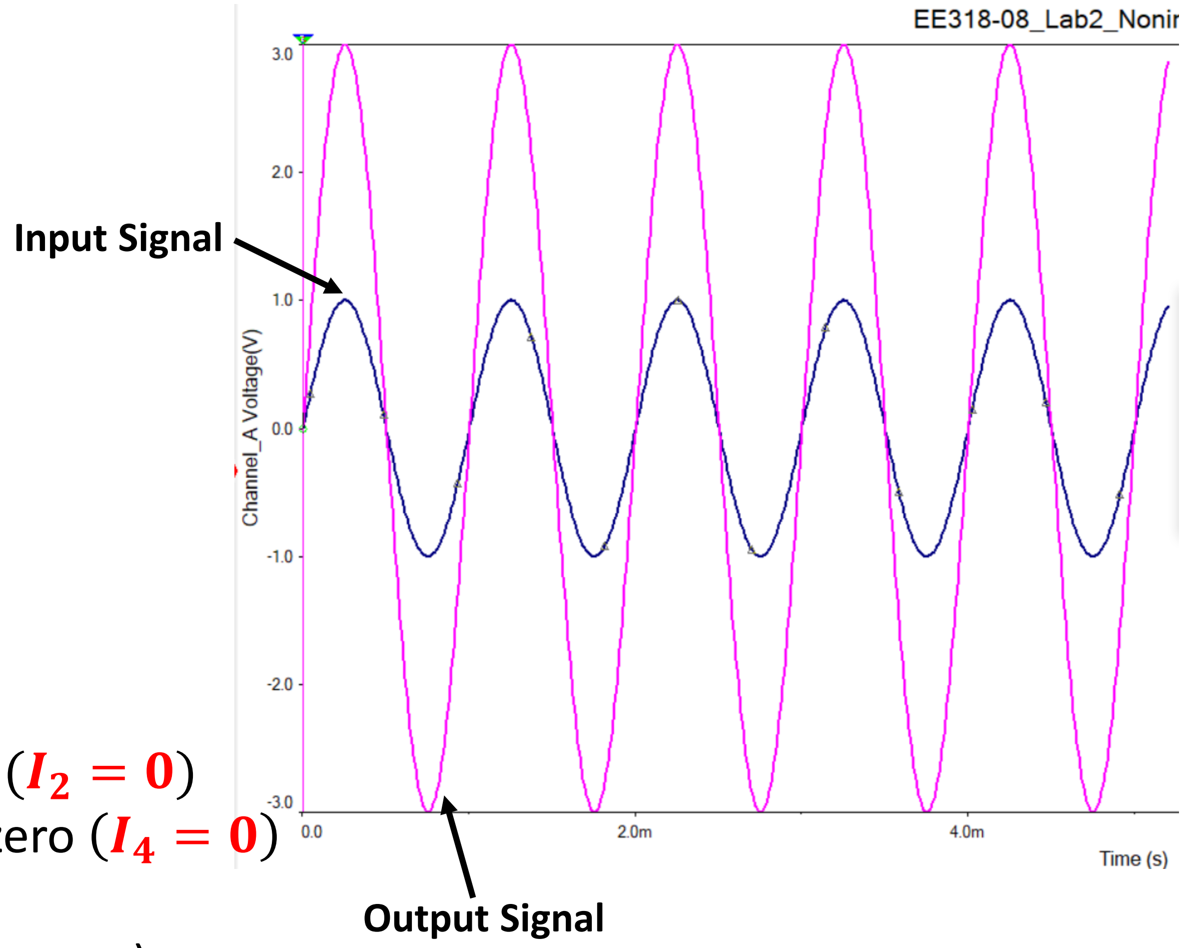


Figure 2.3



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4. The input impedance of an ideal op-amp is infinite ($R_{in} = \infty$)
5. The output impedance of an ideal op-amp is zero ($R_{out} = 0$)

*** Output signal is in phase with respect to input signal. ***

Calculations: Table 2.1 (Inverting Amplifier)

V_{INpp} (V)	R_{IN} (kΩ)	R_F (kΩ)	V_{OUTpp} (V)	Gain (V/V)	V_{OUTrms} (V)
2	1	0.5	1	-0.5	0.353
		1	2	-1	0.706

Note: V peak to peak is the distance from the lowest negative amplitude to the highest positive amplitude of the AC signal.

$$G = \frac{V_{OUT}}{V_{IN}} = \frac{-R_F}{R_{IN}}$$

$$G = \frac{-0.5}{1} = -0.5$$

$$G = \frac{-1}{1} = -1$$

$$V_{OUTpp} = V_{INpp} \cdot G$$

$$V_{OUTpp} = |(2)(-0.5)| = 1$$

$$V_{OUTpp} = |(2)(-1)| = 2$$

$$V_{OUTrms} = \frac{1}{2\sqrt{2}} \cdot V_{OUTpp}$$

$$V_{OUTrms} = (0.353)(1) = 0.353$$

$$V_{OUTrms} = (0.353)(2) = 0.706$$

Calculations: Table 2.2 (Non-Inverting Amplifier)

V_{INpp} (V)	R_{IN} (kΩ)	R_F (kΩ)	V_{OUTpp} (V)	Gain (V/V)	V_{OUTrms} (V)
2	1	0.5	3.0	1.5	1.059
		1	4.0	2	1.412

$$G = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_{IN}}$$

$$G = 1 + \frac{0.5}{1} = 1.5$$

$$G = 1 + \frac{1}{1} = 2$$

$$V_{OUTpp} = V_{INpp} \cdot G$$

$$V_{OUTpp} = (2)(1.5) = 3.0$$

$$V_{OUTpp} = (2)(2) = 4.0$$

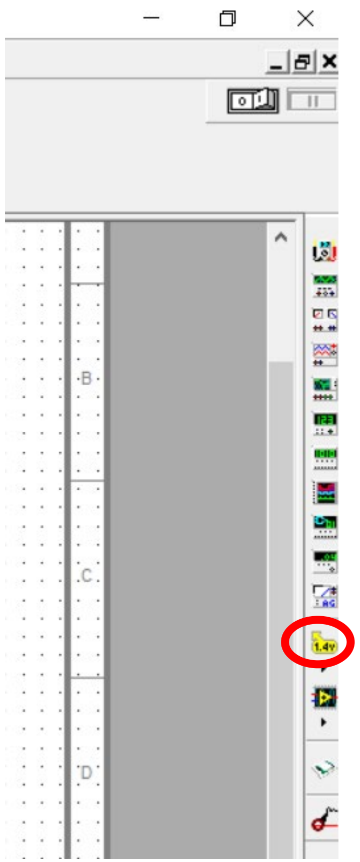
$$V_{OUTrms} = \frac{1}{2\sqrt{2}} \cdot V_{OUTpp}$$

$$V_{OUTrms} = (0.353)(3.0) = 1.059$$

$$V_{OUTrms} = (0.353)(4.0) = 1.412$$

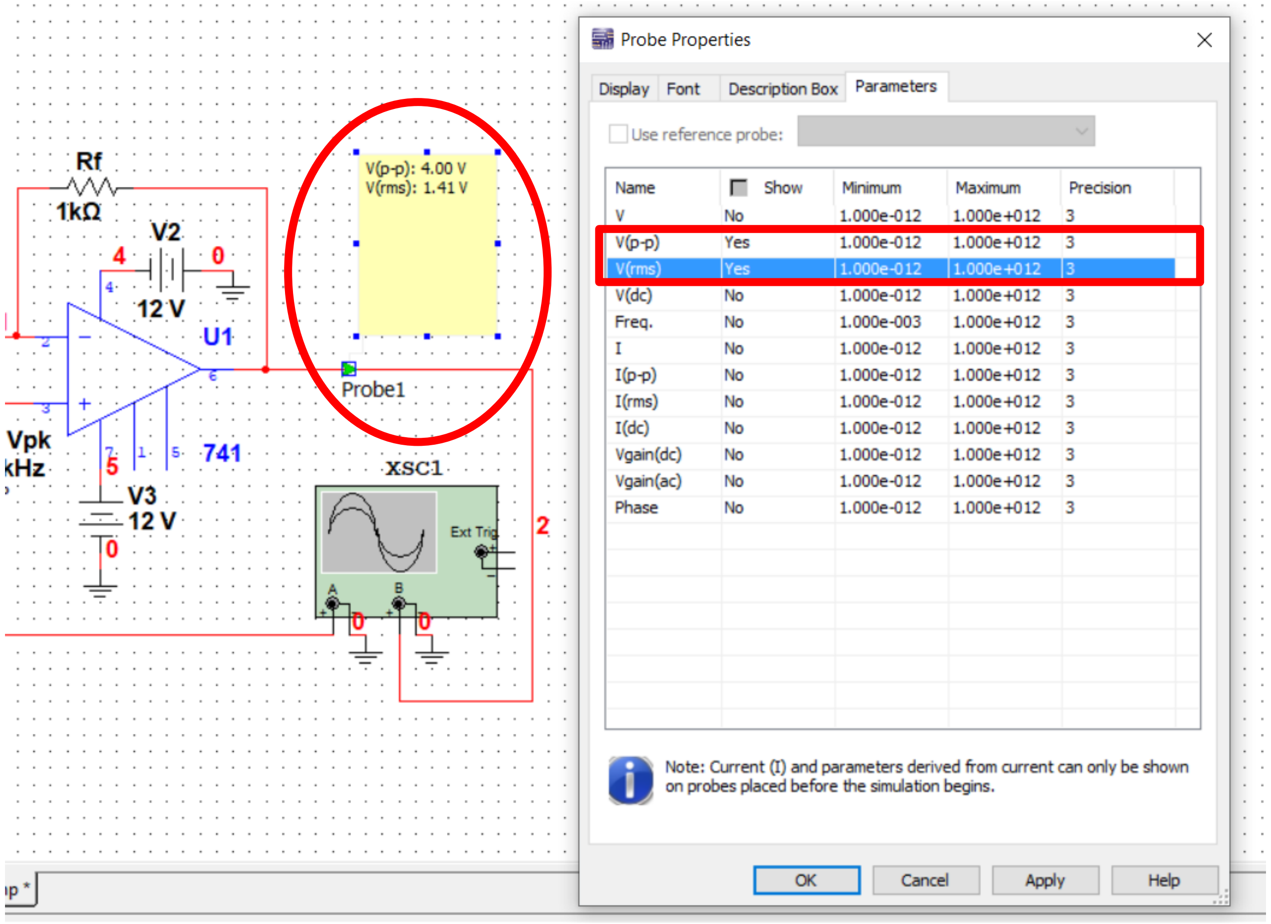
Multisim: Measure V_{OUTpp} and V_{OUTrms}

1. Select **measurement probe**



2. Place the probe in the desired area

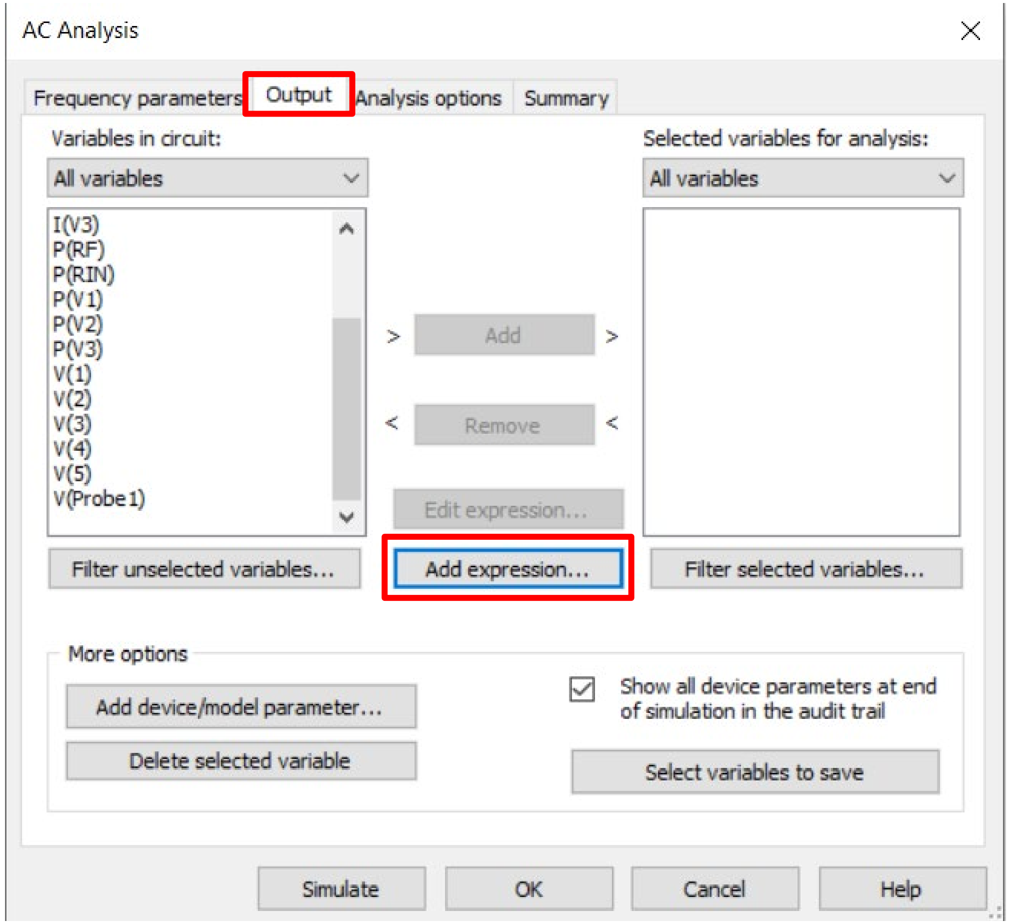
3. Right click at the probe and select property



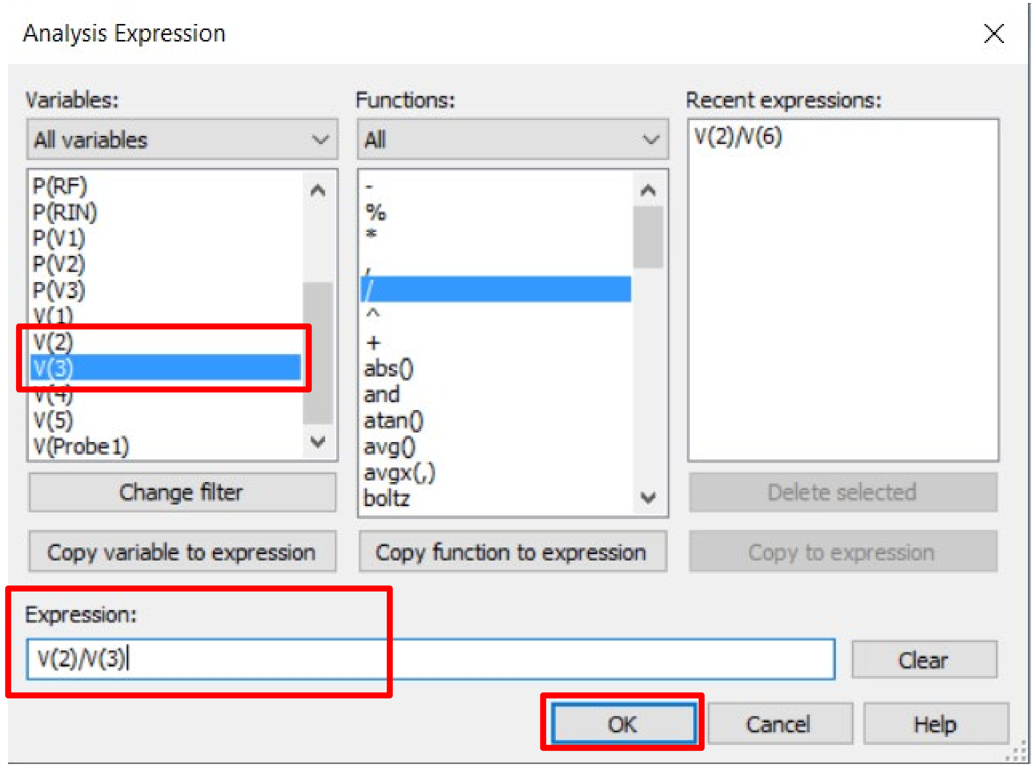
Multisim: Measure Gain

1. Click **Simulate** -> **Analyses** -> **AC Analysis…**

2. Select **Output** -> **Add expression**



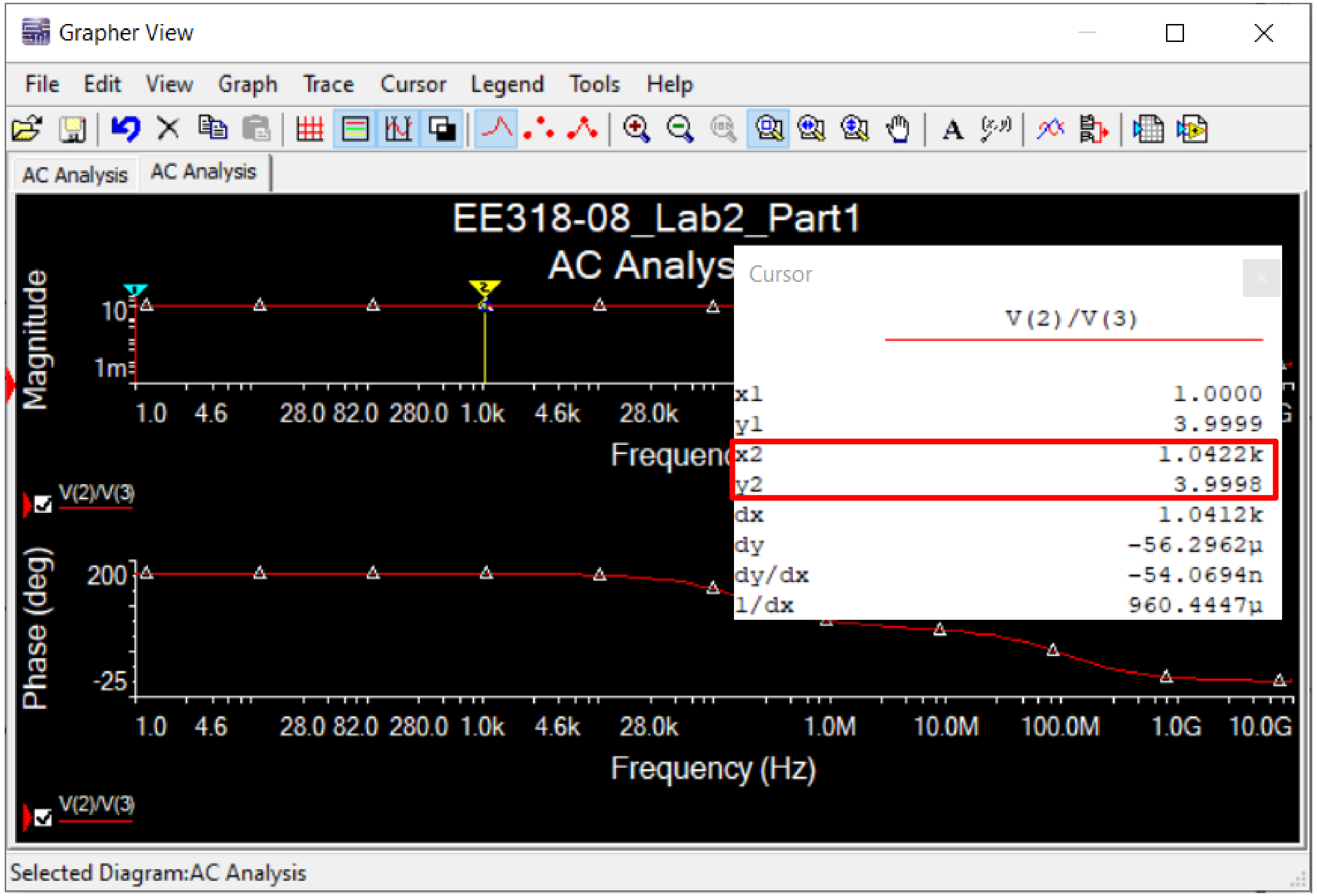
3. Make sure you select $\frac{V_{OUT}}{V_{IN}}$ -> **OK** -> **Simulate**



Note: V_{OUT} is V(2) and V_{IN} is V(3) in this case.

Multisim: Measure Gain (cont.)

4. Move **Cursor** to the desired location. In this case, when x is equal to 1 kHz, y is equal to 3.9998. Note: y is $\frac{V_{OUT}}{V_{IN}}$



Summary

- Lab 2 Report & Pre-lab 3 are due on Tuesday 2nd February 2021 by midnight.

- Analyze Fig. 2.2-2.3 and complete Table 2.1-2.2
  - Calculations
  - Simulation
  - ~~Experimental results~~