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APPLICATION BULLETIN
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# PRECISION IA SWINGS RAIL-TO-RAIL ON SINGLE 5V SUPPLY

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You can combine a precision instrumentation amplifier (IA) and an inexpensive CMOS op amp to get the best of two worlds—the precision of a bipolar IA and 5V single-supply operation. Using the INA131 gives 50µV max voltage offset, 0.25µV/°C max offset drift, and 110dB min common-mode rejection. How close the output swings to the power supply rail depends on which "rail-to-rail" CMOS op amp you use. With a TI TL2272 you can expect the output to swing within 100mV of the rails.

The circuit is shown in Figure 1. INA131 is fixed Gain = 100 IA specified to operate on power supplies as low as ±2.25V. Its output can swing ±1.25V on ±2.5V supplies. Adding a gain-of-2 "rail-to-rail" CMOS op amp, $A_4$, inside the feedback loop boosts output swing to ±2.5V (0 to 5V on a single 5V supply). Because the CMOS op amp is inside the feedback loop, its errors are divided-down by the loop gain of $A_3$ in the INA131 so they contribute negligible error to the composite amplifier.

The gain of the CMOS amplifier is set by $R_1$, $R_2$, and $R_3$.

$$\text{Gain} = 1 + \frac{R_1 \cdot R_2 + R_2 \cdot R_3}{R_1 \cdot R_3}$$

With the values shown, Gain ≈ 2V/V. Remember, since $A_4$ is in the INA131 feedback loop, its exact gain is unimportant. The INA131 will still have a precise gain of 100V/V ±0.024%.

Using the $R_1$, $R_3$ divider to set the gain forces the INA131 output swing to be centered midway between the +5V supply and ground for rail-to-rail output swing.

Compensation capacitor, $C_1$, provides high-frequency feedback around $A_4$ to assure loop stability. It is important to choose $A_4$ with at least 2MHz small-signal bandwidth for good loop stability.

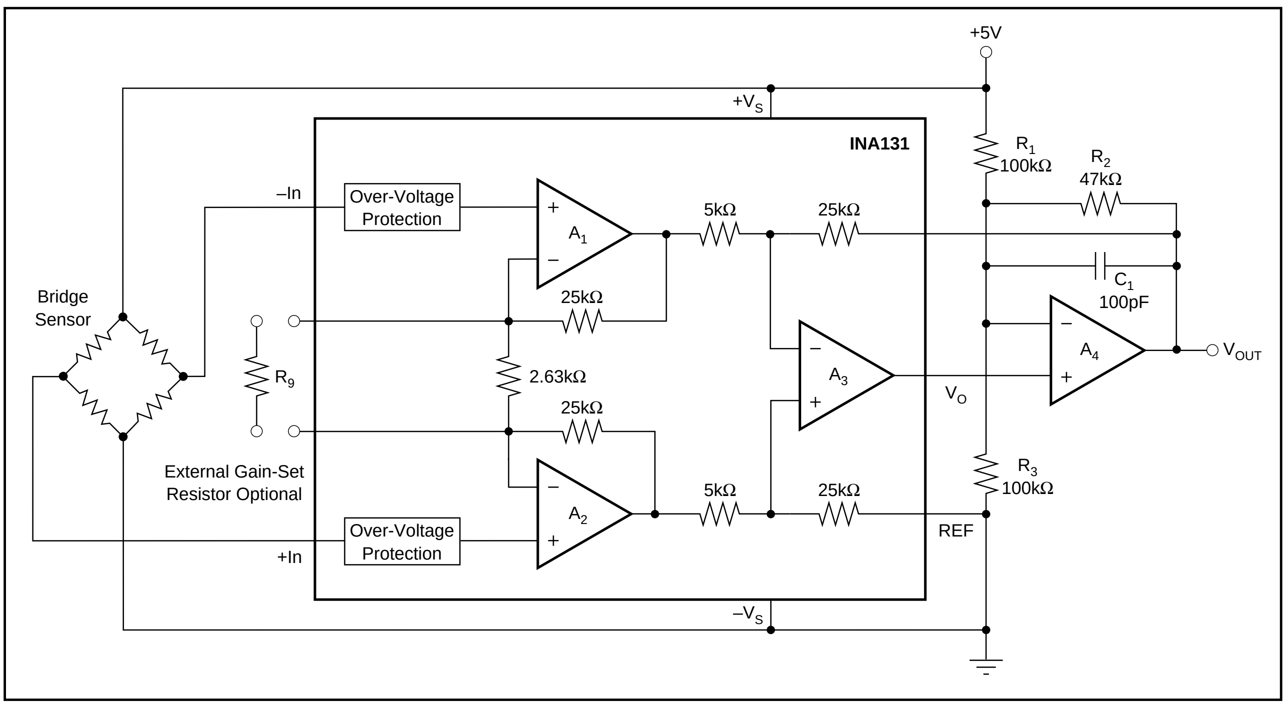


FIGURE 1. Adding a "Rail-to-Rail" CMOS Op Amp in its Feedback Loop Allows the INA131 Output to Swing Rail-to-Rail on a Single 5V Supply.

Figure 2 shows the output swing of the composite IA. In this triple exposure, the output sine-wave signal is superimposed with the ground rail and +5V rail.

Although the output of the composite IA will swing rail-to-rail, its inputs will not function at ground. This is not a problem for the bridge application shown. In this application, the bridge is biased from the +5V power supply to ground. With a balanced bridge, the IA inputs are at 2.5V (midway between the +5V power supply and ground). Because the INA131 uses a gain-of-five difference amplifier, the inputs to $A_3$ are at 2V when the INA131 inputs are at 2.5V. This allows the INA131 to operate properly with common-mode input voltages from 2V to 3V.

As with most rail-to-rail op amps, the TLC2272 is a dual op amp. If the second op amp is not used elsewhere, it can be used for filtering or added gain.

Gain can also be increased by connecting an optional gain-set resistor, $R_G$, as shown in Figure 1. Gain-set resistors in the INA131 are trimmed for precise ratios, not to absolute values. Absolute accuracy of the internal gain-set resistors is ±40%. To compensate for this tolerance, the value of the external gain-set resistor may need to be adjusted from device to device. Nominal gain with an external $R_G$ can be calculated as follows:

$$\text{Gain} = 100 + \frac{250k\Omega}{R_G}$$

Where:

$R_G$ is the external gain-set resistor (Ω)
Accuracy of the 250kΩ term is ±40%.

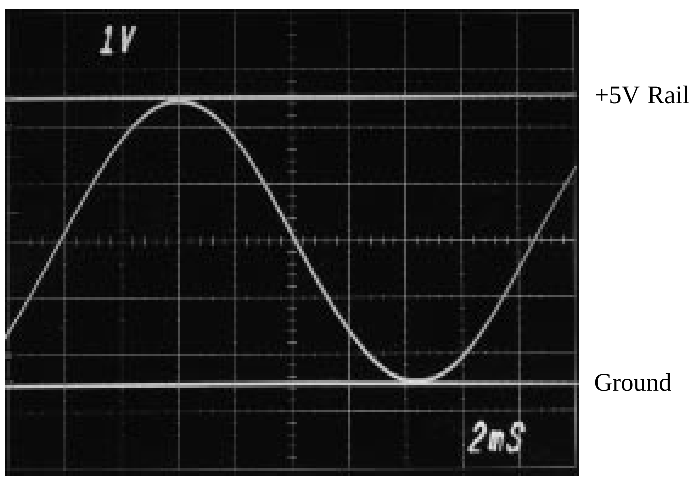


FIGURE 2. Triple Exposure Showing Rail-to-Rail Output Swing of Composite Precision IA.