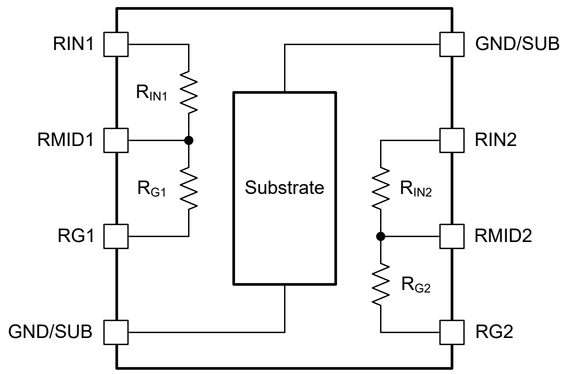
Product Overview

Navigating Precision Resistor Networks

What are matched resistor pairs?

A resistor pair is made up of two resistors connected in series making up a resistor divider. With matched pairs, each pair functions independently and is made up of an R_{IN} and an R_G with $R_{IN1} = R_{IN2}$ and $R_{G1} = R_{G2}$. A tap point can be found between the resistors of each divider, labeled R_{MID1} and R_{MID2} in the Functional Block Diagram. Additionally, one of the two GND pins can be used to bias the substrate for best AC performance.



Functional Block Diagram

To determine the value of the resistors, consider the ratio of the RES11Axx device in question. The divider ratio for a resistor pair is R_{IN} divided by R_G, where R_{IN} is fixed to 1kΩ for all RES11A-Q1 and R_G is the variable gain resistor that sets the dividing ratio. Each orderable part number (OPN) is associated with a different ratio, as noted in the RES11A-Q1 Ratios table. For example, a RES11A20 has a 1:2 ratio, thus the resistor has a 1kΩ R_{IN} and a 2kΩ R_G. For additional specifications see the *RES11A-Q1 Automotive, Matched, Thin-Film Resistor Dividers With 1-kΩ Inputs* data sheet.

RES11A-Q1 Ratios

OPN	R_{IN} (Nominal)	R_G (Nominal)	Maximum Differential Divider Voltage (R_{INX} Pin to R_{GX} Pin)[1]
RES11A00	1kΩ	10kΩ	44.7V
RES11A10	1kΩ	1kΩ	24.4V
RES11A15	1kΩ	1.5kΩ	20.3V
RES11A16	1kΩ	1.667kΩ	19.9V
RES11A20	1kΩ	2kΩ	18.3V
RES11A25	1kΩ	2.5kΩ	28.4V
RES11A30	1kΩ	3kΩ	32.5V
RES11A40	1kΩ	4kΩ	30.5V
RES11A50	1kΩ	5kΩ	29.9V
RES11A90	1kΩ	9kΩ	40.7V

[1] The maximum sustained differential voltage rating per divider is determined by a number of factors, including the maximum junction temperature and the self-heating associated with a given voltage and divider impedance. See the specifications section of the *RES11A-Q1 Automotive, Matched, Thin-Film Resistor Dividers With 1-kΩ Inputs* data sheet for more details.

Ratio Tolerance vs Initial Tolerance

The RES11A-Q1 features a ±0.05% maximum ratio tolerance (t_{D1} and t_{D2}) meaning that the ratio of R_{IN1}:R_{G1} and R_{IN2}:R_{G2} are at most 0.05% off of the specified ratio values at a room temperature of 25°C. The initial tolerance (t_{abs}) of 14% refers to the part-to-part variation of the individual resistors to the nominal or printed resistance. The four resistors within the device track each other much more closely, with a typical absolute error span of 235 ppm. This means a RES11A-Q1 (which has a nominal R_{IN1} of 1kΩ) can have an R_{IN1} value as high as 1140Ω; however, because of the maximum ratio tolerance specification this means all other resistors (R_{IN2}, R_{G1}, R_{G2}) have values approximately 14% above the nominal values of these resistors.

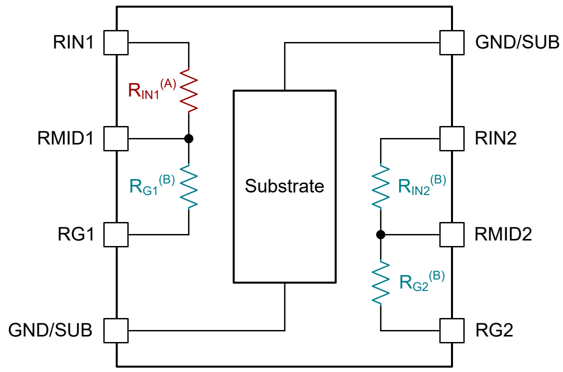


Figure 2. Resistor Ratio Matching

Considerations for use

- Connect only one of the two GND pins to a low-impedance ground or bias point. Float the other pin to avoid the formation of current return paths through the device substrate. See the *RES11A-Q1* data sheet for more information.
- The RES11A-Q1 is AEC-Q200 Grade 1 qualified and has an operating temperature range of –40°C to 125°C, desirable for industrial and automotive applications. AEC-Q200 is the worldwide standard for stress and temperature resistance that all passive electric components must meet to be qualified for use in the automotive industry. Pair the RES11A-Q1 with AEC-Q100 active components (amplifiers, comparators, ADC, DAC, and so forth) for a full automotive qualified design.
- Though labeled R_{INX} and R_{GX} there is no requirement for the direction of current flow. The RES11A can be rotated 180° for an attenuating gain configuration. With R_{GX} used as the input and R_{INX} as the output the divider ratio becomes inverted. For example, a RES11A-Q1 with a nominal resistance ratio of 1:2 has a 1:0.5 ratio when R_{GX} is used as the input.

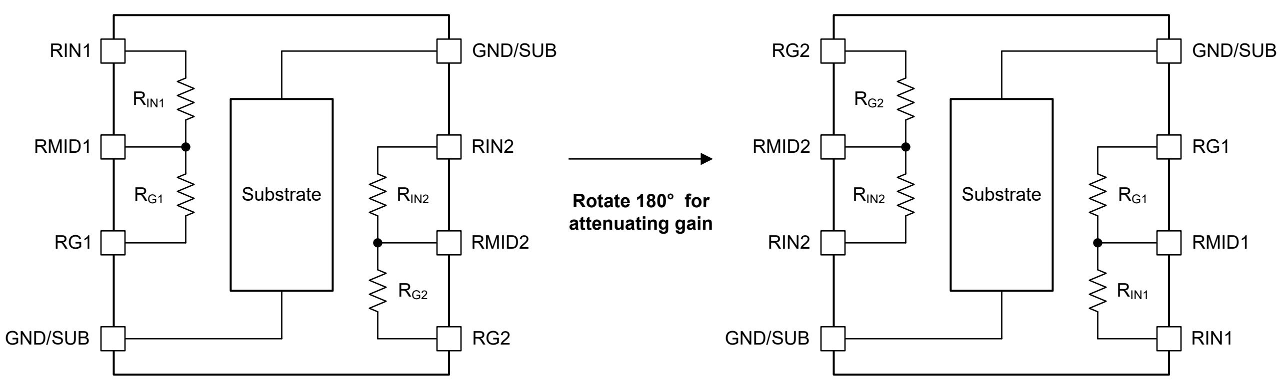


Figure 3. Attenuating Gain Configuration

Importance of Matched Resistors For Maximizing CMRR in Discrete Amplifier Implementations

Consider a standard differential amplifier as Figure 3 shows. When simplified to $R_1 = R_2$, and $R_3 = R_4$, CMRR can be expressed as CMRR(dB) = $20 \times \log[(1+R_3 / R_1) / (4T / 100)]$ where T is resistor tolerance in percent. This means CMRR is expected to be only 54dB in a unity gain configuration ($R_1 = R_3$) with unmatched 0.1% tolerance resistors. If both divider ratios are matched to a 0.05% ratio tolerance then the value for T in this formula is 0.025% resulting in an improved CMRR of 66dB. See the application information section in the *RES11A-Q1* data sheet to learn more about how this number is calculated. An operational amplifier has infinite CMRR, which is a specification pertaining to the amount of the common mode signal present at the output of an amplifier. Ultimately, CMRR is a factor impacting the output signal noise. Learn more about CMRR with the *Common-mode rejection ratio* TI Precision Labs video on this topic.

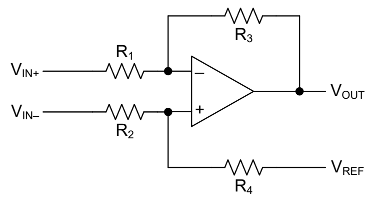


Figure 4. Standard Differential Amplifier

Discrete Implementations of Difference and Instrumentation Amplifiers

Difference Amplifier

Utilizing an operational amplifier such as the OPA392 and a single RES11A-Q1 in the *Difference Amplifier Configuration* yields a differential amplifier topology including differential inputs and a single-ended output. The gain of the amplifier can be calculated by the formula in Equation 1.

$$G = R_G / R_{IN} \quad (1)$$

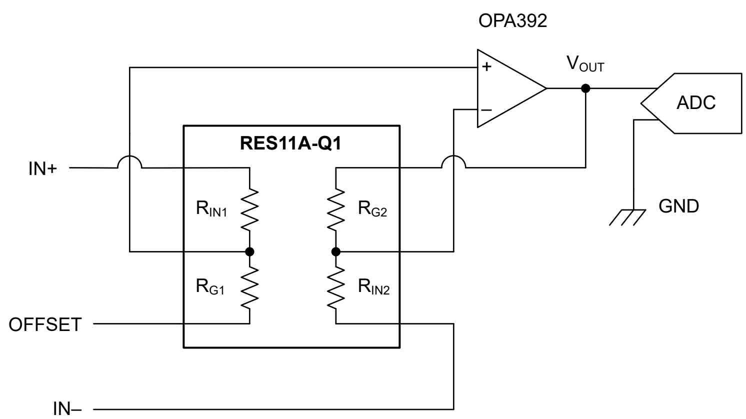


Figure 5. Difference Amplifier Configuration

Instrumentation Amplifier

Utilizing two operational amplifiers such as OPA392 and a single RES11A-Q1 in the *Instrumentation Amplifier Configuration* yields an instrumentation amplifier topology with two high-impedance inputs and differential output. In some cases, a weak path for input bias current is needed[2]. The gain of the amplifier is calculated using Equation 2.

$$G = 1 + R_G / R_{IN} \quad (2)$$

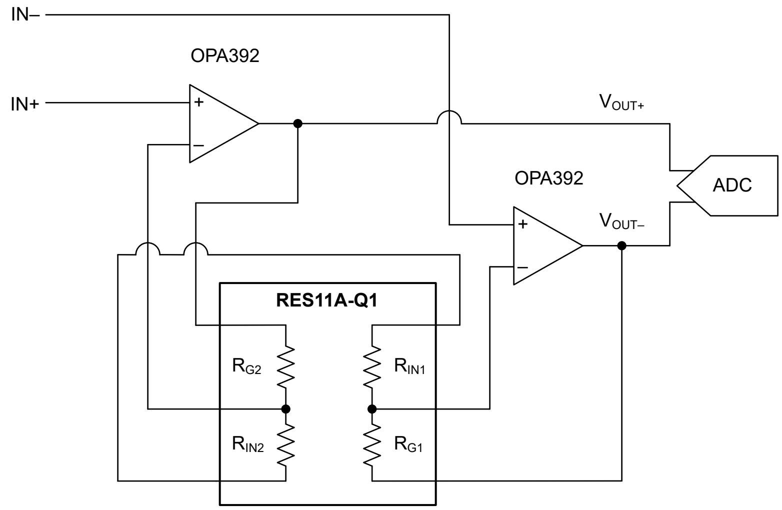


Figure 6. Instrumentation Amplifier Configuration With Differential Output

Utilizing two operational amplifiers such as OPA392 and a single RES11A-Q1 as illustrated in Figure 6 yields an instrumentation amplifier topology with two high-impedance differential inputs, one single-ended output, and a reference input. is important to simulate the design to check that the input common mode ranges and output swings meet the requirements of the desired application. The gain of the amplifier is calculated with Equation 3.

$$G = 1 + R_{IN} / R_G \quad (3)$$

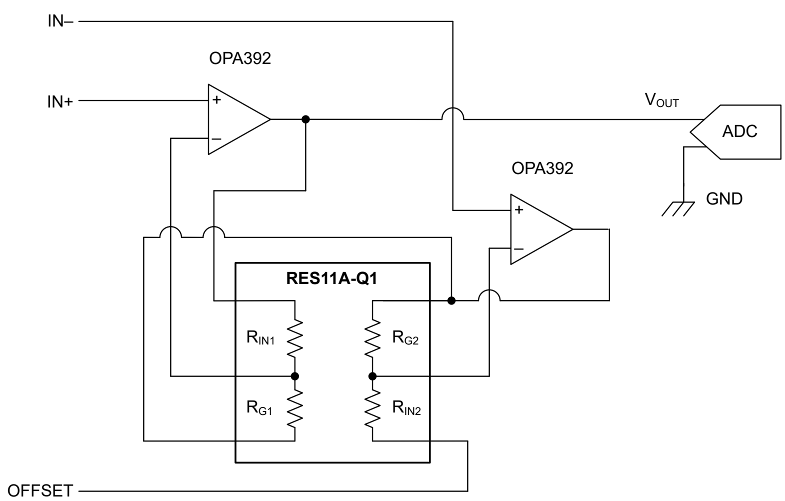


Figure 7. Instrumentation Amplifier Configuration With Reference Input

[2] See the Importance of Input Bias Current Return Paths in Instrumentation Amplifier Applications application note for applications such as AC-coupled measurements or thermocouple measurements.

Fully-Differential Amplifier

A fully-differential amplifier requires resistors to set the gain as Figure 7 illustrates. The ratio between these resistors determines the gain, thus matching is important to make sure the circuit behaves as intended. Equation 4 shows the formula for gain in this configuration.

$$G = R_G / R_{IN} \tag{4}$$

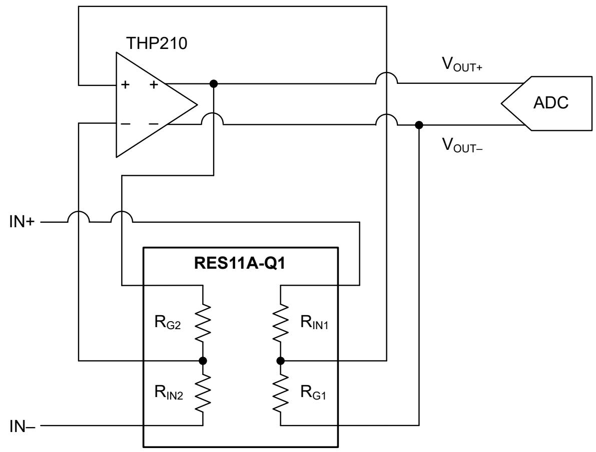


Figure 8. Fully-Differential Amplifier Configuration

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