

Keysight Technologies

Performing a Precision ADC Evaluation Using a Low Noise DC Source

Application Note



Featuring the Keysight B2961A/
B2962A 6.5 Digit Low Noise
Power Source



Introduction

As the operating voltages of analog-to-digital converters (ADCs) continue to decrease, the voltage step associated with the least significant bit (LSB) also decreases. If the voltage step of the LSB becomes smaller than the ADC's equivalent input noise, then a stable and low-noise test signal is essential for precise ADC evaluation. In these situations, a conventional DC power supply cannot be used to evaluate precision ADCs because its noise level is too high compared to the LSB step size. A solution for making these types of measurements is to use a dual-channel low noise power source, such as the Keysight Technologies, Inc. B2961A or B2962A 6.5 digit low noise power source.

This application note outlines the importance of, and the requirements for, low-noise DC signal sources for ADC evaluation, and explains why the Keysight B2961A/62A is the well-suited for this application.

Key Terms

There are three key terms used throughout this application note. In the context of this paper, their definitions are as follows:

– LSB size

The input voltage step size which changes one bit of the ADC's output bits.

– ADC's input noise

The noise level of the ADC which is expressed in the input of the ADC.

– Reference voltage (Vref)

The voltage to set the full-scale input voltage of the ADC. A noise level lower than the LSB size is required.

Ultra-Low Noise Filter Performance

The noise density of the B2961A or B2962A when used with the N1294A-021 ultra low noise filter (ULNF) is 1 nVrms/ $\sqrt{\text{Hz}}$ at 10 kHz. For a 20 MHz bandwidth this corresponds to a noise level of less than 10 μVrms (about 60 $\mu\text{Vp-p}$ noise). This is lower than the LSB voltage of most high-speed, 14-bit ADCs, allowing the B2961A/62A and ULNF pair to easily test these devices.¹

As shown in the Figure 1, the typical range of a conventional precision DC power supply is about 1 $\mu\text{Vrms}/\sqrt{\text{Hz}}$. This is more than 100 times larger than the B2961A/62A with the ULNF.

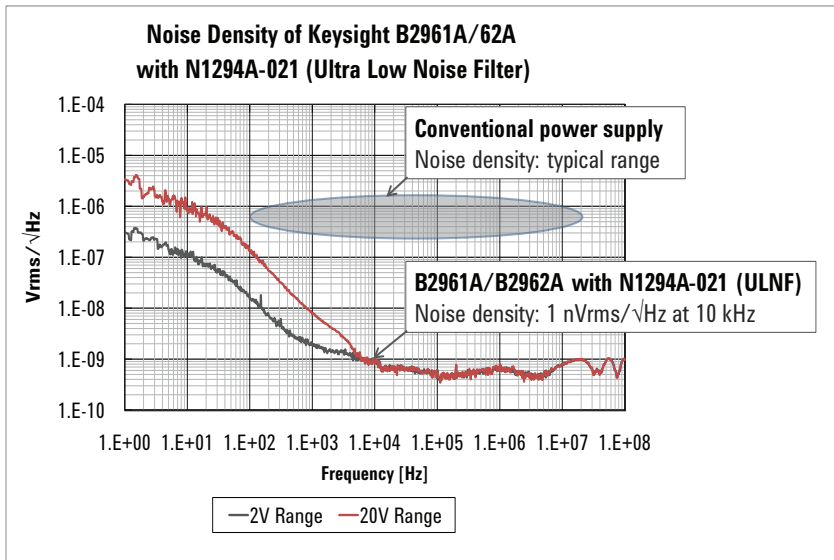


Figure 1. Noise density of the Keysight B2961A/62A with a N1294A-021 (ULNF)

1. LSB = 120 μV for $\pm 1\text{ V}$ input range

Test Configuration Example

The ADC requires low noise performance on the following inputs:

Input B2962A Ch1 with the ULNF connected

Vref B2962A Ch2 with the ULNF or low noise filter (LNF) connected

As noted in Figure 2, the ADC's noise level is highly dependent on the Vref noise. The LNF can be used if the noise filter is included inside the Vref path.

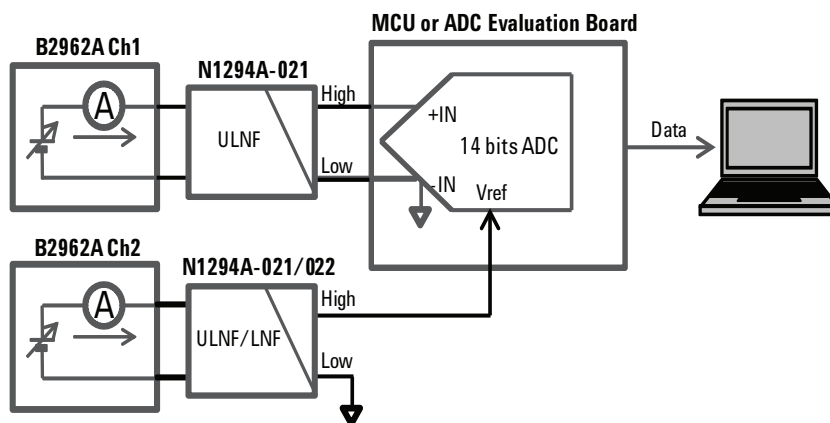


Figure 2. Connection diagram for testing the ADC

Output noise comparison for a 14-bit ADC using three different DC signal sources

The output noise of the ADC was evaluated under the different connections. Each example in this section has three test conditions in common:

DC source voltage: 0 V

ADC Vref: 1.5 V

Sample size: 2048

Test Configuration Example

Example 1. Reference: Input shorted

The reference data shown in Figure 3 was obtained by shorting the input cable of the ADC at the DC source input. Therefore, this data shows the residual noise of the ADC.

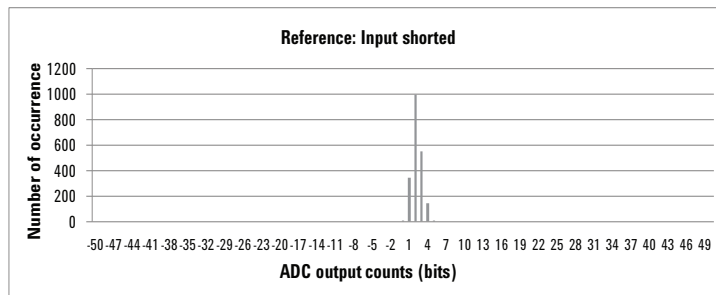


Figure 3. Reference: input shorted

The equivalent input noise of the ADC used in the example is calculated as:

$$\begin{aligned} & 1.5 V_{\text{ref}}/2^{14\text{bits}} \times 2 \times 0.8 \text{ (= standard deviation)} \\ & = 0.15 \text{ mV}_{\text{rms}} \text{ or } 150 \text{ }\mu\text{V}_{\text{rms}} \end{aligned}$$

Example 2. B2962A with the ULNF

The DC source in this example is the B2962A with the N1294A-021 ULNF. As shown in Figure 4, the output noise distribution from the ADC is almost the same as the reference data shown in Example 1.

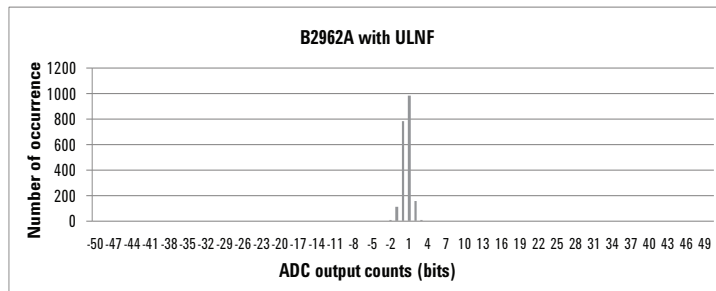


Figure 4. B2962A with ULNF

The noise level of the B2962A with ULNF is less than $10 \mu\text{V}_{\text{rms}}$ ($< 20 \text{ MHz}$), which is more than 10 times lower than the noise level of the ADC used in the three examples.

Example 3: Conventional DC source

The DC source in this example is a conventional precision DC source. As shown in Figure 5 the vertical scale is 10 times that of the vertical scale shown in Examples 1 and 2. This was done to show the noise distribution (275 bits p-p in this example) of conventional DC power supplies. As this data shows, the noise distribution from a conventional precision DC source is too large for use in evaluating modern-day precision ADCs.

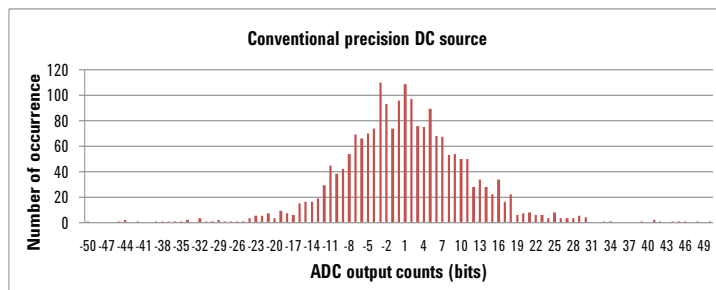


Figure 5. Conventional precision DC source

Comparison Conclusion

Table 1 summarizes the ADC output bit noise distribution for the DC signal sources from the three examples provided.

Table 1. Output noise summary with three signals

	Example 1	Example 2	Example 3
Input source	Reference	B2962A with ULNF	Conventional DC source
Ave. Reading	2.2	0.6	1.1
St. Dev	0.8	0.75	11.5
P-P Noise	6	6	275

As Table 1 shows, a low-noise DC signal source (such as the B2962A with its ULNF) provides much lower noise than conventional precision DC sources/power supplies, which is essential for testing 14 bit ADCs.

The relation of the ADC's total bits, reference voltage, and the LSB size is shown in Figure 6 and shows that the B2962A noise level with ULNF also is effective for testing 16 to 18 bits ADCs.

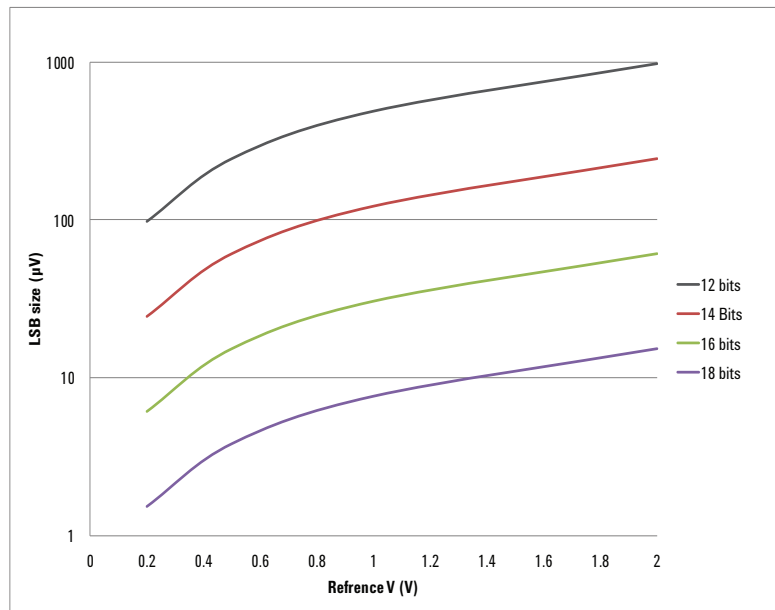


Figure 6. LSB size by ADC bits and reference voltage

Keysight B2961A/B2962A Low Noise Power Source Voltage Key Specification and Characteristics

Product Number	Accessory	Max output (DC)	Source Resolution		Noise ¹	
			Digit	Min resolution	0.1 to 10 Hz	10 to 20 MHz
B2961A B2962A	---	210 V	6 1/2	100 nV	<5 µVpp	3 mVrms
	N1294A-021 (ULNF)	42 V (105 mA)	6 1/2	100 nV	<5 µVpp	10 µVrms (1 nVrms/√Hz at 10 kHz)
	N1294A-022 (LNF)	210 V	6 1/2	100 nV	<5 µVpp	350 µVrms

1. Supplemental characteristics

myKeysight

myKeysight

www.keysight.com/find/mykeysight

A personalized view into the information most relevant to you.



www.axistandard.org

AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. Keysight is a founding member of the AXIe consortium.



www.lxistandard.org

LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. Keysight is a founding member of the LXI consortium.



www.pxisa.org

PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.



Three-Year Warranty

www.keysight.com/find/ThreeYearWarranty

Keysight's commitment to superior product quality and lower total cost of ownership. The only test and measurement company with three-year warranty standard on all instruments, worldwide.



Keysight Assurance Plans

www.keysight.com/find/AssurancePlans

Up to five years of protection and no budgetary surprises to ensure your instruments are operating to specification so you can rely on accurate measurements.



www.keysight.com/quality

Keysight Electronic Measurement Group
DEKRA Certified ISO 9001:2008
Quality Management System

Keysight Channel Partners

www.keysight.com/find/channelpartners

Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

www.keysight.com/find/b2900a

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	0800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-06-16-14)