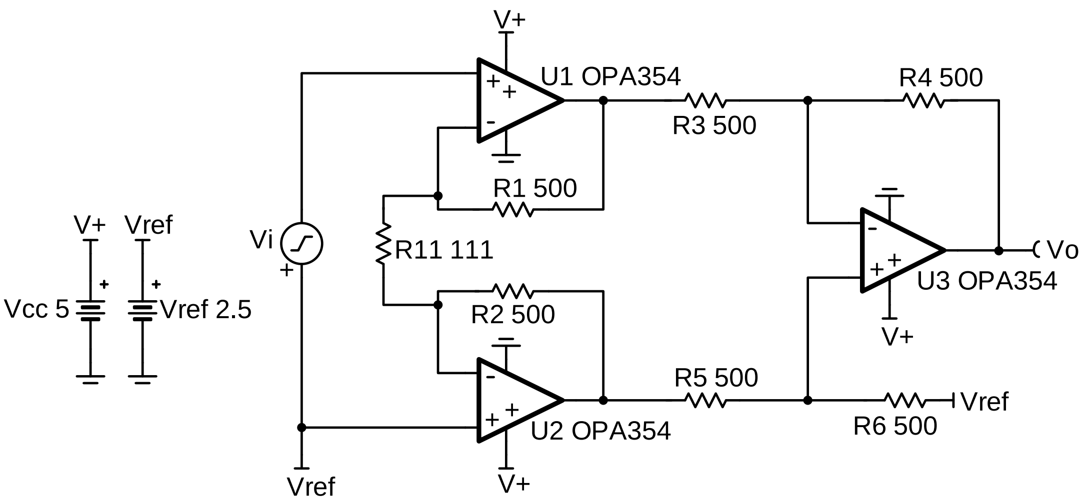
Discrete wide bandwidth INA circuit

Design Goals

Input		Output		Bandwidth	Supply		
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	BW	V_{cc}	V_{ee}	V_{ref}
–0.24V	+0.24V	+0.1V	+4.9V	10MHz	+2.5V	0V	2.5V

Design Description

This design uses 3 op–amps to build a discrete wide bandwidth instrumentation amplifier. The circuit converts a differential, high frequency signal to a single–ended output.



Design Notes

1. Reduce the capacitance on the output of each op amp to avoid stability issues.
2. Use low gain configurations to maximize the bandwidth of the circuit.
3. Use precision resistors to achieve high DC CMRR performance.
4. Use small resistors in op–amp feedback to maintain stability.
5. Set the reference voltage, V_{ref}, at mid–supply to allow the output to swing to both supply rails.
6. Phase margin of 45° or greater is required for stable operation.
7. R_{11} sets the gain of the instrumentation amplifier.
8. Linear operation depends 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.
9. V_{ref} also sets the common-mode voltage of the input, V_i, to ensure linear operation.

Design Steps

1. The transfer function of the circuit is given below.

$$V_o = V_i \times \left(1 + \frac{2 \times R_1}{R_{11}}\right) \times \left(\frac{R_6}{R_5}\right) + V_{ref}$$

where V_i = the differential input voltage

V_{ref} = the reference voltage provided to the amplifier

$$Gain = \left(1 + \frac{2 \times R_1}{R_{11}}\right) \times \frac{R_6}{R_5}$$

2. To maximize the usable bandwidth of design, set the gain of the diff amp stage to 1V/V. Use smaller value resistors to minimize noise.

Choose $R_3 = R_4 = R_5 = R_6 = 500\Omega$ (Standard value)

3. Choose values for resistors R_1 and R_2. Keep these values low to minimize noise.

$R_1 = R_2 = 500\,\Omega$ (Standard value)

4. Calculate resistor R_{11} to set the gain of the circuit to 10V/V

$$G = \left(1 + \frac{2 \times R_1}{R_{11}}\right) = 10\frac{V}{V} \rightarrow 1 + \frac{2 \times 500\,\Omega}{R_{11}} = 10\frac{V}{V} \rightarrow \frac{2 \times 500\,\Omega}{R_{11}} = 9\frac{V}{V}$$

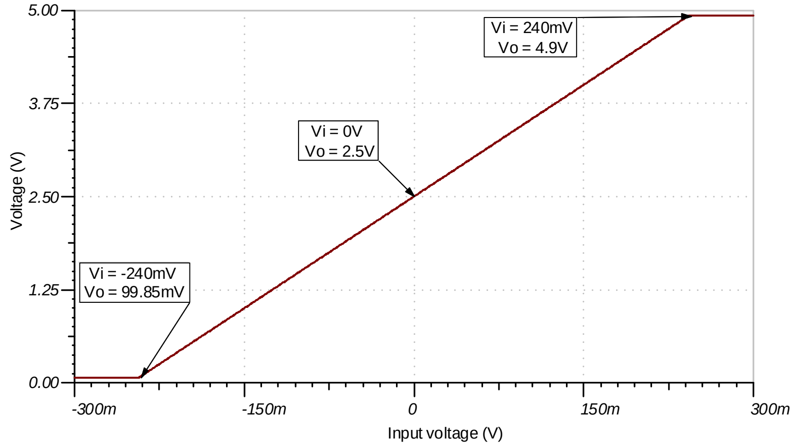
$$R_{11} = \frac{1000\,\Omega}{9\,\frac{V}{V}} = 111.11\,\Omega \rightarrow R_{11} = 111\,\Omega \text{ (Standard value)}$$

5. Calculate the reference voltage to bias the input to mid-supply. This will maximize the linear output swing of the instrumentation amplifier. See References for more information on the linear operating region of instrumentation amplifiers.

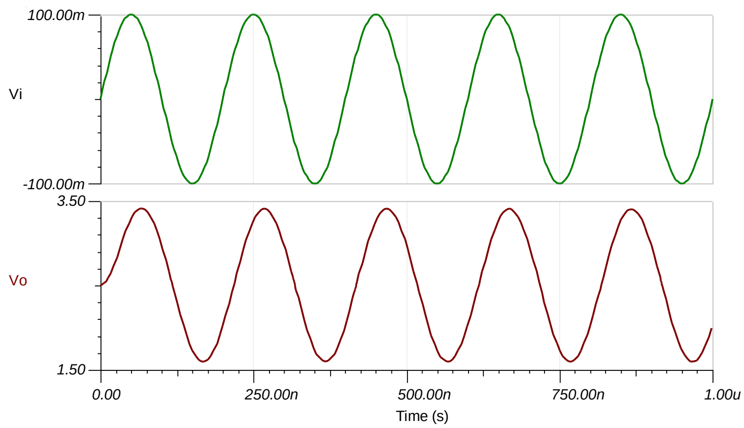
$$V_{ref} = \frac{V_s}{2} = \frac{5\text{ V}}{2} = 2.5\text{ V}$$

Design Simulations

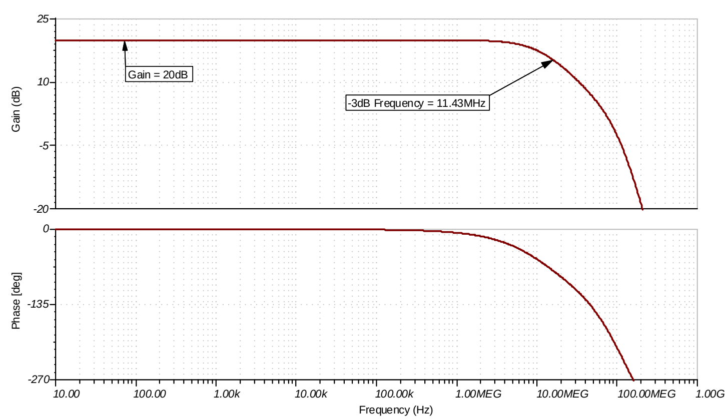
DC Simulation Results



Transient Simulation Results



AC Simulation Results



References

1. Analog Engineer's Circuit Cookbooks
2. SPICE Simulation File SBOMAU6
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

OPA354	
V_{ss}	2.5V to 5.5V
V_{inCM}	Rail–to–rail
V_{out}	Rail–to–rail
V_{os}	2mV
I_q	4.9mA/Ch
I_b	3pA
UGBW	250MHz
SR	150V/µs
#Channels	1,2,4
www.ti.com/product/opa354	

Design Alternate Op Amp

OPA322	
V_{ss}	1.8V to 5.5V
V_{inCM}	Rail–to–rail
V_{out}	Rail–to–rail
V_{os}	500µV
I_q	1.6mA/Ch
I_b	0.2pA
UGBW	20MHz
SR	10V/µs
#Channels	1,2,4
www.ti.com/product/opa322	