

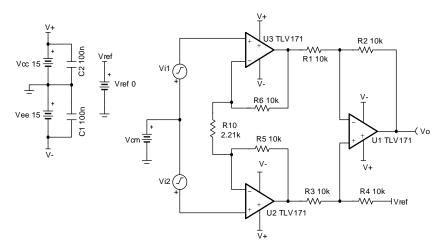
Three op amp instrumentation amplifier circuit

Design Goals

Input V _{idiff} (V _{i2} - V _{i1})		Common- mode Voltage	Output		Supply		
V _{i diff Min}	V _{i diff Max}	V _{cm}	V_{oMin}	V _{oMax}	V _{cc}	V_{ee}	V_{ref}
-0.5V	+0.5V	±7V	-5V	+5V	+15V	-15V	0V

Design Description

This design uses 3 op amps to build a discrete instrumentation amplifier. The circuit converts a differential signal to a single-ended output signal. Linear operation of an instrumentation amplifier depends upon linear operation of its 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. Use precision resistors to achieve high DC CMRR performance
- 2. R_{10} sets the gain of the circuit.
- 3. Add an isolation resistor to the output stage to drive large capacitive loads.
- 4. High-value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit.
- 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_{ol} test conditions in the op amps datasheets.



Design Steps

1. Transfer function of this circuit:

$$\begin{split} V_o &= (V_{i2} - V_{i1}) * G + V_{ref} \\ \text{When } V_{ref} &= 0, \quad \text{the transfer function simplifies to the following equation:} \\ V_o &= (V_{i2} - V_{i1}) * G \\ \text{where } G &= \frac{R_4}{R_3} * 1 + \frac{2 \times R_5}{R_{10}} \end{split}$$

2. Select the feedback loop resistors R₅ and R₆:

Choose
$$R_5 = R_6 = 10 \text{ k}\Omega$$
 (Standard Value)

3. Select R_1 , R_2 , R_3 , R_4 . To set the Vref gain at 1V/V and avoid degrading the instrumentation amplifier's CMRR, ratios of R_4/R_3 and R_2/R_1 must be equal.

Choose
$$R_1 = R_2 = R_3 = R_4 = 10 \text{ k}\Omega$$
 (Standard Value)

4. Calculate R₁₀ to meet the desired gain:

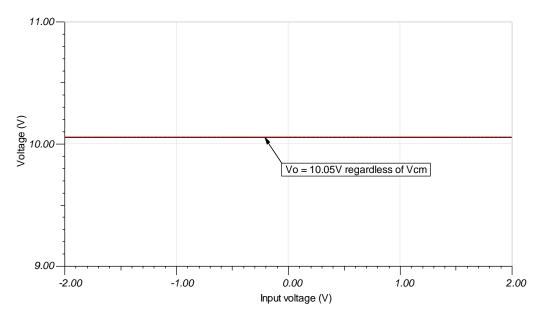
$$\begin{split} G &= \frac{R_4}{R_3} \times (1 + \frac{2^{\times}R_5}{R_{10}}) = 10 \, \frac{V}{V} \qquad \qquad () \\ R_4 &= R_3 = 10 \, k\Omega \\ &\to G = \ 1 + \frac{2^{\times}10 \, k\Omega}{R_{10}} \, = 10 \frac{V}{V} \to \ 1 + \frac{20k\Omega}{R_{10}} \, = 10 \frac{V}{V} \\ &\frac{20 \, k\Omega}{R_{10}} = 9 \frac{V}{V} \to R_{10} = \frac{20k\Omega}{9} = 2222.2 \, \Omega \to R_{10} = 2.21 \, k\Omega \quad \text{(Standard Value)} \end{split}$$

5. To check the common-mode voltage range, download and install the program from reference [5]. Edit the INA_Data.txt file in the installation directory by adding the code for a 3 op amp INA whose internal amplifiers have the common-mode range, output swing, and supply voltage range as defined by the amplifier of choice (TLV172 in this case). There is no V_{be} shift in this design and the gain of the output stage difference amplifeir is 1 V/V. The default supply voltage and reference voltages are ±15 V and 0 V, respectively. Run the program and set the gain and reference voltage accordingly. The resulting V_{CM} vs. V_{OUT} plot approximates the linear operating region of the discrete INA.

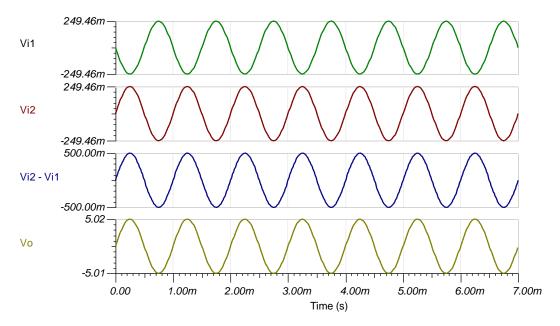


Design Simulations

DC Simulation Results



Transient Simulation Results





References:

- 1. Analog Engineer's Circuit Cookbooks
- 2. SPICE Simulation File SBOMAU8
- 3. TI Precision Labs
- 4. Instrumentation Amplifier V_{CM} vs. V_{OUT} Plots
- 5. Common-mode Range Calculator for Instrumentation Amplifiers

Design Featured Op Amp

TLV171				
V _{ss}	4.5V to 36V			
V _{inCM}	(V−) − 0.1V < Vin < (V+) − 2V			
V _{out}	Rail-to-rail			
V _{os}	0.25mV			
I _q	475µA			
I _b	8pA			
UGBW	3MHz			
SR	1.5V/µs			
#Channels	1,2,4			
www.ti.com/product/tlv171				

Design Alternate Op Amp

	OPA172	OPA192	
V_{ss}	4.5V to 36V	4.5V to 36V	
V _{inCM}	(V-) - 0.1V < Vin < (V+) - 2V	V_{ee} –0.1V to V_{cc} +0.1V	
V_{out}	Rail-to-rail	Rail-to-rail	
V _{os}	0.2mV	±5µV	
I _q	1.6mA	1mA/Ch	
I _b	8pA	5pA	
UGBW	10MHz	10MHz	
SR	10V/µs	20V/µs	
#Channels	1,2,4	1, 2, 4	
	www.ti.com/product/op a172	www.ti.com/product/op a192	

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