

Two op amp instrumentation amplifier circuit

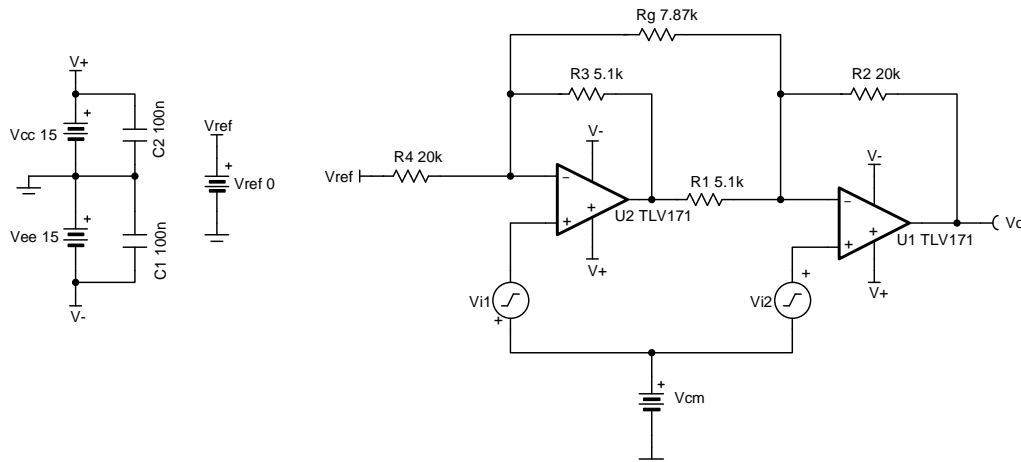
Design Goals

Input $V_{IDiff}(V_{i2} - V_{i1})$		Output		Supply		
V_{IDiff_Min}	V_{IDiff_Max}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}	V_{ref}
+/-1V	+/-2V	-10V	+10V	15V	-15V	0V

V_{cm}	Gain Range
+/-10V	5V/V to 10V/V

Design Description

This design amplifies the difference between V_{i1} and V_{i2} and outputs a single ended signal while rejecting the common-mode voltage. Linear operation of an instrumentation amplifier depends upon the linear operation of its primary building block: op amps. An op amp operates linearly when the input and output signals are within the device's input common-mode and output-swing ranges, respectively. The supply voltages used to power the op amps define these ranges.



Design Notes

1. R_g sets the gain of the circuit.
2. High-value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit.
3. The ratio of R_4 and R_3 set the minimum gain when R_g is removed.
4. Ratios of R_2/R_1 and R_4/R_3 must be matched to avoid degrading the instrumentation amplifier's DC CMRR and ensuring the V_{ref} gain is 1V/V.
5. Linear operation is contingent upon the input common-mode and the output swing ranges of the discrete op amps used. The linear output swing ranges are specified under the A_{o1} test conditions in the op amps datasheets.

Design Steps

1. Transfer function of this circuit.

$$V_o = V_{iDiff} \times G + V_{ref} = (V_{i2} - V_{i1}) \times G + V_{ref}$$

when $V_{ref} = 0$, the transfer function simplifies to the following equation:

$$V_o = (V_{i2} - V_{i1}) \times G$$

where G is the gain of the instrumentation amplifier and $G = 1 + \frac{R_4}{R_3} + \frac{2R_2}{R_g}$

2. Select R_4 and R_3 to set the minimum gain.

$$G_{min} = 1 + \frac{R_4}{R_3} = 5 \frac{V}{V}$$

Choose $R_4 = 20k\Omega$

$$G_{min} = 1 + \frac{20k\Omega}{R_3} = 5 \frac{V}{V}$$

$$R_3 = \frac{R_4}{5-1} = \frac{20k\Omega}{4} = 5k\Omega \rightarrow R_3 = 5.1k\Omega \text{ (Standard Value)}$$

3. Select R_1 and R_2 . Ensure that R_1/R_2 and R_3/R_4 ratios are matched to set the gain applied to the reference voltage at $1V/V$.

$$\frac{V_{o-ref}}{V_{ref}} = \left(-\frac{R_3}{R_4}\right) \times \left(-\frac{R_2}{R_1}\right) = \frac{R_3 \times R_2}{R_4 \times R_1} = 1 \frac{V}{V}$$

$$\frac{R_2}{R_1} = \frac{R_4}{R_3} \rightarrow R_1 = R_3 = 5.1k\Omega \text{ and } R_2 = R_4 = 20k\Omega \text{ (Standard Value)}$$

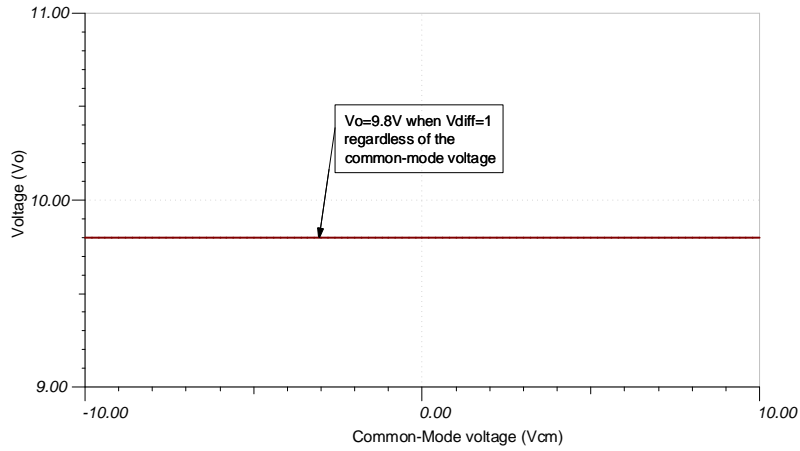
4. Select R_g to meet the desired maximum gain $G = 10V/V$.

$$G = 1 + \frac{R_4}{R_3} + \frac{2R_2}{R_g} = 1 + \frac{20k\Omega}{5.1k\Omega} + \frac{2 \times 20k\Omega}{R_g} = 10 \frac{V}{V}$$

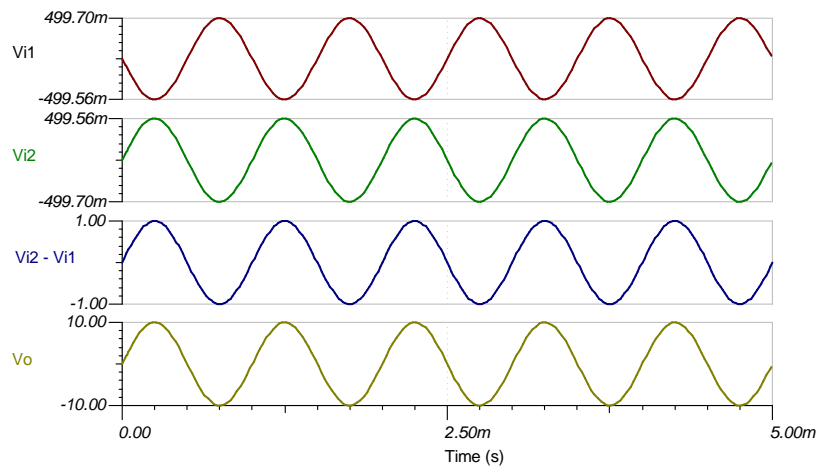
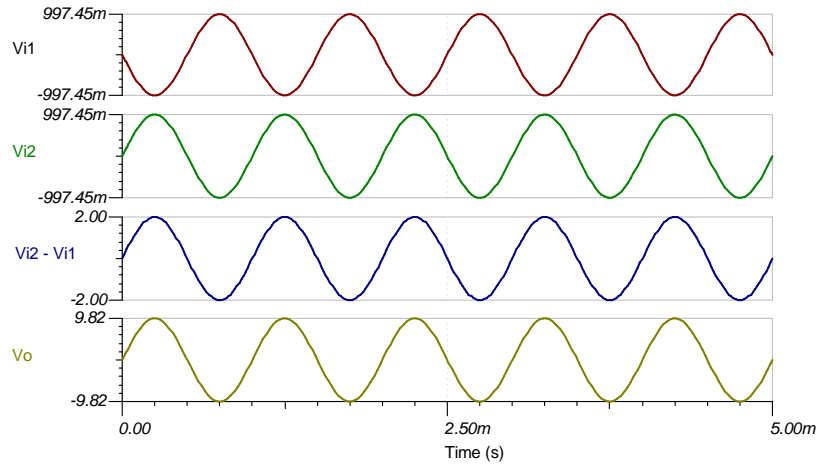
$$R_g = 8k\Omega \rightarrow R_g = 7.87k\Omega \text{ (Standard Value)}$$

Design Simulations

DC Simulation Results



Transient Simulation Results



References:

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBOMAU7](#)
3. [TI Precision Labs](#)
4. *V_{CM} vs. V_{OUT} plots for instrumentation amplifiers with two op amps*
5. [Common-mode Range Calculator for Instrumentation Amplifiers](#)

Design Featured Op Amp

TLV171	
V_{SS}	4.5V to 36V
V_{inCM}	$(V_{EE}-0.1V)$ to $(V_{CC}-2V)$
V_{out}	Rail-to-rail
V_{OS}	0.25mV
I_q	475 μ A
I_b	8pA
UGBW	3MHz
SR	1.5V/ μ s
#Channels	1,2,4
www.ti.com/product/tlv171	

Design Alternate Op Amp

OPA172	
V_{SS}	4.5V to 36V
V_{inCM}	$(V_{EE}-0.1V)$ to $(V_{CC}-2V)$
V_{out}	Rail-to-rail
V_{OS}	0.2mV
I_q	1.6mA
I_b	8pA
UGBW	10MHz
SR	10V/ μ s
#Channels	1,2,4
www.ti.com/product/opa172	

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