APPLICATION NOTE
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NCV77320 Dual 180 mm Linear Sensor Reference Design

AND90414/D

Introduction

This application note presents the characterization and performance evaluation of a dual 180 mm inductive linear position sensor implemented using the NCV77320. The complete sensor design files are available as reference design on the NCV77320 product page at www.onsemi.com.

The scope of this document includes calibration procedure and results, piecewise-linear (PWL) linearization data, and detailed measurements of linearity and accuracy. Performance is evaluated across multiple mechanical configurations, with particular focus on varying airgaps. These tests are intended to demonstrate the robustness of the sensor architecture and to validate its suitability for precise position-sensing applications operating under real-world mechanical tolerances.

Sensor Design

The sensor is implemented on a 4-layer PCB, with the excitation and receiver coils routed on the bottom two layers, while the upper two layers are dedicated to signal routing and component placement. The PCB has a total thickness of 1.5 mm, including a 1.2 mm core separating the inner layers. An overview of the sensor layout is shown in Figure 1, and a 3D rendering of the sensor from the PCB design tool is provided in Figure 2. The design incorporates two fully independent coil structures (two excitation coils and two sets of receiving coils), which are galvanically isolated from each other to support enhanced functional safety, potentially up to ASIL D when combined with appropriate system-level diagnostics.

In this evaluation, the analog output interface is used; however, a SENT interface can also be enabled by populating the required filter components at R2, C2, C3 and R4, C7, C8. Although the NCV77320 supports SPI communication, this PCB revision does not utilize the SPI interface, and the SPI pins are therefore tied to ground.

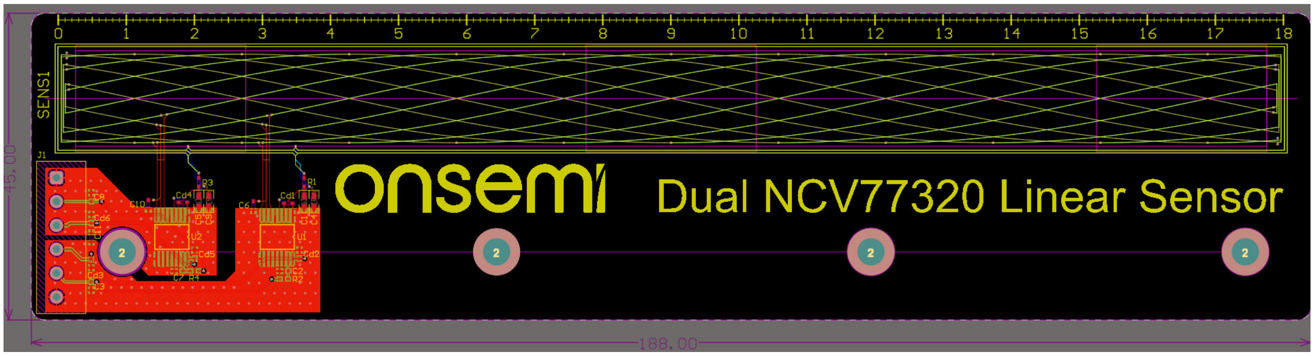


Figure 1. Layout of the Stator PCB

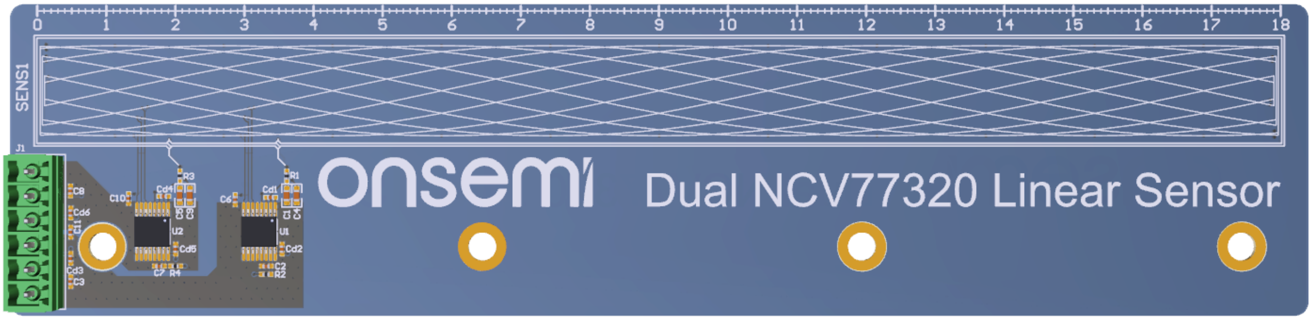


Figure 2. 3D Model of the Sensor as Displayed in the PCB Design Software

Test Setup

The evaluation was performed using a dedicated test bench equipped with a linear actuator. The actuator consists of a precision ball-screw mechanism driven by a stepper motor, enabling controlled motion of a mounting block along the X-axis of the sensor. An aluminum target, made from a 2 mm x 25 mm flat bar, is attached to the mounting block. The airgap between the target and the sensor PCB can be adjusted directly on the fixture. The complete setup is shown in Figure 3.

With this target geometry, the sensor supports a usable measurement range of approximately 150 mm. This ensures a clearance of 2.5 mm between the target and the ends of the receiver coil structure at both extremes of travel. Extending the target beyond the receiver coil pattern is not recommended, as the effective sensing range must remain less than or equal to the receiver coil length minus the target width to maintain the signal strength.

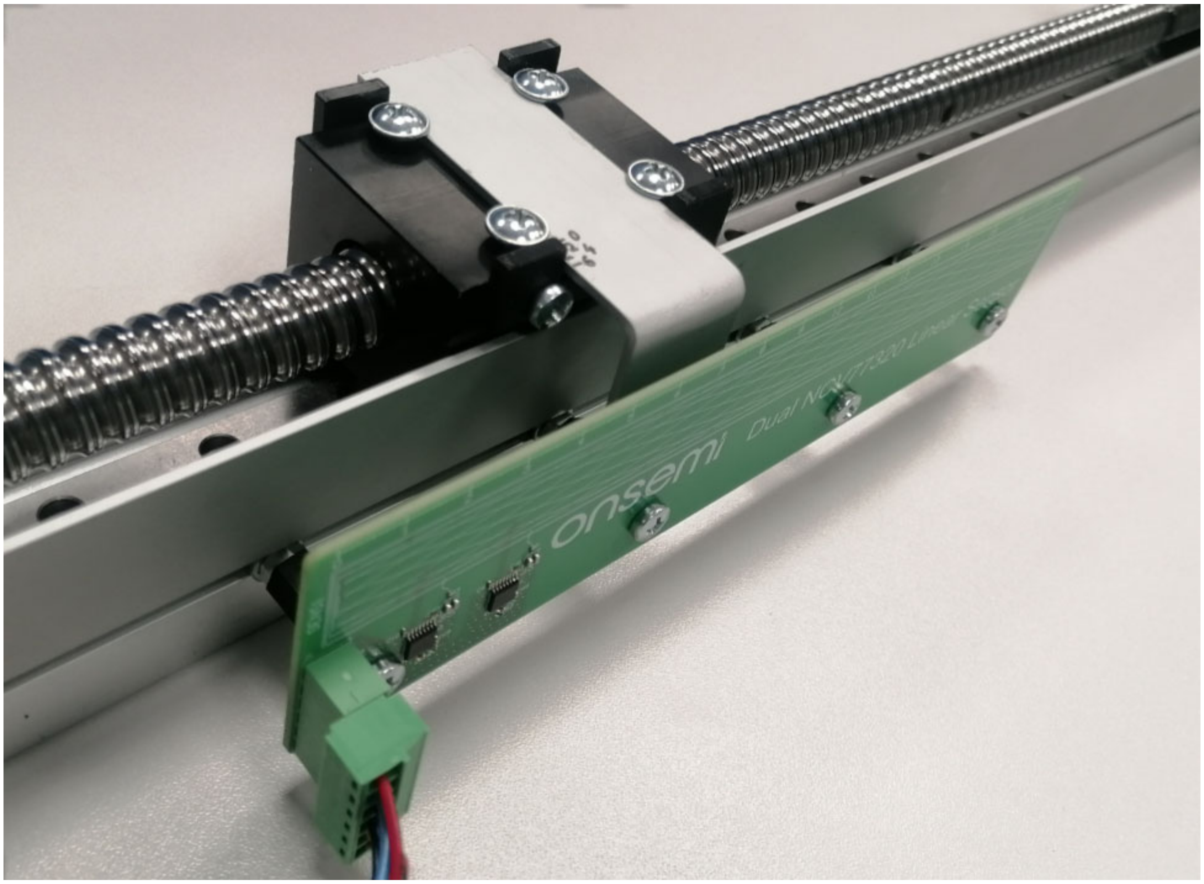


Figure 3. The Sensor Mounted at Test Bench Linear Actuator

Calibration and Measurements

The sensor’s V_REC (input voltage amplitude) was measured across airgaps ranging from 2 mm to 6 mm, with the results summarized in Table 1. The nominal airgap selected for calibration is 4 mm, providing sufficient mechanical tolerance of ±1 mm or even more while maintaining signal amplitudes above the 4 mV minimum specified in the NCV77320 datasheet.

Table 1. V_REC INPUT VOLTAGE AMPLITUDE VS. AIRGAP

Airgap [mm]	Vrec Amplitude [mV]
2	23.5 – 29
3	18 – 23
4	13.5 – 17
5	11 – 13.5
6	7.5 – 10

Sensor calibration was performed using a standard DCC (Direct Coupling Compensation) with no target present. The resulting calibration coefficients are listed in Table 2 and were held constant for all subsequent measurements. The improvement in linearity achieved through this calibration is illustrated in Figure 4. Additional details on the calibration procedure can be found in application note AND90226/D. For linear sensors, DCC calibration without the target is the recommended approach; PWL linearization may then be applied if further correction is required. The full-circle calibration method described in AND90226/D applies only to rotary sensor designs.

Table 2. CALIBRATION COEFFICIENTS FOR LINEAR SENSOR MOUNTED IN THE TEST SETUP

	CHIP	dcc_pwr [2:0]	dcc_c23 [6:0]	dcc_sgn23	dcc_c12 [6:0]	dcc_sgn12
DCC without the target outside of the actuator assembly	CH1	5	15	1	86	0
	CH2	4	26	0	67	0
DCC without the target with the actuator assembly	CH1	5	28	1	98	0
	CH2	4	22	0	82	0

It is important to note that the calibration coefficients are influenced by nearby metal components in the actuator assembly, as indicated in Table 2. For this reason, DCC calibration must be performed in the final mechanical configuration to achieve optimal accuracy. Reusing coefficients across completely different assemblies is not recommended. However, the same coefficients obtained during the evaluation phase may be reused across multiple units, provided they share the same PCB design and identical mechanical assembly. The resulting impact of calibration on sensor linearity is shown in Figure 4.

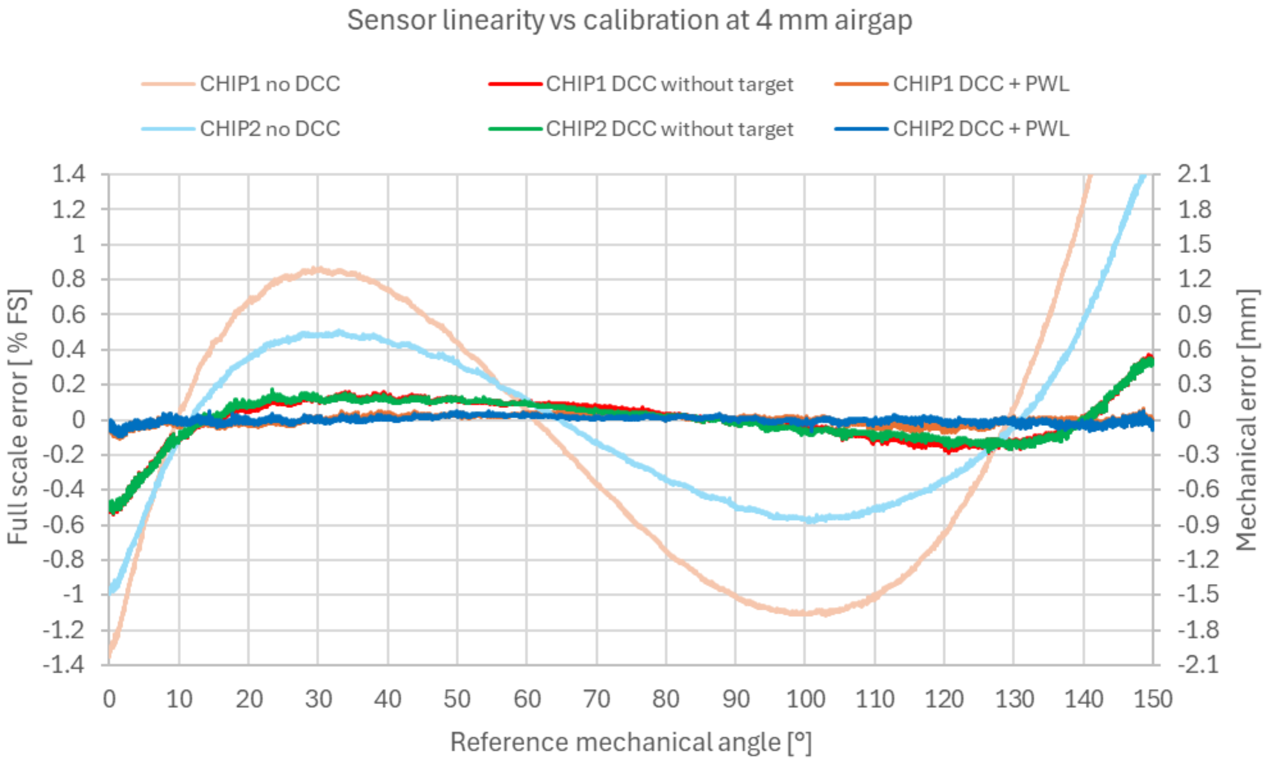


Figure 4. Linearity Measurement

It is evident that a simple DCC calibration without the target improves the sensor accuracy from more than ±1.4% FS to approximately ±0.5% FS (±0.75 mm). Because the residual non-linearity is most pronounced near the ends of the sensor, two approaches can be used to further enhance linearity.

The simplest option is to reduce the effective travel range from 150 mm to approximately 130 mm (e.g., from 10 mm to 140 mm). As shown in Figure 4, limiting the operating range in this way improves the accuracy to better than ±0.2% FS (±0.3 mm).

A better solution, without reducing the sensing range, is to apply the 15-point PWL (piece-wise-linear) correction available in the NCV77320. Examination of the green and red curves reveals three distinct linear regions: 0–10 mm, 25–130 mm, and 140–150 mm. To achieve optimal linearization, most PWL points should therefore be concentrated in the transition regions between 10–25 mm and 130–140 mm, where the non-linearity is most pronounced. The calculated PWL points for this test setup are listed in Table 3.

Before defining the PWL points, verify that the sensor output stays within a single electrical turn across the full travel range of the target. This ensures there is no abrupt high-to-low or low-to-high transition that would indicate crossing an electrical-turn boundary. If necessary, the position can be shifted by programming the pos_shift[15:0] register.

Additionally, it is recommended to program a unity-gain transfer function into the NCV77320. This sets the first PWL point to [0,0] and the second to [65535,65535], allowing the X-coordinates of the PWL table to be sampled directly as pos_out values without additional scaling, because pos_adj[15:0] = pos_out[15:0]. This approach was used for the X-values shown in Table 3: the target was positioned at each intended PWL location, and both the reference position and the corresponding pos_out value were recorded. The procedure was repeated for all 11 points. The X-coordinates of the PWL table must be programmed in ascending order, so it is recommended to acquire the sample points in the same sequence.

Table 3. CALCULATED CORRECTION 11-POINT PWL TABLE

Reference position [mm]	–	150	140.01	135	129.99	25.01	20.01	15	10.01	0	–
Reference position [%]	–	100	93.34	90	86.66	16.67	13.34	10	6.67	0	–
Position output [% FS]	95.00	95.00	89.01	86.00	82.99	20.01	17.01	14.00	11.01	5.00	5.00
CH1	X0	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
	0	6405	10067	11875	13638	50063	51818	53589	55394	59085	65535
	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
	62258	62258	58330	56360	54390	13111	11145	9175	7213	3277	3277
CH2	X0	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
	0	5932	9609	11402	13163	49608	51368	53135	54928	58630	65535
	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
	62258	62258	58330	56360	54390	13111	11145	9175	7213	3277	3277

To calculate the output (Y) values, the output range must first be defined. Because the analog driver is not fully rail-to-rail, the usable range is limited to 5–95% of the full-scale output as mentioned in the datasheet. This corresponds to an effective span of 90% of the 16-bit range, resulting in a usable digital resolution of 65535 * 0.9 = 58981.

Here is an example for the Y4 point on CH2:

Target was positioned at 129.99 mm, which corresponds to 86.66 % of the sensor travel range. The position output is calculated as

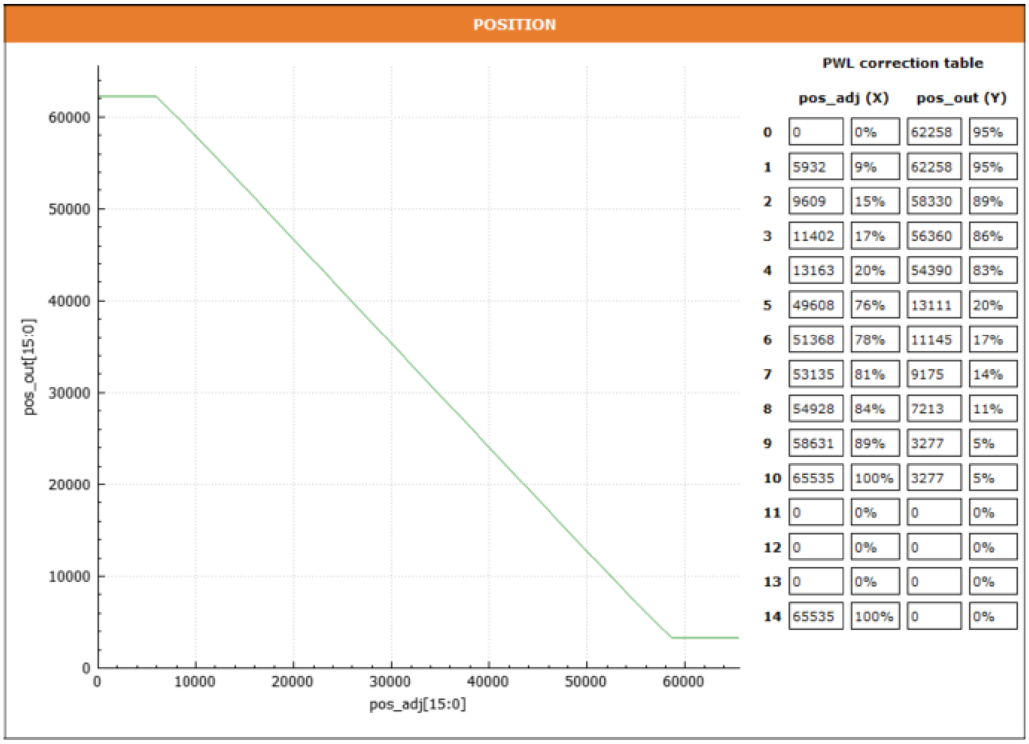
$$\textbf{Position output}\left[\%\ \textbf{FS}\right] = \left(\text{output range }\% \cdot \text{reference position }\% + \text{low limit }\%\right) \qquad \text{(eq. 1)}$$

The position output (Y4 point) is then calculated as Position output [% FS] * 65535

$$\textbf{Y4} = (0.9 \cdot 0.8666 + 0.05) \cdot 65535 = 54390 \qquad \text{(eq. 2)}$$

The first PWL X-point (X0) is always **0**, and the final X-point (X10 in this case) must be **65535**, which corresponds to the maximum 16-bit value. The resulting transfer function for CH2, programmed using the evaluation-kit software, is shown in Figure 5.

After calibration, the sensor output was sampled with a 16-bit ADC ratiometrically to the VCC supply voltage and plotted against the reference position, as shown in Figure 6, resulting in a highly linear transfer function.



PWL correction table

	pos_adj (X)		pos_out (Y)	
0	0	0%	62258	95%
1	5932	9%	62258	95%
2	9609	15%	58330	89%
3	11402	17%	56360	86%
4	13163	20%	54390	83%
5	49608	76%	13111	20%
6	51368	78%	11145	17%
7	53135	81%	9175	14%
8	54928	84%	7213	11%
9	58631	89%	3277	5%
10	65535	100%	3277	5%
11	0	0%	0	0%
12	0	0%	0	0%
13	0	0%	0	0%
14	65535	100%	0	0%

Figure 5. Programmed PWL (transfer function) for CH2

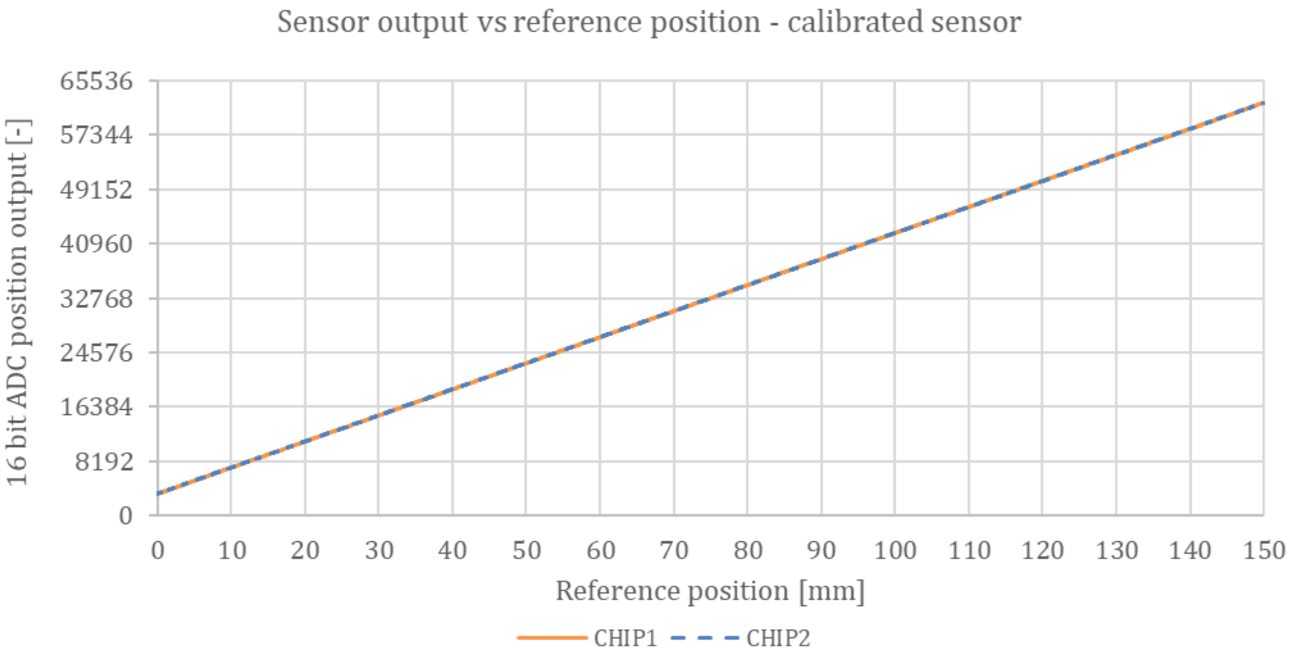


Figure 6. Position Output via Analog Interface Sampled via 16-bit ADC vs. Reference Position

To evaluate the sensor accuracy, measurements taken at 3 mm and 5 mm airgaps were referenced to the ideal output of the calibrated sensor at the nominal 4 mm airgap. The resulting accuracy for an airgap variation of ±1 mm is ±0.26% of full-scale, or ±0.39 mm, as shown in Figure 7. The error is largest near the ends of the sensor coil structure; therefore, limiting the usable sensing range to 130 mm (from 10 mm to 140 mm) can further improve the accuracy under ±1 mm airgap variation to within ±0.12% of full-scale, corresponding to ±0.18 mm.

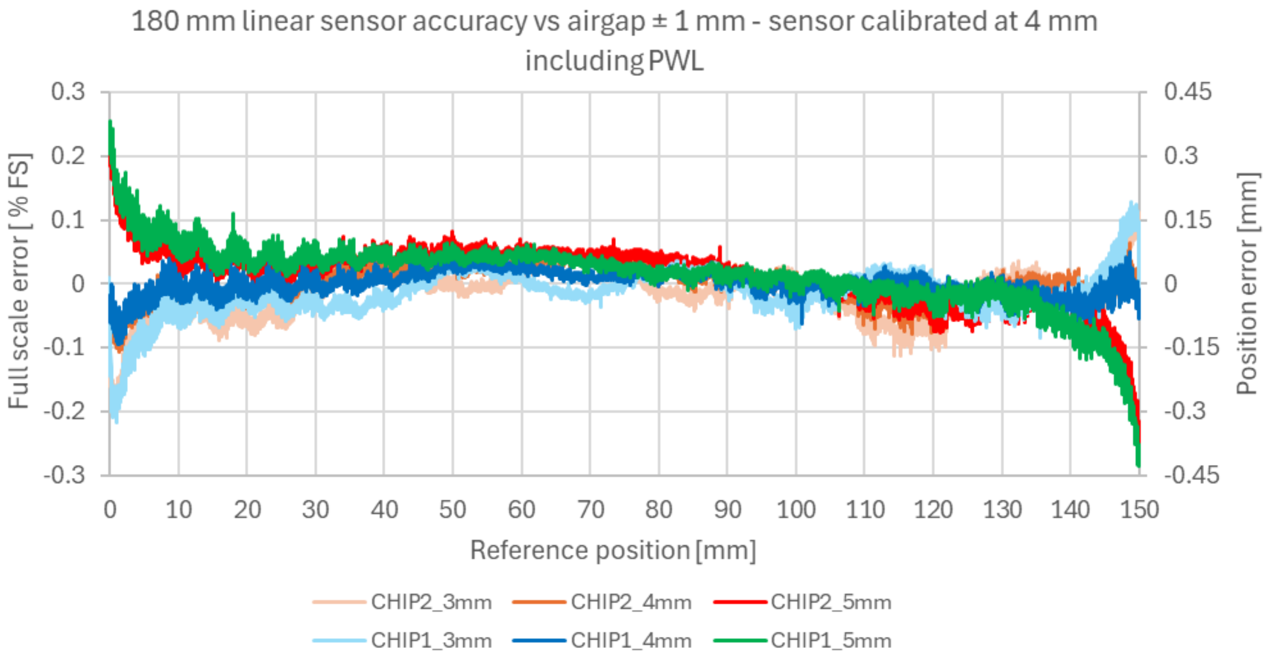


Figure 7. The Accuracy Measurement for the Sensor Calibrated and Linearized at 4 mm, Airgap ± 1 mm

Summary

This document demonstrates the accuracy performance of the NCV77320_dual 180 mm linear sensor paired with two NCV77320 devices over mechanical displacement in the Z-axis (airgap). The target used for evaluation is a 25 mm-wide aluminum plate with a length exceeding the width of the coil structure in the Y-axis. As a result, the sensor is effectively insensitive to the displacement in the Y-axis as long as the target continues to fully cover the coil structure. The target may even be slightly smaller, provided that the minimum signal amplitude remains above 4 mV throughout the entire travel range.

The sensor is implemented on a 4-layer PCB, with excitation and receiver coils located on the bottom two layers. Consequently, the target should be positioned on the bottom side of the PCB for proper operation. Although it is technically possible to place the target on the top side as well, doing so reduces the maximum achievable airgap by the thickness of the PCB and is therefore not recommended.

REVISION HISTORY

Revision	Description of Changes	Date
0	Initial document release.	4/8/2026

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