APPLICATION NOTE 7130

PRESSURE SENSOR USING THE MAX11254 ANALOG TO DIGITAL CONVERTER

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Abstract: This application note discusses the exceptional performance of the MAX11254 for pressure sensor applications thanks to its attractive features including multiple differential input channels, low noise, high internal programmable gain amplifiers, and low power consumption.

Introduction

A pressure sensor measures the force applied to a unit area, such as gas, liquid, or a body of force on a certain platform like a mattress. A pressure sensor acts as a transducer and generates an electrical signal in terms of voltage that corresponds to the force that it is exposed to. This output voltage is typically very low within the millivolt range. To capture this low voltage signal, a very sensitive and accurate device such as the MAX11254 analog-to-digital converter (ADC) is essential.

MAX11254 ADC Essential Features

The MAX11254 is a 6-channel, 24-bit delta-sigma ADC that achieves exceptional performance while consuming only 2.2mA in operating mode and 1µA in sleep mode. Sample rates up to 64ksps allow precision DC measurements. Additionally, the internal programmable gain differential amplifier (PGA) is low noise at only 6.2nV/√Hz and is programmable from 1 to 128, which makes it an ideal device for measuring a pressure sensor with a very low output voltage signal.

The input-referred noise of the MAX11254 is at least 13 times lower at the low sample rate of 50sps (0.81µVRMS) than at the higher sample rate of 12.8ksps (10.8µVRMS). **Table 1** shows the noise data of the MAX11254 in single-cycle conversion mode from the MAX11254 data sheet.

Table 1. Noise vs. PGA Mode and Gain (Single-Cycle Conversion) (μV_{RMS})

	PGA: 1		2		4		8		16		32		64		128	
Data Rate (sps)	**LP**	**LN**	**LP**	**LN**	**LP**	**LN**	**LP**	**LN**	**LP**	**LN**	**LP**	**LN**	**LP**	**LN**	**LP**	**LN**
50	0.81	0.58	0.38	0.27	0.18	0.13	0.1	0.07	0.09	0.07	0.08	0.06	0.08	0.06	0.08	0.06
62.5	0.88	0.63	0.48	0.34	0.21	0.15	0.12	0.09	0.09	0.07	0.08	0.06	0.08	0.05	0.08	0.05
100	1.18	0.84	0.61	0.44	0.3	0.21	0.17	0.12	0.12	0.08	0.09	0.07	0.09	0.07	0.1	0.07
200	1.38	0.99	0.68	0.49	0.35	0.25	0.21	0.15	0.15	0.1	0.12	0.08	0.11	0.08	0.11	0.08
400	1.63	1.16	0.85	0.61	0.45	0.32	0.27	0.19	0.19	0.14	0.16	0.12	0.15	0.11	0.16	0.11
800	2.12	1.51	1.1	0.79	0.61	0.43	0.36	0.26	0.27	0.2	0.24	0.17	0.23	0.16	0.23	0.16
1,000	2.38	1.7	1.25	0.89	0.69	0.49	0.41	0.29	0.31	0.22	0.27	0.19	0.26	0.18	0.26	0.19
1600	3.21	2.29	1.67	1.19	0.89	0.64	0.56	0.4	0.41	0.29	0.36	0.26	0.35	0.25	0.49	0.35
3200	4.41	3.15	2.28	1.63	1.25	0.89	0.78	0.55	0.58	0.41	0.51	0.36	0.49	0.35	0.59	0.42
4000	5.18	3.7	2.68	1.91	1.48	1.06	0.91	0.65	0.69	0.49	0.6	0.43	0.58	0.41	0.83	0.59
6400	7.34	5.24	3.83	2.73	2.08	1.48	1.29	0.92	0.98	0.7	0.86	0.61	0.81	0.58	1.16	0.83
12800	10.8	7.74	5.59	3.99	3.01	2.15	1.85	1.32	1.37	0.98	1.23	0.88	1.17	0.83	1.16	0.83

In Table 1, LP is low-power mode and LN is low-noise mode. In LP mode, the device consumes approximately 1mA less than in low-noise mode. However, in LN mode, the device is optimized for low-noise performance and has input-referred noise voltage typically 40% lower than in low power mode.

Based on the noise data in Table 1, the lower the sample rate, the lower the input-referred noise, which implies a higher signal-to-noise ratio (SNR) and signal-to-noise plus distortion (SINAD) values. Hence, the effective number of bits (ENOB) is higher at a low sample rate per the following equation:

$$ENOB = \frac{SINAD - 1.76}{6.02} \qquad \text{(EQ. 1)}$$

The MAX11254 dynamic performance was evaluated. **Figure 1** through **Figure 4** show the ENOB values for single-cycle and continuous modes for sample rates up to 64ksps.

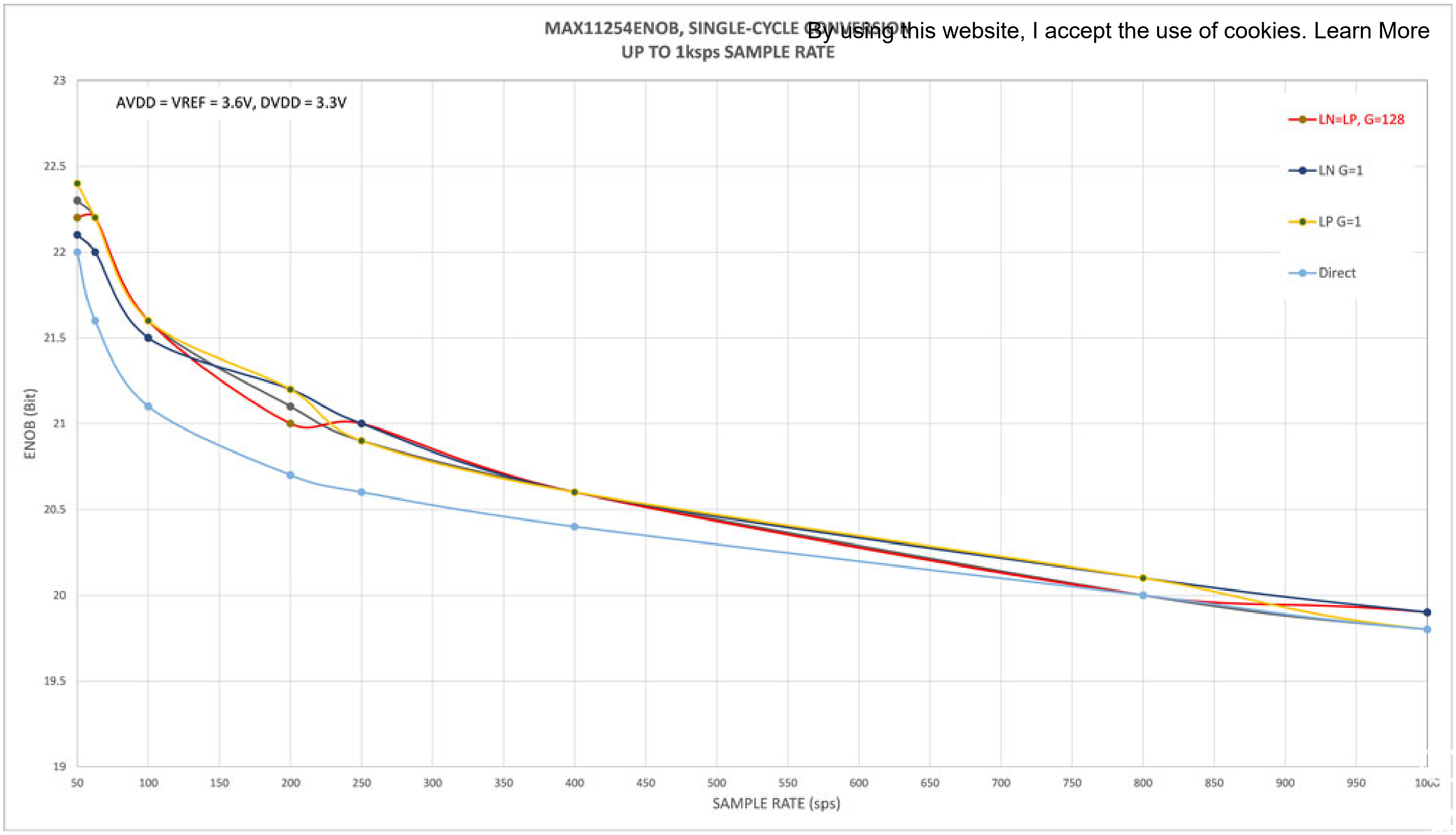

Figure 1. The MAX11254 ENOB values when direct and gain range from 1 to 128 in single-cycle conversion mode with sample rates up to 1ksps.

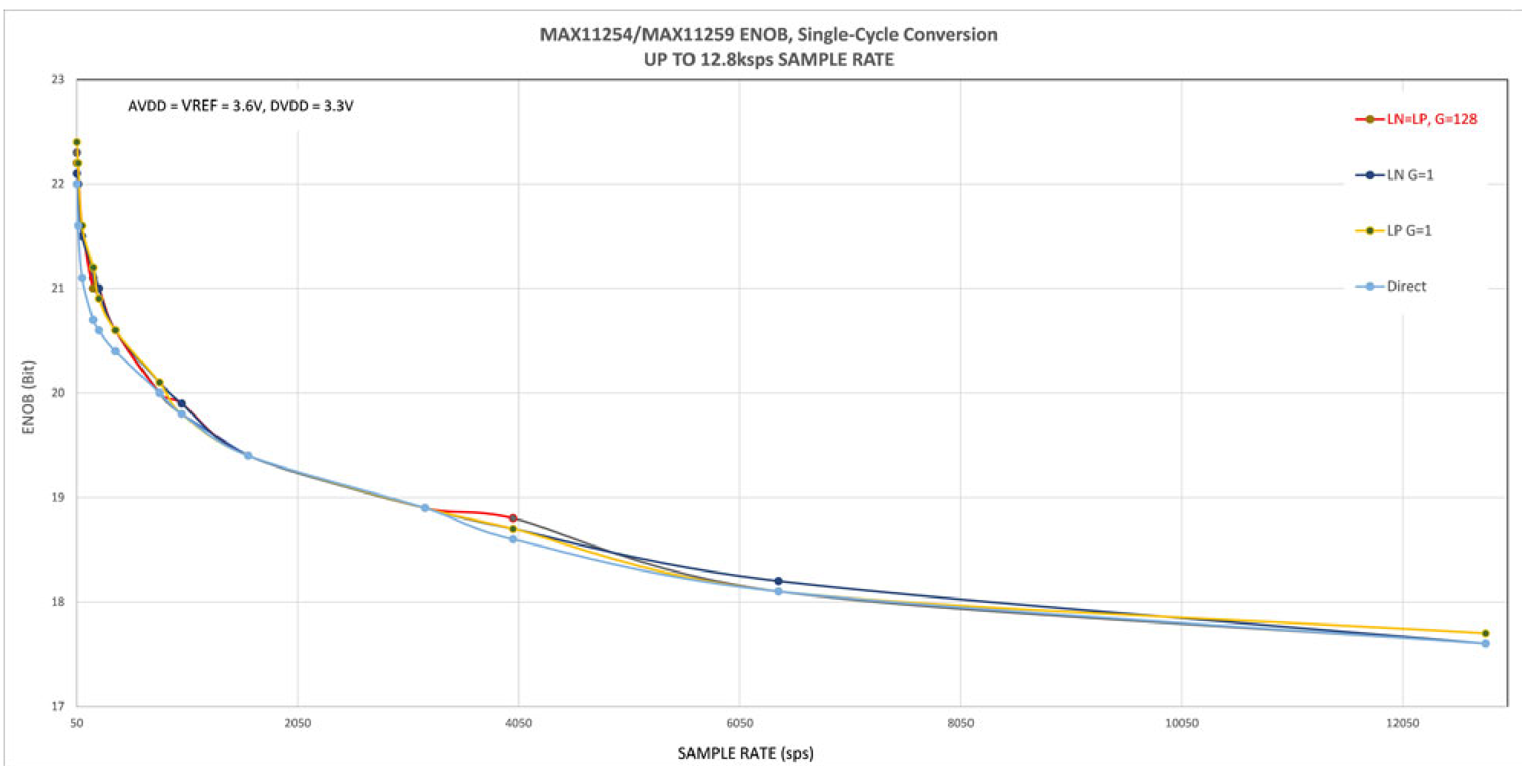

Figure 2. The MAX11254 ENOB values when direct and gain range from 1 to 128 in single-cycle conversion mode with sample rates up to 12.8ksps.

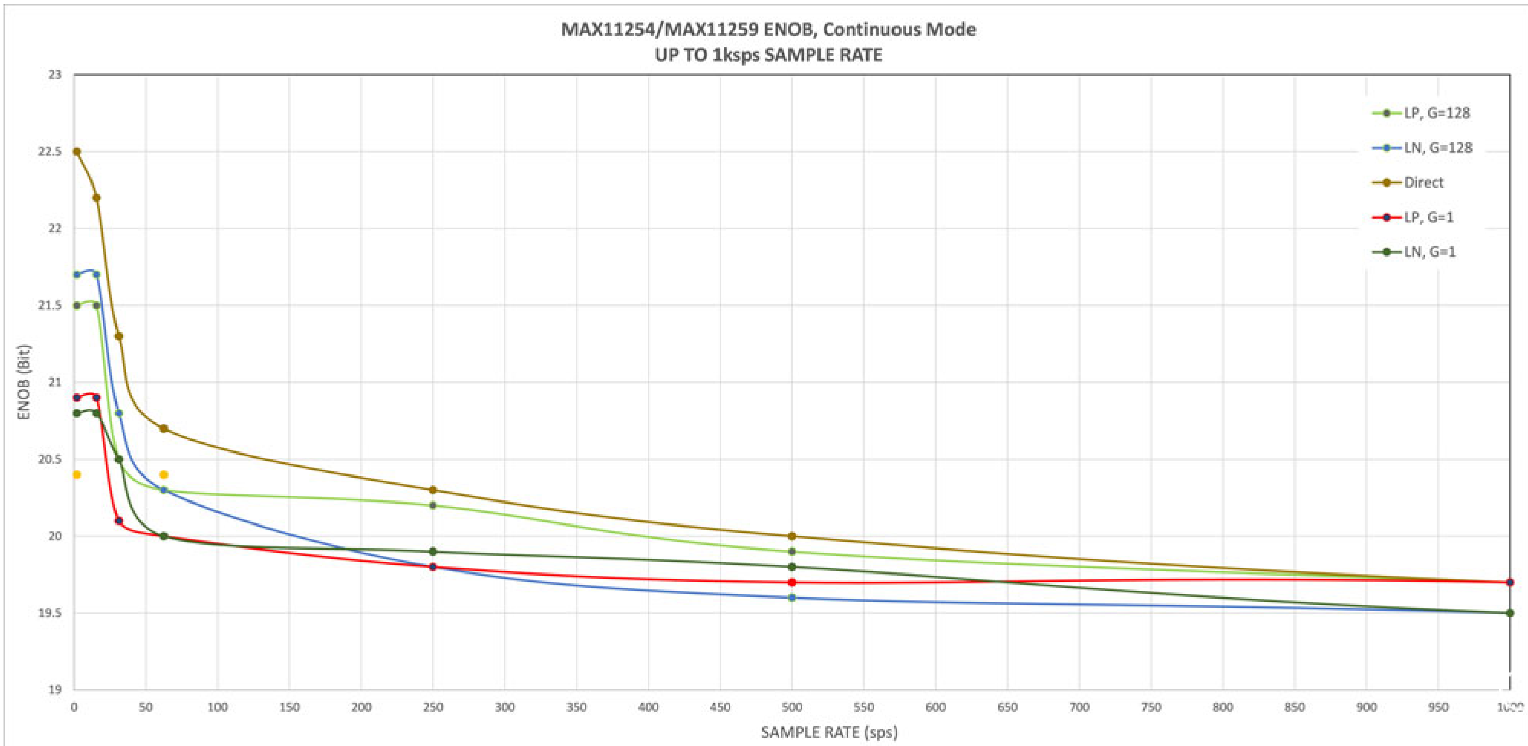

Figure 3. The MAX11254 ENOB values when direct and gain range from 1 to 128 in continuous mode with sample rates up to 1ksps.

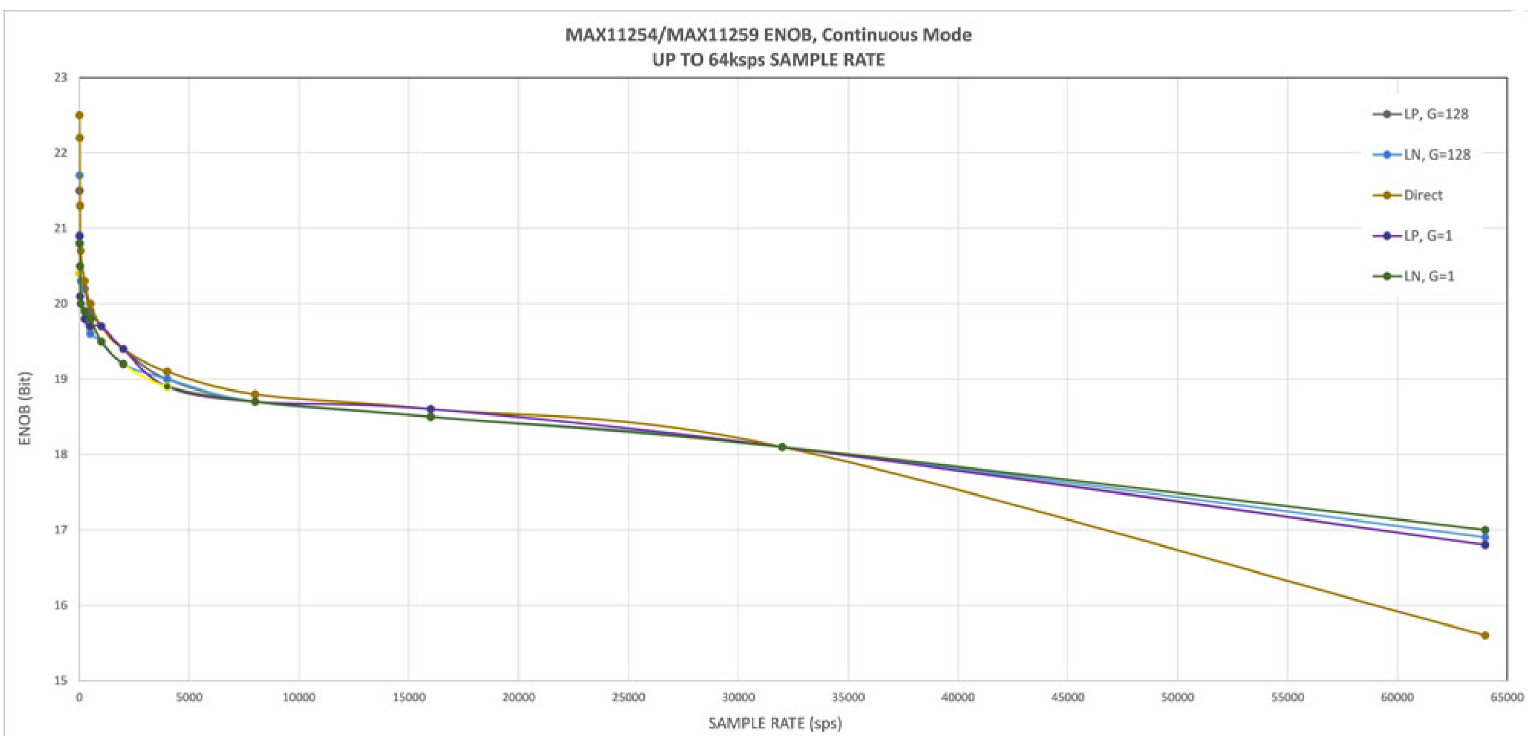

Figure 4.The MAX11254 ENOB values when direct and gain range from 1 to 128 in continuous mode with sample rates up to 64ksps.

The measured data as shown from **Figures 1 to 4** confirm that the ENOB of 22.5 bits is the highest at the lowest sample rate. Based on this measured data, to more accurately capture the low output voltage from pressure sensors, it's best to perform it at lower sample rates. The reason is that the noise is predominantly flat vs. frequency. So, lowering the sample rate proportionally decreases the noise due to narrower bandwidth. Ergo, the ENOB is higher at lower sample rates. Furthermore, because the noise of the PGA is lower than that of the ADC modulator, using PGA typically yields higher ENOB than a bypass or direct mode.

Figure 5 shows the MAX11254 ADC with the MPXV10GC6U configured as a pressure sensor to measure the output voltage from the sensor corresponding to the applied input pressure.

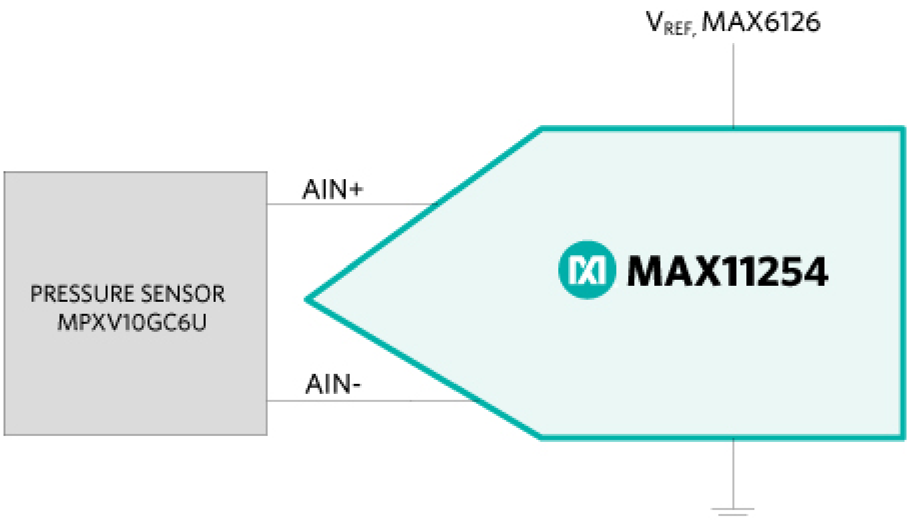

Figure 5. The MAX11254 ADC pressure sensor connection.

At 0 PSI, the output voltage of the pressure sensor indicates 19.998mV on a precision voltage meter, such as the Agilent 34401A. The MAX11254 measured this voltage as 20.034mV.As the pressure is increased up to 1.35 PSI, the MAX11254 captured the corresponding output voltage from the sensor as 53.103mV. **Figures 6** and **Figure 7** illustrate the measured voltage vs. pressure and the captured data on the MAX11254EVKIT software, respectively.

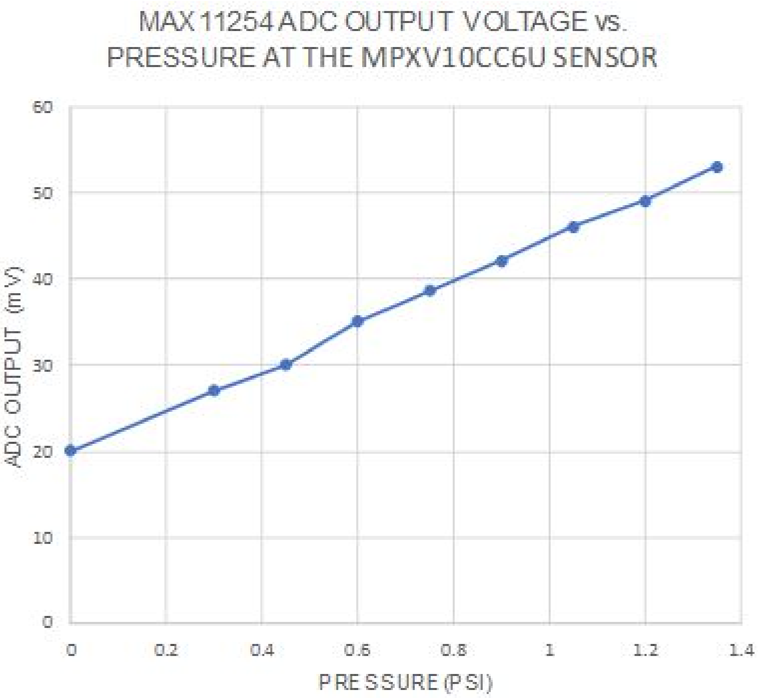

Figure 6. Transfer function of a pressure sensor.

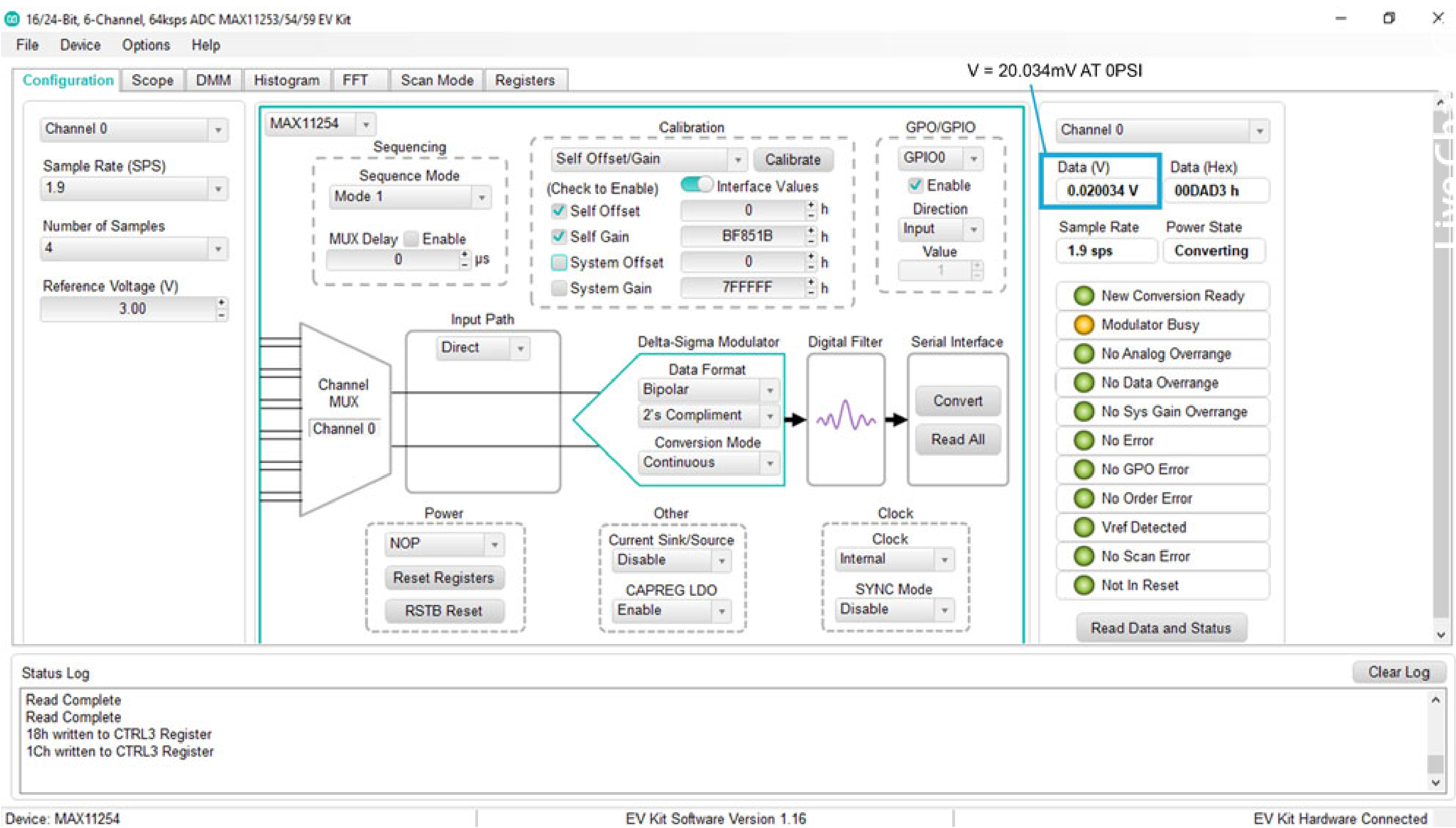

Figure 7. The MAX11254 output voltage at 0 PSI.

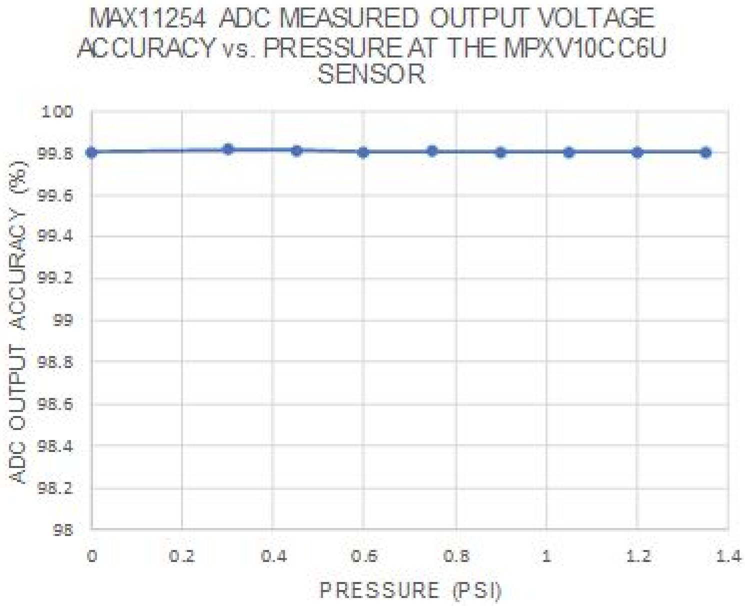

Figure 8. The MAX11254 measured output voltage accuracy vs. pressure at the MPXV10CC6U sensor.

Conclusion

Pressure sensors typically provide very low output voltage in millivolts, which demands low-noise and high-precision ADCs with a wide dynamic range of gain to accurately measure the voltage. The MAX11254 ADC is designed to meet all these stringent requirements since it has an exceptionally low density noise of only 6.2nV/√Hz PGA with gain ranges from 1x to 128x. This internal PGA also provides input signal isolation. Therefore, no other external amplifiers are required to achieve exceptional performance. Furthermore, with the built-in sequencer and the six differential inputs, the MAX11254 supports scanning of selected analog channels, programmable conversion delay, and math operations. This makes it an ideal device for automatic pressure sensor monitoring.

Related Parts		
MAX11254	24-Bit, 6-Channel, 64ksps, 6.2nV/√Hz PGA, Delta-Sigma ADC with SPI Interface	Free Sample
MAX6126	Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference	Free Sample

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