Difference Instrumentation Amplifier Worksheet – fall 2022

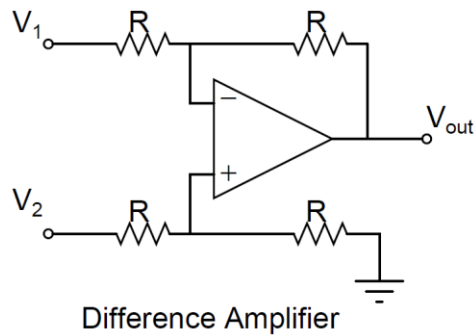

Difference Amplifier

Figure 1. Classic difference amplifier Notice that the "bottom" side has V2 <u>connected to ground</u> through 2 resistors. Power connections are not shown.

1. Figure 1 shows an op-amp configured as a ***difference amplifier.*** It is called a difference amplifier because it computes the difference between the two inputs, V_1 and V_2. Show that:

$$V_{out} = V_2 - V_1$$

2. Figure 2 shows a difference amplifier, but now there is a reference potential introduced at the 'bottom right', as indicated by red arrow. This connection is not necessarily grounded. Show that the input-output relation is given by:

$$V_{out} = (V_2 - V_1) + V_{ref}$$

In other words, it computes the difference of two inputs, but now the output is centered around the reference potential Vref.
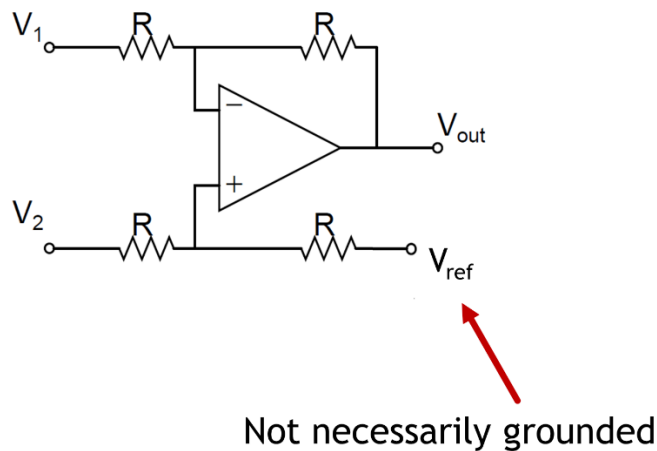

Not necessarily grounded

Figure 2. Difference amp with reference potential.

3. List 2 or more practical shortcomings with using the difference amps shown in Figures 2 and 3?

4. The ***instrumentation amplifier*** was invented to solve the issues enumerated in #3 above. This configuration got its name because it was so useful for measuring signals from a variety of lab instruments—strain gauges, temperature gauges, biomedical equipment, etc. Figure 3 shows the internals of an AD623 instrumentation amplifier.
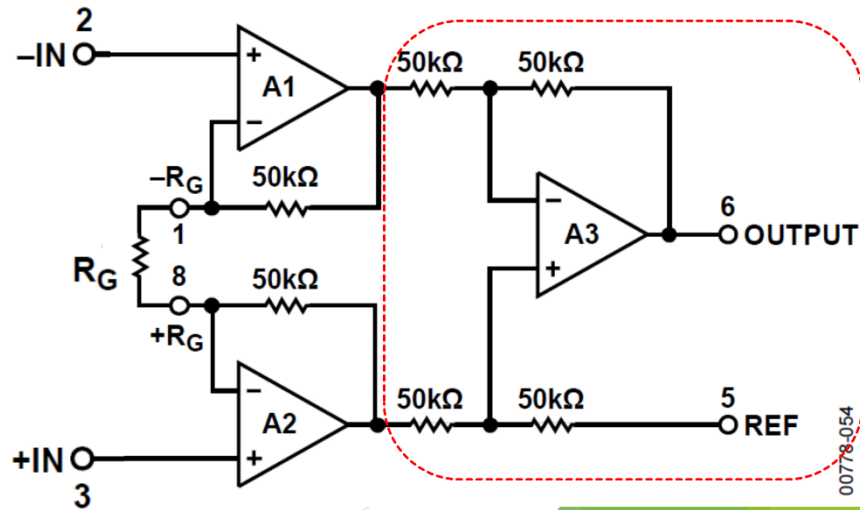

Figure 3. Simplified schematic for AD623 instrumentation amplifier. The two inputs are labed +IN (pin 3) and –IN (pin 2), respectively.

5. Show that this instrumentation amp has an input-output-relation given by:

$$V_{out} = G(V_{in}^+ - V_{in}^-) + V_{ref}$$

Where the ***voltage gain*** is given by:

$$G = 1 + \frac{100k}{R_G}$$

(Do not confuse G here with the decibel gain...only so many letters in the alphabet/unfortunate choice for variable naming...)

6. Imagine you are building a design (for strain gauge or even EMG circuitry) where you want have a single supply system powering at +5V and GND. Therefore, you want the output centered around 2.5V. You also want the voltage gain set for G = 100. Show how you will achieve this in practice, choosing appropriate components values and using a ***rail splitter***, as necessary.

Take home message: instrumentation amps appear in many measurement instruments because we often need to measure and amplify a difference in voltages!