EXPERIMENT NO. 3

DATE: : -- / -- /----

DIFFERENCE AMPLIFIER AND INSTRUMENTATION AMPLIFIER

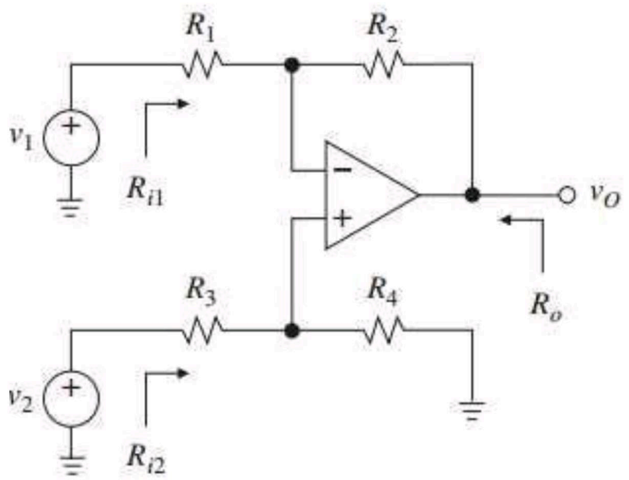
AIM

To design and setup

1 A Difference amplifier using op-amp IC 741 for a differential gain of 10
2. An instrumentation amplifier using op-amp IC 741 for a differential gain of 100

THEORY

Difference Amplifier



A op-amp based difference amplifier has two inputs and one output.

The output voltage is given by, $v_O = \frac{R_2}{R_1}\left(\frac{1+R_1/R_2}{1+R_3/R_4} \times v_2 - v_1\right)$

<u>Special case</u>: When $\frac{R_3}{R_4} = \frac{R_1}{R_2}$, we have, $v_O = \frac{R_2}{R_1}(v_2 - v_1)$ i.e., The output is proportional to the true difference of the inputs

However, in practice, there will also be a common mode component in the output due to some mismatches in the resistance values and the non-ideal parameters of the op-amp

Hence $v_O = A_{dm}v_{dm} + A_{cm}v_{cm}$ where $v_{dm} = v_2 - v_1$ and $v_{cm} = \frac{v_1+v_2}{2}$

In the ideal case with balanced and matched resistors: $A_{dm} = \frac{R_2}{R_1}$ and $A_{cm} = 0$

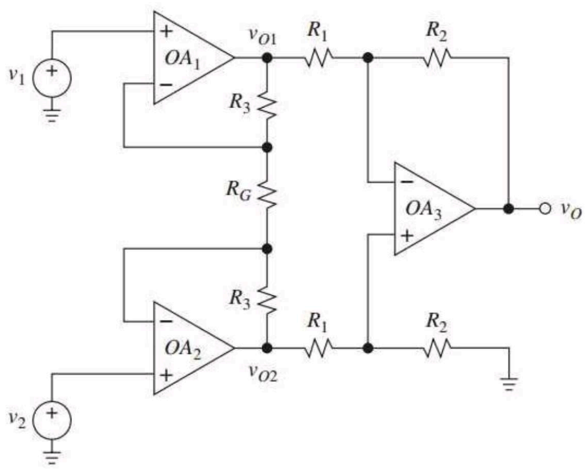
Instrumentation Amplifier

An instrumentation amplifier (IA) is a difference amplifier with:

- Extremely high(ideally infinite) common-mode and differential mode input impedances
- Very low (ideally zero) output impedance
- Accurate and stable gain and
- Extremely high CMRR

The IA is used to accurately amplify a low-level signal in the presence of a large common-mode component, such as a transducer output in process control and biomedicine. IAs find widespread application in test and measurement instrumentation - hence the name

A difference amplifier can meet the last 3 specifications. But it fails to meet the first specification. This is solved by preceding it with two high-input-impedance buffers which gives us the triple-op-amp IA as shown below.



The expression for output voltage of the above IA: $v_O = \left(1 + \frac{2R_3}{R_G}\right)\left(\frac{R_2}{R_1}\right)(v_2 - v_1)$

DESIGN

Difference Amplifier

Let $A_{dm} = \frac{R_2}{R_1} = 10;$

Choose $R_1 = R_3 = 1k$; and $R_2 = R_4 = 10k$;

Instrumentation Amplifier

Let $A_{dm} = \left(1 + \frac{2R_3}{R_G}\right)\left(\frac{R_2}{R_1}\right) = 100;$

Choose $R_1 = 1k, R_2 = 10k, R_3 = 10k$

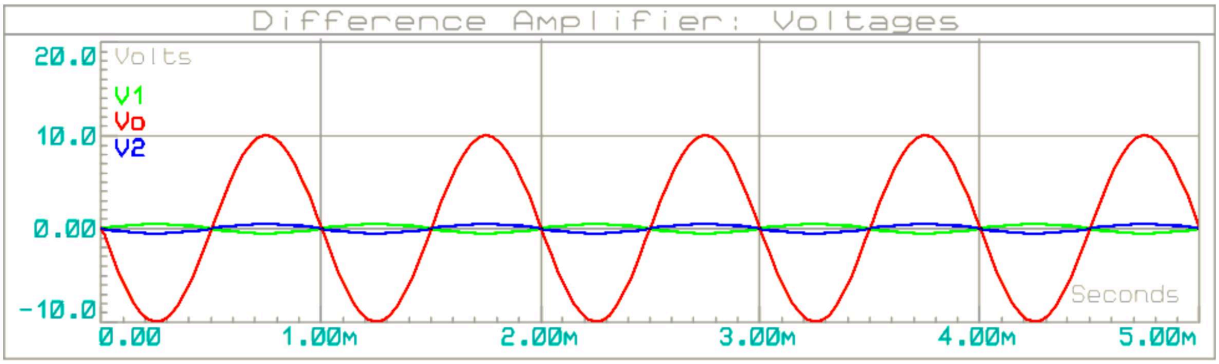
Then $R_G = 2.2k$ std

PROCEDURE

Difference Amplifier

- Setup the circuit as shown and provide supply voltages to the op-amp
- For measuring A_{cm}, give $v_1 = v_2 = 10Vpp$ sine wave of $200Hz$ frequency
- Now $v_{CM} = \frac{v_1+v_2}{2} = 10vpp$ sinewave and $v_{dm} = v_2 - v_1 = 0V$
- Measure $v_O(pp)$ and compute $A_{cm} = \frac{v_O}{v_{cm}}$
- For measuring A_{dm}, give $v_1 = -v_2 = 1Vpp$ sine wave of $200Hz$ frequency (Use an inverting amplifier of gain -1 to obtain v_2 from v_1)
- Now $v_{CM} = \frac{v_1+v_2}{2} = 0$ and $v_{dm} = v_2 - v_1 = 2Vpp$ sine wave of $200Hz$ frequency
- Measure $v_O(pp)$ and compute $A_{dm} = \frac{v_O}{v_{dm}}$
- Calculate $CMRR = 20\log_{10}\left|\frac{A_{dm}}{A_{cm}}\right|$

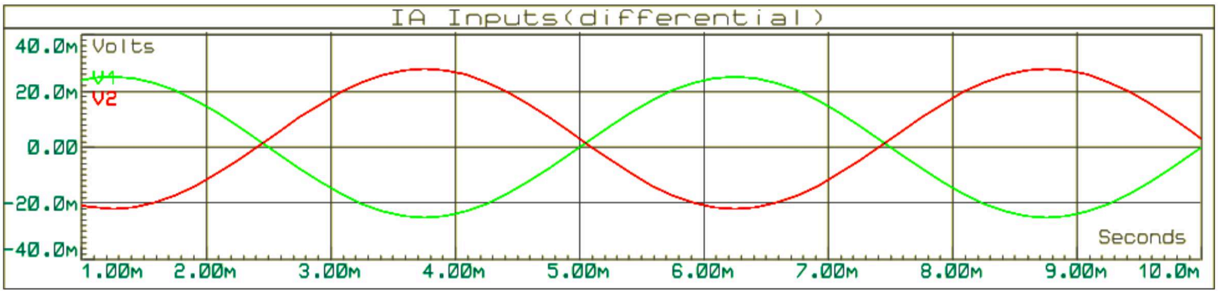
DA: Expected Waveforms: Measuring Differential mode gain

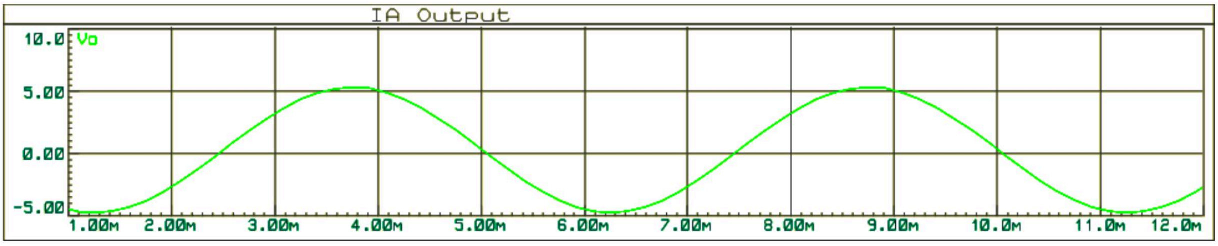


Instrumentation Amplifier

- Setup the circuit as shown and provide supply voltages to the op-amp
- For measuring A_{cm}, give $v_1 = v_2 = 10Vpp$ sine wave of $200Hz$ frequency
- Now $v_{CM} = \frac{v_1+v_2}{2} = 10vpp$ sinewave and $v_{dm} = v_2 - v_1 = 0V$
- Measure $v_O(pp)$ and compute $A_{cm} = \frac{v_O}{v_{cm}}$
- For measuring A_{dm}, give $v_1 = -v_2 = 50mVpp$ sine wave of $200Hz$ frequency (Use an inverting amplifier of gain -1 to obtain v_2 from v_1)
- Now $v_{CM} = \frac{v_1+v_2}{2} = 0$ and $v_{dm} = v_2 - v_1 = 100mVpp$ sine wave of $200Hz$ frequency
- Measure $v_O(pp)$ and compute $A_{dm} = \frac{v_O}{v_{dm}}$
- Calculate $CMRR = 20\log_{10}\left|\frac{A_{dm}}{A_{cm}}\right|$

IA: Expected Waveforms: Measuring Differential mode gain





Results:

1 A difference amplifier was designed and setup using op-amp IC 741 for a differential gain of 10

- Observed Differential Gain = -------
- Observed Common Mode Gain = -------
- CMRR = -------

2. An instrumentation amplifier was designed and setup using three IC 741 op-amps for a differential gain of 100

- Observed Differential Gain = -------
- Observed Common Mode Gain = -------
- CMRR = -------