

Applying the **ADE7912/ADE7913** to 4 mA to 20 mA DC Measurements

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INTRODUCTION

This application note describes how to apply the [ADE7912/ADE7913](#) to measure analog 4 mA to 20 mA current loops.

Within the field of industrial process control, there has been widespread adoption of digital signals and communications, such as in the RS-485 interface. However, many industrial process control applications still employ analog 4 mA to 20 mA current loops for analog signaling and monitoring. The reason is that the analog 4 mA to 20 mA current loop is a very robust sensor signaling standard.

Current loops are ideal for data transmission because of their inherent robustness to electrical noise. In an analog 4 mA to 20 mA current loop, all signaling current flows through all components; the same current flows even if the wire terminations are less than perfect. All the components in the loop drop voltage due to the signaling current flowing through them. The signaling current is not affected by these voltages as long as the power supply voltage is greater than the sum of the voltage drops around the loop at the maximum signaling current of 20 mA (see Figure 1).

Compared with other communications methods, an output of 4 mA to 20 mA has several unique advantages.

- The current signal has good anti-interference ability.
- The current signal can be transmitted relatively long distances.
- A 4 mA to 20 mA output allows convenient determination of a short circuit or of a broken circuit.
- Because the minimum current is 4 mA, many transducers can obtain power directly from two lines, simplifying wiring connections.
- Because the 0 point and full scale from different transducers constitute similar signals, it is easy to quantify the conversion correlations on a unitary basis.

As a result, many process control instruments incorporate analog 4 mA to 20 mA dc input measurement modules.

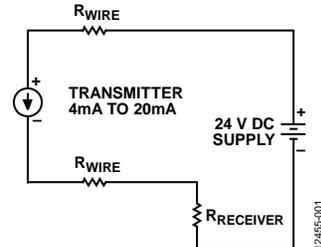


Figure 1. Current Loop Schematic

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REVISION HISTORY

7/14—Revision 0: Initial Version

HARDWARE DESIGN

This section explains the hardware design of the 4 mA to 20 mA current loop sensing with the [ADE7912/ADE7913](#).

For measuring an analog 4 mA to 20 mA current signal, an ADC and an isolated power supply module are required. A diagram of the traditional solution that uses an SPI communication interface is shown in Figure 2.

Sampling resistance is employed to convert a 4 mA to 20 mA signal to a voltage signal, and an analog-to-digital converter (ADC) then converts the voltage signal to a digital signal. Because most interface circuits on industrial equipment require isolation, an isolated dc-to-dc power supply must provide power exclusively to the ADC. Because the ADC ground is isolated from the microcontroller ground, a batch of high speed digital isolators are placed in the communication path. As an example, Figure 2 shows four isolated channels for an SPI communication. Thus, the measurement system requires three

major components: an ADC, an isolated power supply, and a batch of high speed digital isolators.

Compared with the traditional platform, the [ADE7912/ADE7913](#) isolated ADCs contain all the core elements of a traditional solution. As shown in Figure 3, the [ADE7912/ADE7913](#) integrate the isolated power supply and the signal isolation circuits.

The operating temperature range of the [ADE7912/ADE7913](#) is -40°C to $+85^{\circ}\text{C}$, the temperature requirements of the industrial process control. The dynamic range of the analog 4 mA to 20 mA is 5:1. The [AN-1304 Application Note, ADE7912/ADE7913 DC Measurement Performance](#), provides a typical temperature coefficient of the dc measurements for a dynamic range of 10:1 equal to 62 ppm/ $^{\circ}\text{C}$. Thus, 62 ppm/ $^{\circ}\text{C}$ is considered the typical temperature coefficient of the analog 4 mA to 20 mA dc measurement.

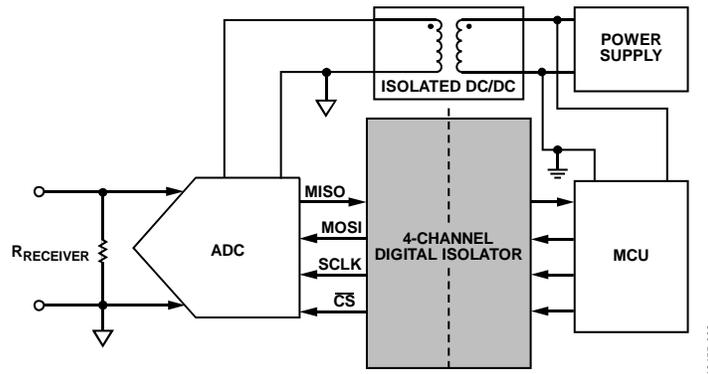


Figure 2. Block Diagram of a Traditional 4 mA to 20 mA DC Input Measurement Circuit

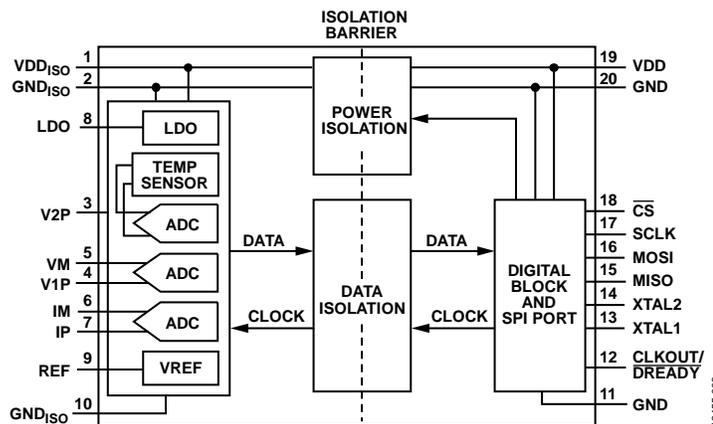


Figure 3. Block Diagram of the [ADE7912](#)

Using the [ADE7912/ADE7913](#), the 4 mA to 20 mA current loop sensing schematic can be simplified as shown in Figure 4. It is recommended to use the V1 channel for this measurement; therefore, the analog signals are provided at the V1P input.

Note that the three circuit blocks needed in a traditional 4 mA to 20 mA dc input measurement element have been simplified into a single chip, and no other auxiliary circuits are needed.

Additionally, the [ADE7912/ADE7913](#) can be cascaded in groups of four ICs maximum that share one crystal and one SPI bus. This feature is useful because usually more than one 4 mA to 20 mA current loop must be sensed in one application.

CALIBRATION AND MEASUREMENT PROCEDURES

To obtain one 4 mA to 20 mA dc measurement, read the V1WV register at least 100 times in 1 second. The measurement result is the average of these readings.

To prepare the [ADE7912/ADE7913](#) for the 4 mA to 20 mA dc measurement, the IC must be calibrated as a two-step process.

1. Supply a calibrated 4 mA signal. Read the V1WV register at least 100 times in 1 second. The average of the readings constitutes the A value.

2. Supply a calibrated 20 mA signal. Read the V1WV register at least 100 times in 1 second. The average of the readings constitutes the B value.

When a general analog 4 mA to 20 mA signal is measured, average 100 readings over 1 second to obtain the C value and use the following formula to calculate the current value, x:

$$x = \frac{16 \times C + 4 \times B - 20 \times A}{B - A}$$

MEASUREMENT PROCEDURE: 4 mA TO 20 mA

To assess the performance of the [ADE7912/ADE7913](#) in 4 mA to 20 mA current loop applications, an evaluation platform was utilized (see Figure 5). The [AD5421](#) is a complete, loop powered, 4 mA to 20 mA digital-to-analog converter (DAC) designed to meet the needs of smart transmitter manufacturers in the industrial control industry.

The [AD5421](#) is guaranteed monotonic to 16 bits. It provides 0.0015% integral nonlinearity, 0.0012% offset error, and 0.0006% gain error under typical conditions. The following testing scenario uses the [AD5421](#) evaluation kit as a 4 mA to 20 mA outputting source, and the [ADE7913](#) evaluation kit sets the measurement device.

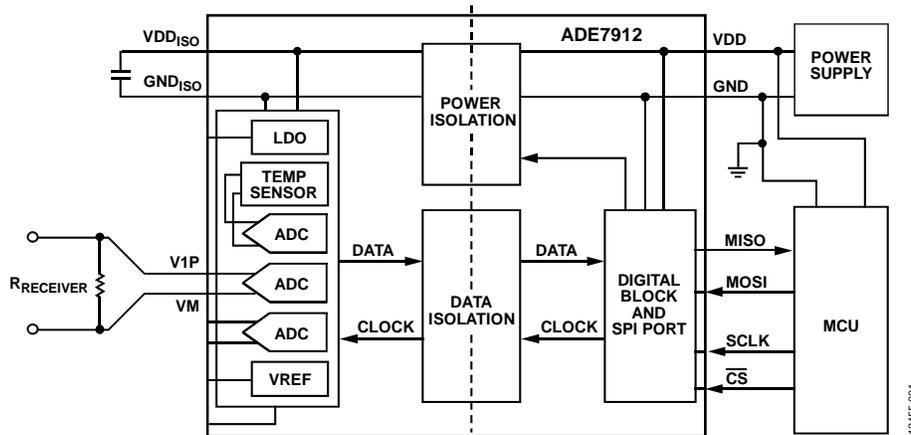


Figure 4. Block Diagram of a 4 mA to 20 mA DC Input Measurement Circuit Using the [ADE7912/ADE7913](#)

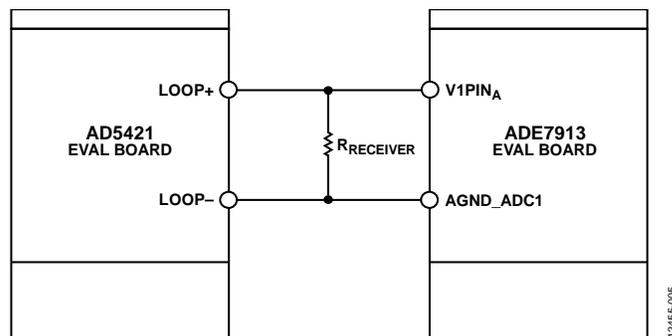


Figure 5. Block Diagram of 4 mA to 20 mA Measurement

An external resistor, $R_{RECEIVER} = 15.1 \Omega$, was used to sense the current value, and its outputs were connected to the V1 channel of the ADE7913. The testing procedure consisted of generating controlled current values from the AD5421 evaluation board and using the ADE7913 for sampling.

Figure 6 shows the ADE7913 outputs obtained for different dc inputs. To measure the linearity of the ADC outputs, calculate the nonlinearity errors (see Figure 7). The goal is for these errors to be very small; thus the calibration procedure is greatly simplified. A line was traced between the 4 mA and 20 mA readings, and errors were computed in relation to the ADC outputs.

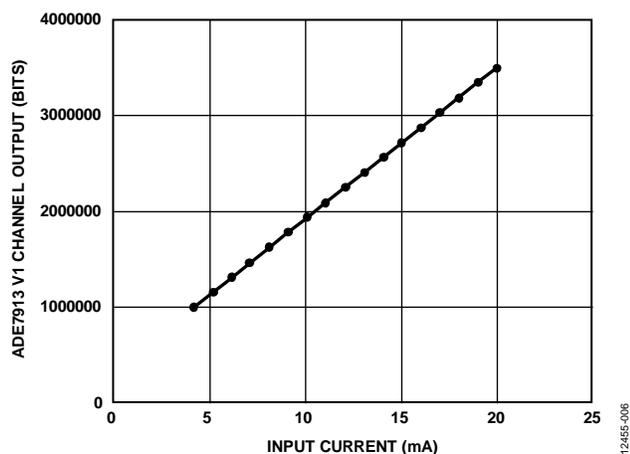


Figure 6. ADE7913 Readings with Different DC Inputs

The ADE7912/ADE7913 exhibit less than 0.04% nonlinearity error over the full range of 4 mA to 20 mA (see Figure 7).

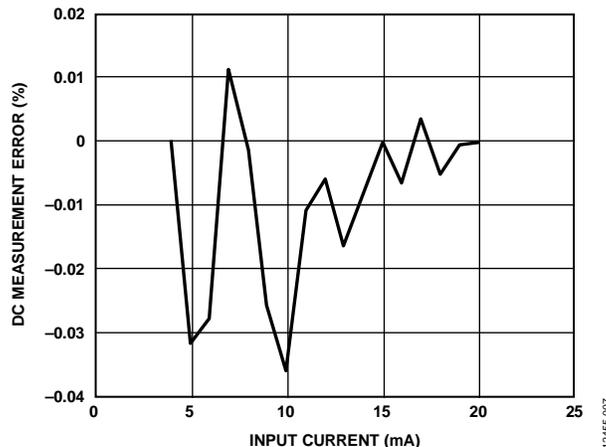


Figure 7. Nonlinearity Error of the ADE7912/ADE7913

CONCLUSION

The ADE7912/ADE7913 are fully isolated ADCs that can perform analog 4 mA to 20 mA current loop measurements. Because the ADC is integrated with the isolated dc-to-dc converter and the digital isolators into a single chip, the circuit design is greatly simplified. This enhances the reliability of the system. The nonlinearity error is under 0.04% for a 5:1 dynamic range at room temperature, which simplifies the calibration procedure.