ABP2 SERIES BOARD MOUNT PRESSURE SENSORS
EFFECTIVE NUMBER OF BITS (ENOB)

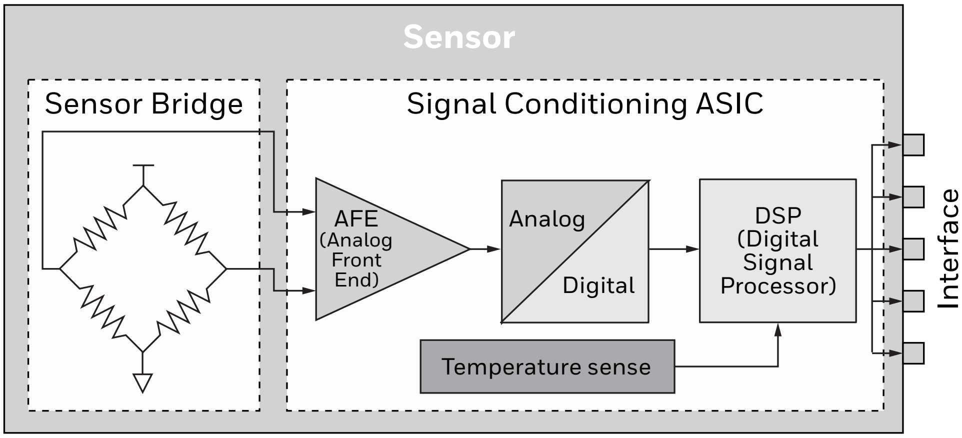
Technical Note

The one source of error found in all systems is noise. Obviously, the higher the noise, the lower the accuracy and resolution. In some systems, such as those used for monitoring very low pressures, noise can be a significant problem. Such low-level measurement designs require a familiarity with noise, its characteristics, and its sources. This Technical Note addresses the low frequency noise that is present in a variety of Honeywell pressure sensors and transducers and provides comparative results.

1.0 INTRODUCTION

For constant DC inputs, the sensor's output error is dominated by so-called "transition" noise, which consists of the broadband thermal noise inherent to the internal ADC (Analog to Digital Converter), such as its drivers and power supplies. If there are no gross DNL (Differential Nonlinearity) issues with the ADC, transition noise produces an approximately Gaussian code distribution at the sensor output.

FIGURE 1: ABP2 SERIES BLOCK DIAGRAM



Similarly, for time-varying inputs, the sensor's output contains dynamic errors, namely, quantization noise and distortion, in addition to the transition noise that degrades the dynamic range. The altered dynamic range is commonly known as SINAD (Signal-to-Noise and Distortion Ratio), and the recomputed sensor resolution is known as ENOB (Effective Number of Bits).

A given sensor may have different resolutions depending on whether the pressure input is steady or sinusoidal. This means that there are separate sensor resolution metrics that correspond to different input conditions:

- ENOB: Time varying inputs
- Effective Resolution (ER): Steady inputs

Deciding which is more appropriate depends on the application.

The sense element and the sensor's signal conditioning components (see Figure 1) all contribute to sensor noise. Other noise sources are:

- Power supply, as previously mentioned
- Pressure input
- Sense resistor
- Environment
- PGA (Programable Gain Amplifier) and ADC system
- Reference voltage

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2.0 TEST SETUP

Five samples each from the three pressure ranges shown in Table 1 were chosen at random for the study. The sensors were calibrated over 10 %FS to 90 %FS counts over their respective pressure and temperature ranges.

During the test, the reference hole and the pressure port were kept open for the gage samples and shorted using a soft silicone tube for the 2 IoWD (inches of water, differential) samples. Tests were conducted under ambient conditions with a nominal room temperature of 26°C. The entire test setup was isolated from the environment in an enclosed metallic chamber to prevent any external noise.

Each sample stayed on for 10 minutes for an initial warm-up and then 10,000 readings were captured at 50 samples per second. The results were then further analyzed, as shown in Table 2.

TABLE 1. TEST CONDITIONS[1,2]

SENSOR SAMPLE GROUP	PRESSURE RANGE	COMMENTS
1-5	0 barG to 12 barG	pressure port open to ambient
6-10	0 IoWD to 2 IoWD	pressure ports shorted
11-15	0 psiG to 1 psiG	pressure port open to ambient

[1] Applied pressure is null.

[2] Applied temperature is 26°C (ambient).

3.0 BACKGROUND CALCULATION [1]

Using the data gathered from the 15 sample sensors, the arithmetic mean of the pressure counts of the individual sensors was calculated and subtracted from their respective original counts. This operation gives the instantaneous noise counts for each sensor:

$$\text{Mean} = (1/N) * \sum_{i=1}^{N} x[i]$$

Where, N is the number of samples and x[i] is the sensor value:

$$\text{Noise} = x[i] - \text{Mean}$$

These noise values may now be used to calculate both ER and ENOB:

$$ER = \log_2 (FSS/Noise_{RMS})$$

Where, FSS (Full Scale Span) is 80% of 2^{24} counts or 13421773 because the sensors under testing were calibrated from 10% to 90% of 2^{24} counts. Noise, in RMS (Root Mean Square), is also expressed in pressure counts.

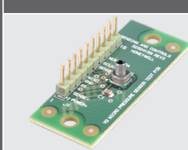
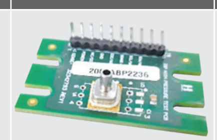
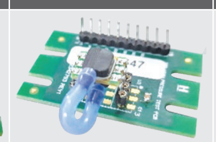
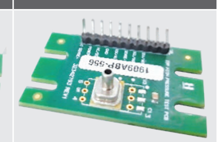
ER should not be confused with ENOB, although the two terms sound similar. Effective resolution and noise-free resolution measure the ADC's noise performance at essentially DC, where spectral distortion is not factored. The most common methodology for measuring ENOB uses an FFT (Fast Fourier Transform) analysis of a sine-wave input to the sensor. However, ENOB is calculated with a steady pressure input.

Similarly,

$$ENOB = \log_2 (FSS/(Noise_{RMS} * \sqrt{12}))$$

4.0 SENSOR SAMPLE COMPARISON (SEE TABLE 3)

TABLE 3. SENSOR SAMPLE COMPARISON[1]

CHARACTERISTIC	MPR SERIES	ABP2 SERIES		
		0 BARG TO 12 BARG	0 IoWD TO 2 IoWD	0 PSIG TO 1 PSIG
				
ER	15	15.81	14.18	14.39
ENOB	14	14.02	12.39	12.59
Noise-free resolution	12.3	13.11	11.69	11.48

[1] It is important when evaluating ADCs to know that the ER and peak-to-peak resolution are calculated differently. The ER gives a value that is greater than the peak-to-peak resolution by 2.7 bits [2].

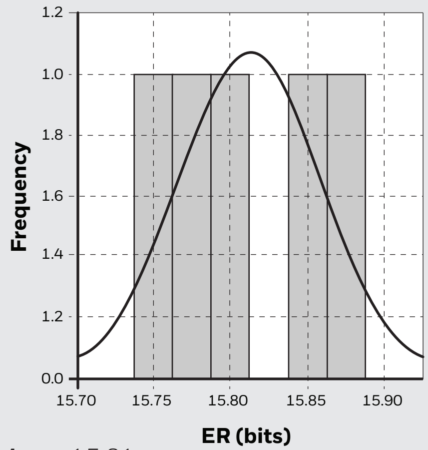
5.0 REFERENCES

[1] Maxim Integrated, "Noise, ENOB and Effective Resiolution in Analog to Digital Converter Circuits," Application Note 5384. Available: www.maximintegrated.com/an5384. [Accessed Jan 18, 2021].

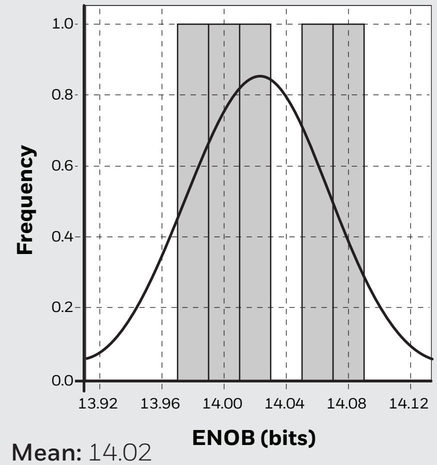
[2] Analog Devices, "Peak-to-Peak Resolution Versus Effective Resolution," Application Note AN-615. Available: www.analog.com/media/en/technical-documentation/application-notes/AN-615.pdf. [Accessed Jan 18, 2021].

TABLE 2. PRESSURE COUNT RESULTS

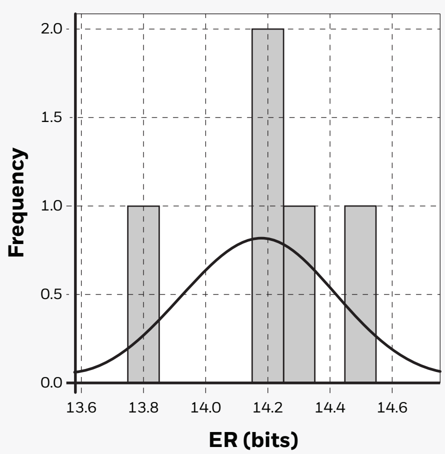
PRESSURE RANGE	SENSOR SAMPLE NUMBER	EFFECTIVE RESOLUTION (ER)	EFFECTIVE NUMBER OF BITS (ENOB)
0 barG to 12 barG	1	15.85	14.06
	2	15.76	13.97
	3	15.80	14.01
	4	15.78	13.99
	5	15.87	14.08
0 loWD to 2 loWD	6	14.22	12.43
	7	13.79	12.00
	8	14.47	12.68
	9	14.25	12.46
	10	14.15	12.36
0 psiG to 1 psiG	11	14.34	12.55
	12	14.39	12.59
	13	14.40	12.60
	14	14.41	12.62
	15	14.40	12.61



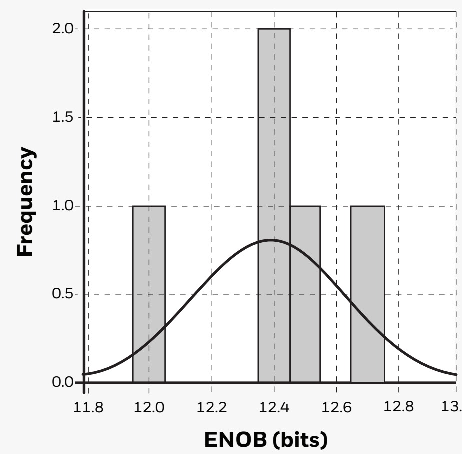
Mean: 15.81
StDev: 0.04658
N: 5



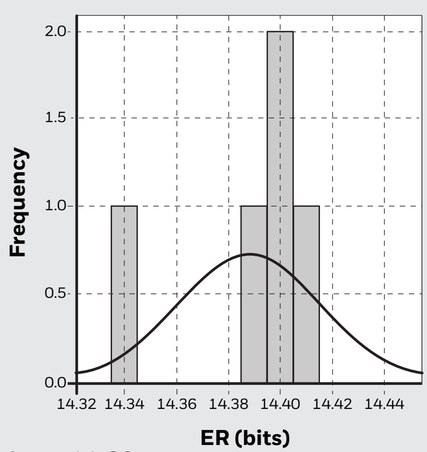
Mean: 14.02
StDev: 0.04658
N: 5



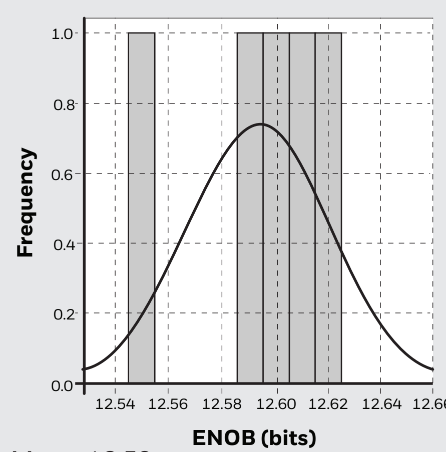
Mean: 14.81
StDev: 0.2426
N: 5



Mean: 12.39
StDev: 0.2467
N: 5



Mean: 14.39
StDev: 0.02775
N: 5



Mean: 12.59
StDev: 0.02702
N: 5

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008352-1-EN | 1 | 03/21

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