Technical Article

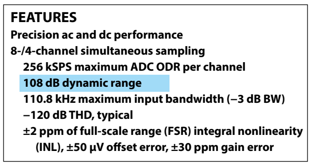
ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

All That Glitters Is Not Gold! Reading Relevant Data Sheet Data to Choose the Right Part

Tejaswini Anand, Product Applications Engineer

Application engineers often repeatedly answer the same questions from different customers, especially queries related to the selection of parts in their application. One mistake we see in part selection happening time and time again is that the customers become over enamored by what I like to call "the sheet" in data sheets. I'm talking about the shiny, glittery, sexy specs. "Wow! That ADC has a high SNR!" This is the story of one such customer who was impressed with one ADC's high SNR but who forgot to consider other important data sheet specs. We will also address common mistakes and how to choose the right parts for your application.

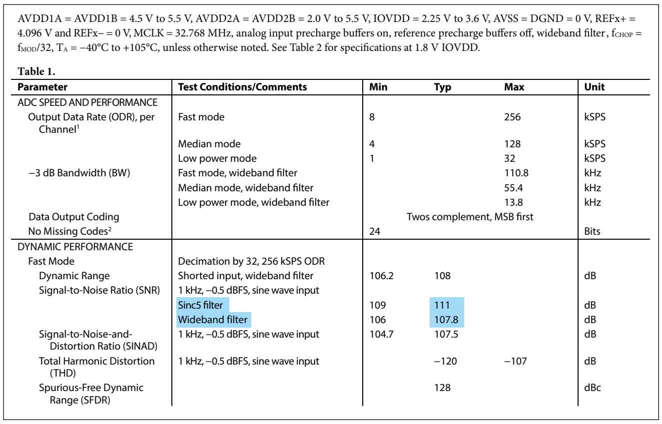
I recently received a customer's case where he wanted a suitable ADC for his seismic- and vibration-related application. He knew he needed an ADC with a high signal-to-noise ratio (SNR) and good total harmonic distortion (THD) for his application and concluded that any SNR above 110 dB is fine. Since vibration sensors output continuously varying ac voltage signal overlapped on a dc voltage signal, we need a very high performance, high resolution ADC that has a high SNR to properly obtain a digitalized version without being affected much by the noise in the vibration-related applications. What customers generally do while choosing parts is that they shortlist them by performing a parametric search of their requirements in third-party websites and just check the front page of each product with their catchy product descriptions and fall for the first page of the data sheet, which describes the product's highlights. Often, data sheets are much more complex and require further investigation beyond the front page highlights. This customer also saw the front page of one the ADI's precision converter ADCs, AD7768, and found its SNR to be just 108 dB (dynamic range and SNR both are a mirror for rms noise and can be treated almost the same as they are proportional).



FEATURES
Precision ac and dc performance
8-/4-channel simultaneous sampling
  256 kSPS maximum ADC ODR per channel
  108 dB dynamic range
  110.8 kHz maximum input bandwidth (−3 dB BW)
  −120 dB THD, typical
  ±2 ppm of full-scale range (FSR) integral nonlinearity (INL), ±50 μV offset error, ±30 ppm gain error

Figure 1. Front page of one of ADI's precision ADC data sheets for the AD7768/AD7768-4.

The customer's reaction was, "Oh! This ADC is definitely not suitable for my application. It has just 108 dB SNR!" On scrolling further down, he found another table, shown in Figure 2, where the SNR for two different filters was shown.



AVDD1A = AVDD1B = 4.5 V to 5.5 V, AVDD2A = AVDD2B = 2.0 V to 5.5 V, IOVDD = 2.25 V to 3.6 V, AVSS = DGND = 0 V, REFx+ = 4.096 V and REFx− = 0 V, MCLK = 32.768 MHz, analog input precharge buffers on, reference precharge buffers off, wideband filter, $f_{CHOP} = f_{MOD}/32$, T_A = −40°C to +105°C, unless otherwise noted. See Table 2 for specifications at 1.8 V IOVDD.

Table 1.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
ADC SPEED AND PERFORMANCE					
Output Data Rate (ODR), per Channel[1]	Fast mode	8		256	kSPS
	Median mode	4		128	kSPS
	Low power mode	1		32	kSPS
−3 dB Bandwidth (BW)	Fast mode, wideband filter			110.8	kHz
	Median mode, wideband filter			55.4	kHz
	Low power mode, wideband filter			13.8	kHz
Data Output Coding			Twos complement, MSB first		
No Missing Codes[2]		24			Bits
DYNAMIC PERFORMANCE					
Fast Mode	Decimation by 32, 256 kSPS ODR				
Dynamic Range	Shorted input, wideband filter	106.2	108		dB
Signal-to-Noise Ratio (SNR)	1 kHz, −0.5 dBFS, sine wave input				
	Sinc5 filter	109	111		dB
	Wideband filter	106	107.8		dB
Signal-to-Noise-and-Distortion Ratio (SINAD)	1 kHz, −0.5 dBFS, sine wave input	104.7	107.5		dB
Total Harmonic Distortion (THD)	1 kHz, −0.5 dBFS, sine wave input		−120	−107	dB
Spurious-Free Dynamic Range (SFDR)			128		dBc

Figure 2. Specifications table of the AD7768/AD778-4.

He concluded, "Okay … I can get 111 dB by using a sinc5 filter. But I recently saw another product from another company that has an SNR greater than 115 dB, I should go with the latter."

Hold on! There's a mistake in this comparison. There is a trade-off between the output data rate (ODR) that determines the speed of operation of the ADC and the SNR that determines the resolution and just how noise free the output is.[1] The higher the ODR, the lesser the SNR, and vice versa. Therefore, each ODR corresponds to a single SNR value. It is important to first identify the output rate needed and then compare ADCs based on the corresponding SNR values. This customer had compared one device with 108 dB SNR at 256 kSPS with another that had an SNR of more than 115 dB at just 1 kSPS ODR. Thus, based on front page data, it appeared that one product had a lesser SNR than the other, and that the latter was better for the application. However, this was not an accurate way to compare the data.

From Figure 3, we can see that with the increase in the ODR, the rms noise also increases and corrupts the digital value, which in turn reduces its SNR. Figure 4 shows a screenshot from the AD7768 data sheet, where we can see SNRs of 123.88 dB and 126.89 dB at 1 kSPS ODR for wideband and sinc5 filters, respectively, which is much higher than that of the competing device at this ODR.

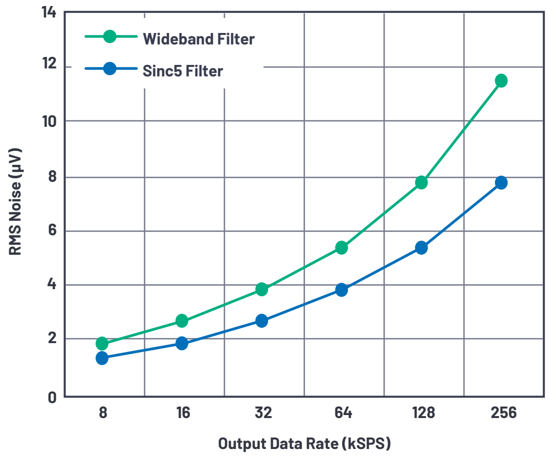


Figure 3. Output data rate vs. rms noise.

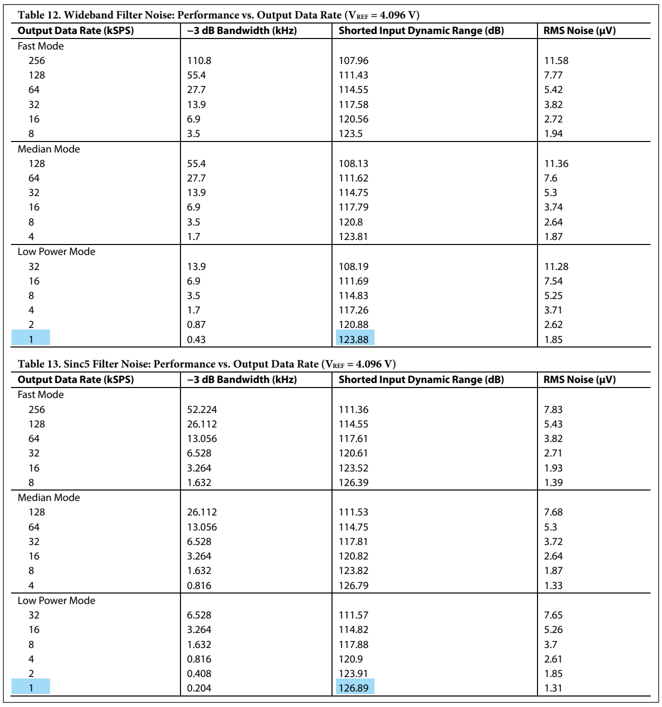


Table 12. Wideband Filter Noise: Performance vs. Output Data Rate (V_{REF} = 4.096 V)

Output Data Rate (kSPS)	−3 dB Bandwidth (kHz)	Shorted Input Dynamic Range (dB)	RMS Noise (µV)
Fast Mode			
256	110.8	107.96	11.58
128	55.4	111.43	7.77
64	27.7	114.55	5.42
32	13.9	117.58	3.82
16	6.9	120.56	2.72
8	3.5	123.5	1.94
Median Mode			
128	55.4	108.13	11.36
64	27.7	111.62	7.6
32	13.9	114.75	5.3
16	6.9	117.79	3.74
8	3.5	120.8	2.64
4	1.7	123.81	1.87
Low Power Mode			
32	13.9	108.19	11.28
16	6.9	111.69	7.54
8	3.5	114.83	5.25
4	1.7	117.26	3.71
2	0.87	120.88	2.62
1	0.43	123.88	1.85

Table 13. Sinc5 Filter Noise: Performance vs. Output Data Rate (V_{REF} = 4.096 V)

Output Data Rate (kSPS)	−3 dB Bandwidth (kHz)	Shorted Input Dynamic Range (dB)	RMS Noise (µV)
Fast Mode			
256	52.224	111.36	7.83
128	26.112	114.55	5.43
64	13.056	117.61	3.82
32	6.528	120.61	2.71
16	3.264	123.52	1.93
8	1.632	126.39	1.39
Median Mode			
128	26.112	111.53	7.68
64	13.056	114.75	5.3
32	6.528	117.81	3.72
16	3.264	120.82	2.64
8	1.632	123.82	1.87
4	0.816	126.79	1.33
Low Power Mode			
32	6.528	111.57	7.65
16	3.264	114.82	5.26
8	1.632	117.88	3.7
4	0.816	120.9	2.61
2	0.408	123.91	1.85
1	0.204	126.89	1.31

Figure 4. Noise performance vs. ODR of the AD7768/AD7768-4.

The following points must be kept in mind before choosing a part:

- It is important to choose the relevant specs suitable to the operating conditions. Before concluding which part is suitable, it is essential to compare V_{REF}, V_{DD}, power consumption, mode of operation, thermal range of operation, and a few other specs. The SNR value itself depends on all of those parameters, which must be decided based on an application's requirements—and the SNR value must be chosen by more than just the first page of the data sheet. Figure 5 shows how the rms noise values—and thus the SNR values—for the AD7768 are different for different V_{REF} voltages and at different temperatures (rms noise is inversely related to SNR). Similar variations can be seen for the other parameters as well.

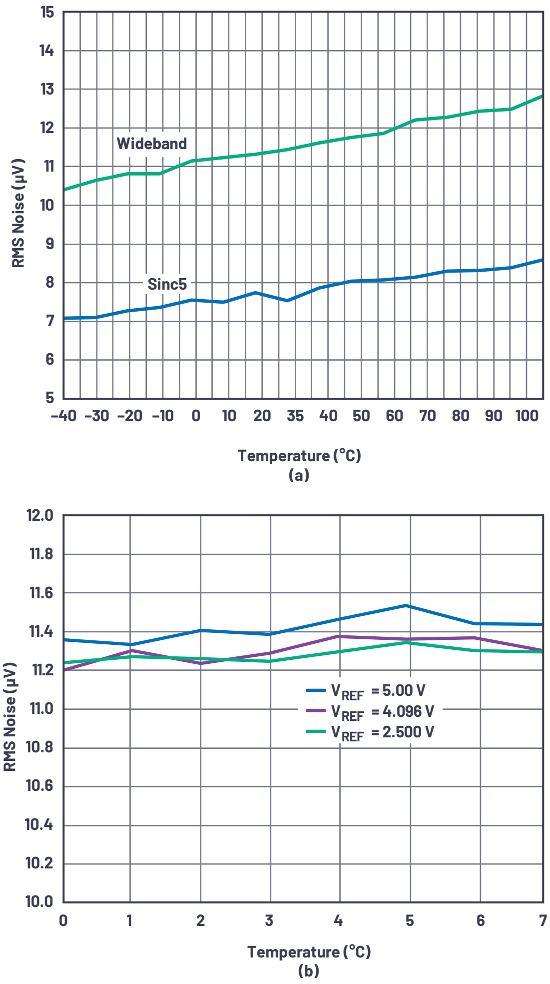
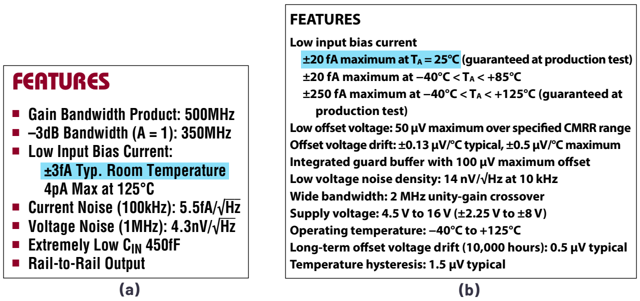


Figure 5. (a) RMS noise vs. temperature, (b) RMS noise per channel for various V_{REF} values.

- The relevent values at all V_{REFS}, ODRs, etc. will not be given in the data sheet, which means we will have to extrapolate the data from the given information to get our required values.
- Be careful while choosing parts. The typical values are different from the minimum and maximum values. While typical values can be expected most of the time, the full range of values must be considered if an application is sensitive to the minimum and maximum values of a given parameter.

Here is another example of a common, but avoidable, misinterpretation. Figure 6 (a) and Figure 6 (b) show the first page of the data sheets for the LTC6268 and ADA4530-1, respectively.



FEATURES

- Gain Bandwidth Product: 500MHz
- –3dB Bandwidth (A = 1): 350MHz
- Low Input Bias Current:
  - ±3fA Typ. Room Temperature
  - 4pA Max at 125°C
- Current Noise (100kHz): 5.5fA/√Hz
- Voltage Noise (1MHz): 4.3nV/√Hz
- Extremely Low C_{IN} 450fF
- Rail-to-Rail Output

(a)

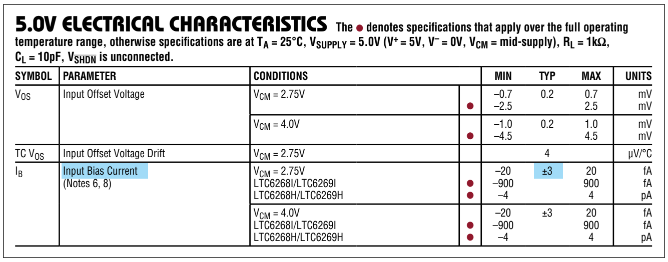
FEATURES

Low input bias current
  ±20 fA maximum at T_A = 25°C (guaranteed at production test)
  ±20 fA maximum at −40°C < T_A < +85°C
  ±250 fA maximum at −40°C < T_A < +125°C (guaranteed at production test)
Low offset voltage: 50 µV maximum over specified CMRR range
Offset voltage drift: ±0.13 µV/°C typical, ±0.5 µV/°C maximum
Integrated guard buffer with 100 µV maximum offset
Low voltage noise density: 14 nV/√Hz at 10 kHz
Wide bandwidth: 2 MHz unity-gain crossover
Supply voltage: 4.5 V to 16 V (±2.25 V to ±8 V)
Operating temperature: −40°C to +125°C
Long-term offset voltage drift (10,000 hours): 0.5 µV typical
Temperature hysteresis: 1.5 µV typical

(b)

Figure 6. (a) Front page of the LTC6268 data sheet (b) front page of the ADA4530-1 data sheet.

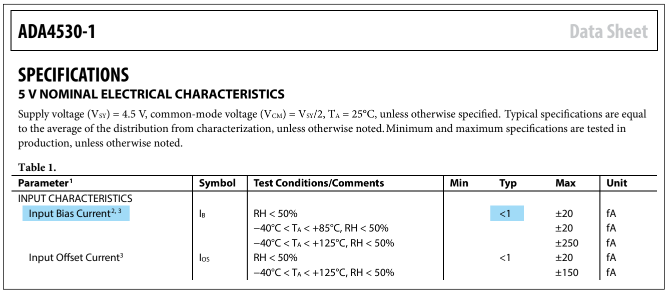
When customers need an amplifier as the next stage after adding a very high impedance source, they primarily look for an amplifier with very low input bias current. Ideally, no current flows into the input terminals of an op amp. In practice, there are always two currents, IB+ and IB–, flowing into the input terminals of the op amp. These are called input bias current. For a high impedance source, amplifiers with less input bias current are chosen to avoid the voltage drop at its input stage. LTC6268 and ADA4530-1 are marketed with the titles "Ultralow Bias Current FET Input Op Amp" and "Femtoampere Input Bias Current." A cursory glance at the first page of their data sheets, as shown in Figure 6, shows that the LTC6268 has 3 fA whereas ADA4530-1 has 20 fA at room temperature, which may lead customers to believe that the former is more suitable for their low input bias current requirement. Being that data sheets vary, the typical bias current is not listed on the first page of the ADA4530-1 data sheet as it is on the LTC6260's first page. Instead the maximum bias current is listed on the first page. To highlight again, typical values are different from the minimum and maximum values! If the application is very sensitive to those values, we should consider the worst-case minimum and maximum values rather than the typical values.



5.0V ELECTRICAL CHARACTERISTICS The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$, $V_{SUPPLY} = 5.0V$ ($V^+ = 5V$, $V^- = 0V$, V_{CM} = mid-supply), $R_L = 1k\Omega$, $C_L = 10pF$, $V_{\overline{SHDN}}$ is unconnected.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = 2.75V$		–0.7	0.2	0.7	mV
			●	–2.5		2.5	mV
		$V_{CM} = 4.0V$		–1.0	0.2	1.0	mV
			●	–4.5		4.5	mV
TC V_{OS}	Input Offset Voltage Drift	$V_{CM} = 2.75V$			4		µV/°C
I_B	Input Bias Current (Notes 6, 8)	$V_{CM} = 2.75V$		–20	±3	20	fA
		LTC6268I/LTC6269I	●	–900		900	fA
		LTC6268H/LTC6269H	●	–4		4	pA
		$V_{CM} = 4.0V$		–20	±3	20	fA
		LTC6268I/LTC6269I	●	–900		900	fA
		LTC6268H/LTC6269H	●	–4		4	pA

(a)



ADA4530-1 Data Sheet

SPECIFICATIONS

5 V NOMINAL ELECTRICAL CHARACTERISTICS

Supply voltage (V_{SY}) = 4.5 V, common-mode voltage (V_{CM}) = $V_{SY}/2$, T_A = 25°C, unless otherwise specified. Typical specifications are equal to the average of the distribution from characterization, unless otherwise noted. Minimum and maximum specifications are tested in production, unless otherwise noted.

Table 1.

Parameter[1]	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Input Bias Current[2, 3]	I_B	RH < 50%		<1	±20	fA
		−40°C < T_A < +85°C, RH < 50%			±20	fA
		−40°C < T_A < +125°C, RH < 50%			±250	fA
Input Offset Current[3]	I_{OS}	RH < 50%		<1	±20	fA
		−40°C < T_A < +125°C, RH < 50%			±150	fA

(b)

Figure 7. (a) Specifications of the LTC6268, (b) specifications of the ADA4530-1.

Figure 7 shows the specifications of LTC6268 and ADA4530-1. We can see that although the maximum input bias current rating for both the parts are the same (±20 fA), the typical value for ADA4530-1 is less than 1 fA, which is much better than the 3 fA bias current of LTC6268. But this number is not highlighted in the first page of ADA4530-1 data sheet. Hence, a more in-depth reading of the data sheets is needed. Although ADA4530-1 is better in terms of typical input bias current, these devices may vary with other features and this feature alone is insufficient to determine which part is better.

As a concluding note, I would like to emphasize the fact that it is important to first decide the operating conditions of an application and then look for specifications corresponding to its purpose. Sometimes the front page of the data sheet or its title might highlight features at some other specification and operating condition, in which case we must be prudent in choosing the suitable one for our need by careful perusal of the data sheet. We should also decide our power budget for our product before choosing a device, because it is always possible to have the best features and good specs, but at a high cost and with a high power budget.

References

[1] "Chapter 20: Analog-to-Digital Conversion." Analog Devices, Inc., September 2013.

About the Author

Tejaswini Anand is a product applications engineer in the Centralized Applications Center (CAC) team at Analog Devices. She is interested in systems design and studying the large spectrum of ADI's product portfolios and their applications and features. Tejaswini graduated from R.V. College of Engineering, Bangalore, India in 2019 as an electronics and communication engineer. During her term she partook in various national-level robotics competitions and hackathons and won a few. She can be reached at *tejaswini.anand@analog.com*.