Analog Engineer's Circuit

Two Op Amp Instrumentation Amplifier Circuit

TEXAS INSTRUMENTS

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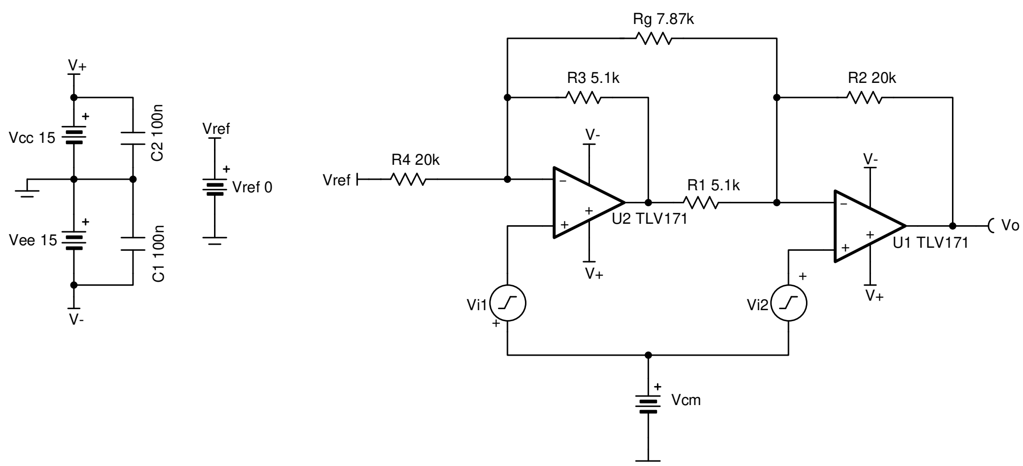
Design Goals

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 amplifiers 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_{ol} test conditions in the op amps data sheets.

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

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

   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.

   $$G_{min} = 1 + \frac{R_4}{R_3} = 5\frac{V}{V}$$
   $$\text{Choose} \quad R_4 = 20k\Omega$$
   $$G_{min} = 1 + \frac{20k\Omega}{R_3} = 5\frac{V}{V}$$
   $$R_3 = \frac{R_4}{5-1} = \frac{20k\Omega}{4} = 5k\Omega \rightarrow R_3 = 5.1k\Omega \ \left(\text{Standard} \quad \text{Value}\right)$$

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.

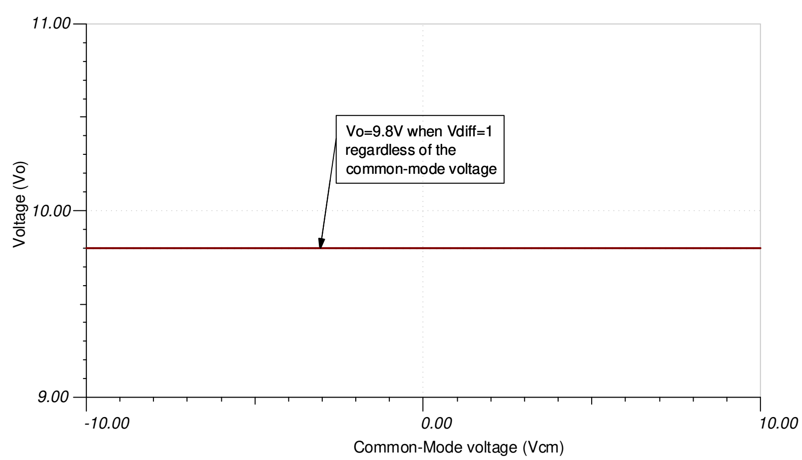
   $$\frac{V_{o\_ref}}{Vref} = \left(-\frac{R_3}{R_4}\right) \times \left(-\frac{R_2}{R_1}\right) = \frac{R_3 \times R_2}{R_4 \times R_1} = 1\frac{V}{V}$$
   $$\frac{R_2}{R_1} = \frac{R_4}{R_3} \rightarrow R_1 = R_3 = 5.1k\Omega \text{ and } R_2 = R_4 = 20k\Omega \ \left(\text{Standad} \quad \text{Value}\right)$$

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

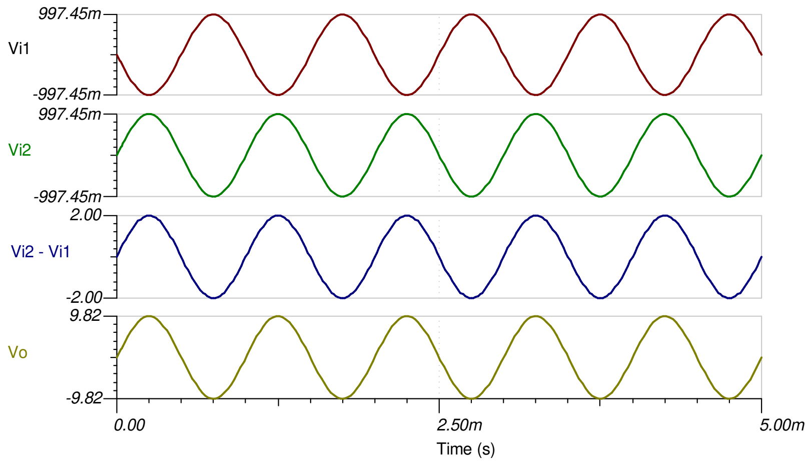
   $$G = 1 + \frac{R_4}{R_3} + \frac{2R_2}{R_g} = 1 + \frac{20\ k\Omega}{5.1\ k\Omega} + \frac{2 \times 20\ k\Omega}{R_g} = 10\ V/V$$
   $$R_g = 8\ k\Omega \rightarrow R_g = 7.87\ k\Omega \ \left(\text{Standard} \quad \text{Value}\right)$$

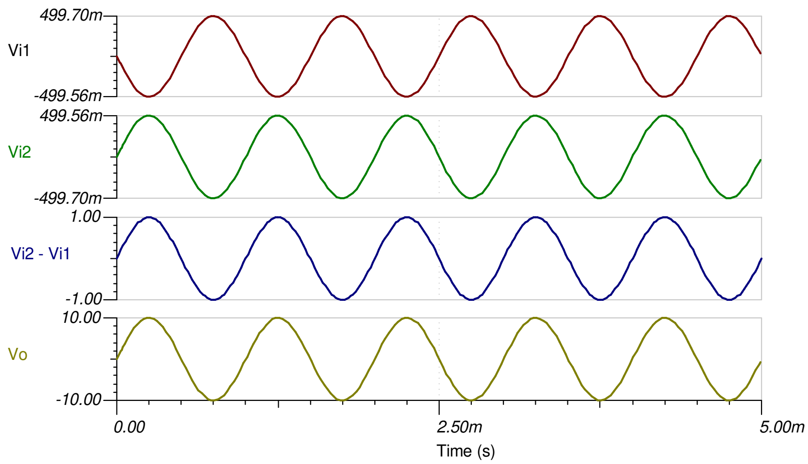
Design Simulations

DC Simulation Results



Transient Simulation Results





References

Texas Instruments, SBOMAU7 simulation file, software support

Texas Instruments, *V_{CM} vs. V_{OUT} Plots for Instrumentation Amplifiers With Two Op Amps*, analog design journal

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	475µA
I_b	8pA
UGBW	3MHz
SR	1.5V/µs
#Channels	1,2,4
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/µs
#Channels	1,2,4
OPA172	

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