

# ***Increasing INA117 and INA149 Differential Input Range Application Report***

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## **ABSTRACT**

The INA117 is a monolithic difference amplifier with the unique ability to accept up to  $\pm 200V$  common-mode input signals while operating on standard  $\pm 15V$  power supplies. Because the gain of the INA117 is set at  $1V/V$ , and because the output would saturate into the rails at about  $\pm 12V$ , the maximum specified differential input range is  $\pm 10V$ . The INA117 is available in three standard 8-pin packages: hermetic TO-99, plastic DIP, and the small surface-mount SOIC package, specified for the  $-40^{\circ}C$  to  $+85^{\circ}C$  temperature range.

Similarly, the INA149 is a precision 36V unity-gain difference amplifier with a very high input common-mode voltage range ( $\pm 275V$ ). On standard  $\pm 15V$  power supplies, the maximum specified differential input range is  $\pm 13.5V$ . The INA149 is available in the SOIC-8 package with operation specified over the extended industrial temperature range of  $-40^{\circ}C$  to  $+125^{\circ}C$ .

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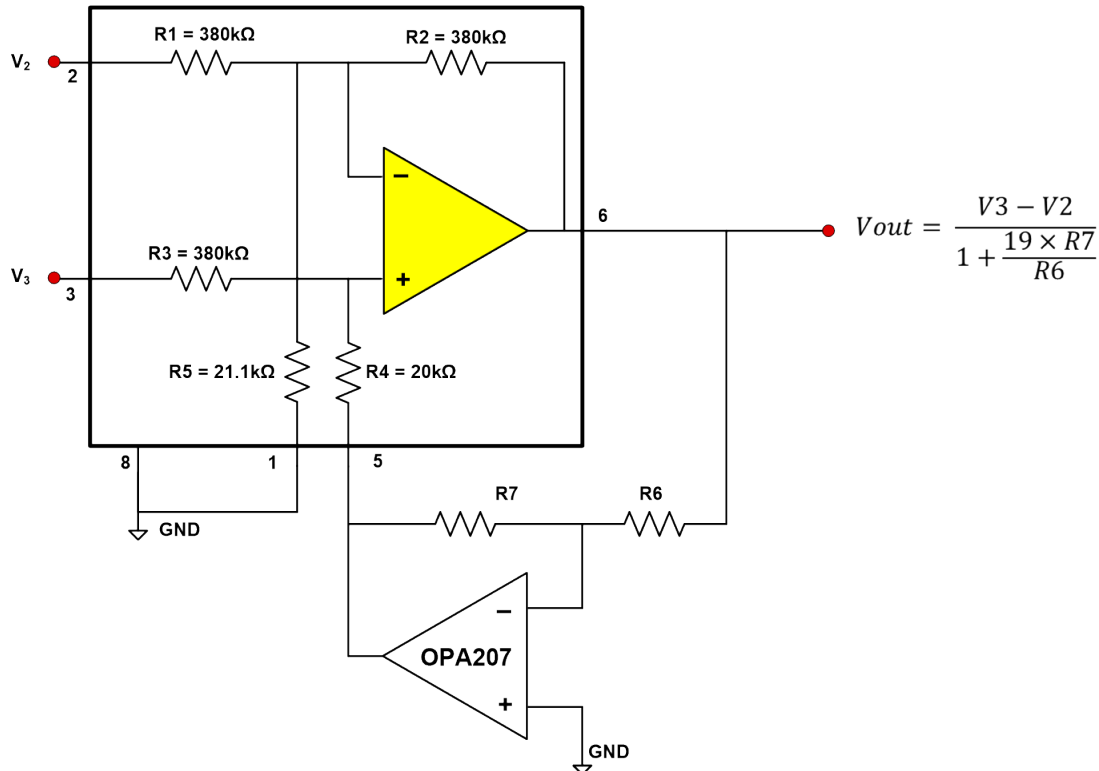
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## 1 Introduction

Since the common-mode input range is high ( $\pm 200\text{V}$  INA117 and  $\pm 275\text{V}$  INA149), it makes sense that some designers would also like to use these part for differential inputs greater than  $\pm 10\text{V}$  and  $\pm 13.5\text{V}$ . [Figure 1](#) shows the recommended circuit for the INA117. Adding resistors to the input may seem simpler, but there are some problems with that approach.



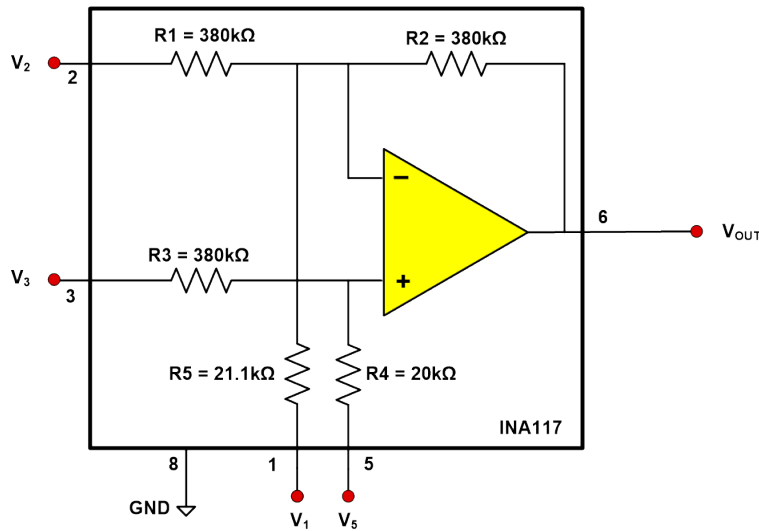
**Figure 1. INA117 with Increased Differential Input Range**

## 2 Device Overview

The performance of the INA117 depends on extremely precise resistor matching (0.005% for 86dB CMRR). These resistors are ratiometrically matched where resistor pairs must match to 0.005%. Absolute resistor values may vary up to  $\pm 15\%$  based on process, but their matching is preserved. Resistors added to the input must be adjusted to at least this accuracy to maintain high performance. Both gain error and CMRR must be adjusted. Maintaining 86dB CMRR over temperature requires 1ppm/ $^{\circ}\text{C}$  resistor TCR tracking. Significant resistance added external to the INA117 would require the same performance.

By using the circuit shown in [Figure 1](#), internal resistor matching is preserved (with absolute values varying up to  $\pm 15\%$ ), and the INA117 CMRR and CMRR drift with temperature are maintained. Gain can be set independently of CMRR by adjusting the inverter resistors, R6, R7. Gain drift is preserved so long as R6 and R7 track with temperature. Furthermore, noise at the output is improved by the gain reduction factor whereas it is unchanged with the other approach.

To understand how the circuit works, consider the INA117 to be a four-input summing amplifier as shown in Figure 2.



$$V_{OUT} = V_3 - V_2 + 19 \times V_5 - 18 \times V_1$$

Figure 2. INA117 Shown as a Four-Input Summing Amplifier

CMRR is preserved and the gain is reduced if a small portion of the output signal is inverted and fed back to pin 5 with  $V_1$  set to zero ( $V_1$  grounded). Since absolute values of the internal resistors can vary up to  $\pm 15\%$ , the following output equation may also exhibit the same level of error. This should be added to the overall system error budget.

Where :  $V_{OUT} = V_3 - V_2 + 19 \times V_5 - 18 \times V_1$

If,  $V_5 = -V_{OUT} \times R_7 \div R_6$ , then

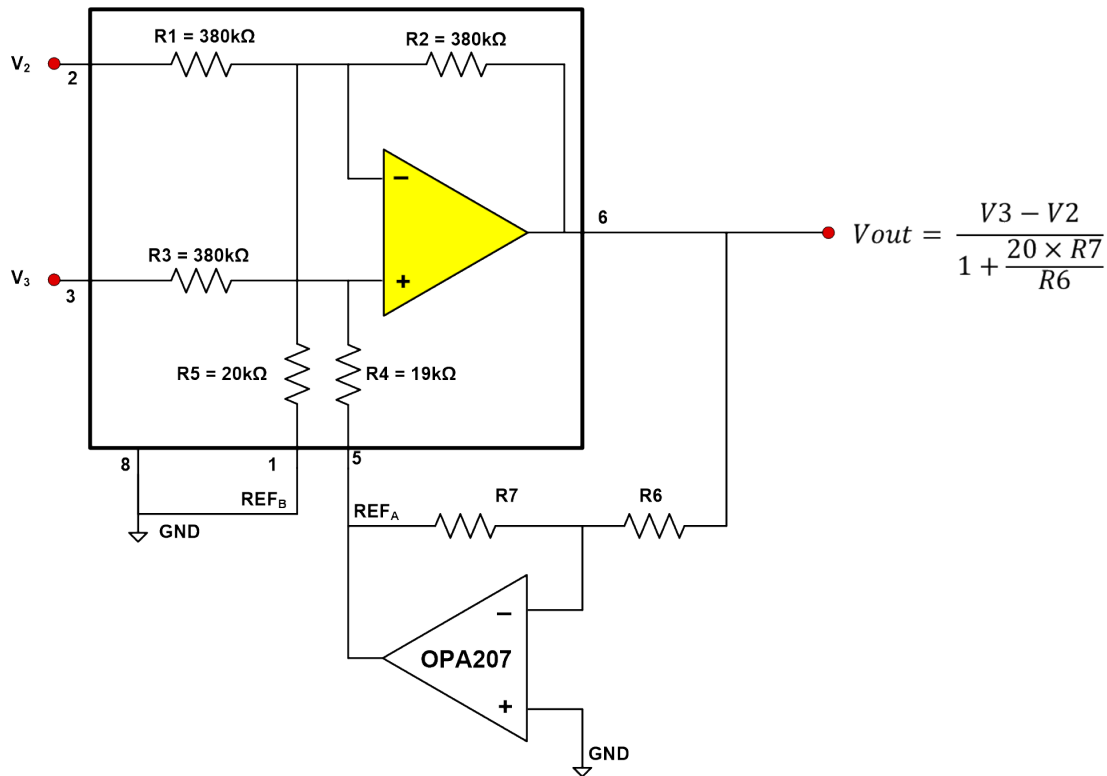
$$V_{OUT} = \frac{V_3 - V_2}{1 + \frac{19 \times R_7}{R_6}} \tag{1}$$

Table 1. INA117 Selected-Gain Examples

GAIN <sup>(1)</sup> (V/V)	$R_7$ (kΩ)	$R_6$ (kΩ)
1/2	1.95	20.0
1/4	3.16	20.0
1/5	4.22	20.0

<sup>(1)</sup> INA117 is not stable in Gain < 1/5.

Similarly, the INA149 may be used. The INA149 is a precision 36V unity-gain difference amplifier with a very high input common-mode voltage range ( $\pm 275V$ ). It consists of a precision op amp and an integrated thin-film resistor network. The absolute value of these resistors are also ratiometrically matched with up to 15% variance in either direction. The INA149 is pin-compatible with the INA117 and offers improved DC performance.


**Figure 3. INA149 with Increased Differential Input Range**

The INA149 has the following transfer function:

$$V_{out} = (+IN) - (-IN) + 20 \times REF_A - 19 \times REF_B \quad (2)$$

Remember that the resistor values internal to the INA149 may also vary up to  $\pm 15\%$  based on process, this error must be added to the overall system error budget. The output equation for increasing the differential input voltage is expressed below. This is derived from the transfer function:

$$V_{OUT} = (+IN) - (-IN) + 20 \times REF_A - 19 \times REF_B$$

$$\text{If, } REF_A = -V_{OUT} \times \frac{R_7}{R_6}, \text{ then}$$

$$V_{OUT} = \frac{(+IN) - (-IN)}{1 + \frac{20 \times R_7}{R_6}} \quad (3)$$

**Table 2. INA149 Selected-Gain Examples**

Gain (V/V) <sup>(1)</sup>	R <sub>7</sub> (kΩ)	R <sub>6</sub> (kΩ)
1/2	1	20
2/3	0.5	20
3/4	0.33	20

<sup>(1)</sup> INA149 is not stable in Gain < 1/2.

### 3 Optional CMRR Adjustment

If CMRR adjustment is desired, add a  $10\Omega$  fixed resistor and a  $20\Omega$  pot as shown in Figure 4. Adjust CMRR by shorting together pins 2 and 3 of the INA117 (or INA149) and driving them with a 500Hz square wave while observing the output on a scope. Using a square wave rather than a sine wave allows the AC signal to settle out so that the DC CMRR can be seen. The CMRR trim will change the gain slightly, so trim CMRR first, then trim gain with  $R_6$ ,  $R_7$  if desired.

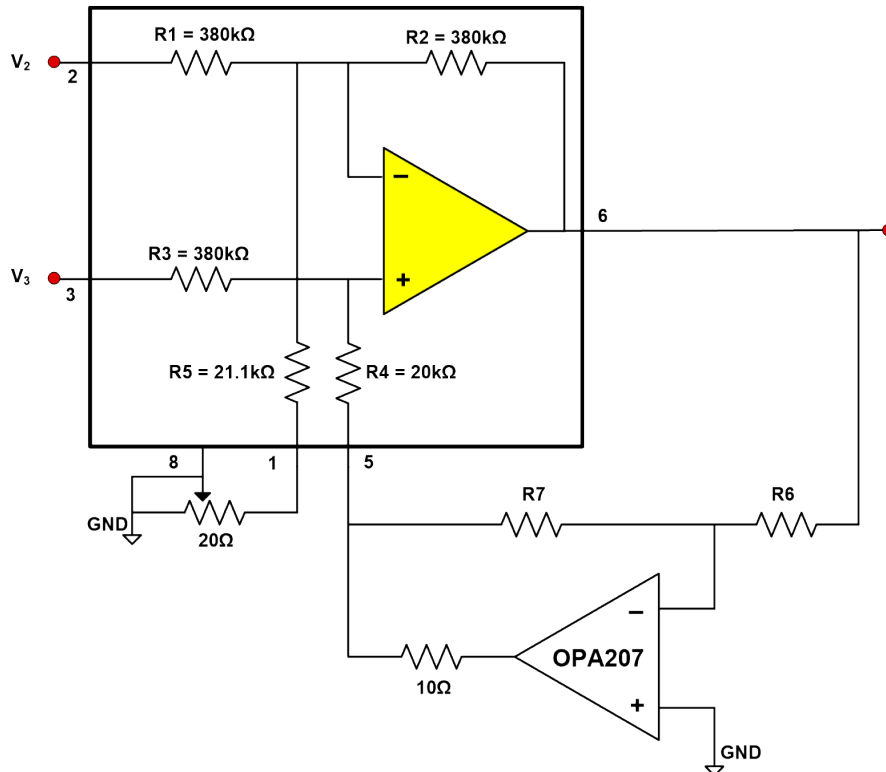


Figure 4. INA117 with Increased Differential Input Range with CMRR Trim

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