

Practical Phase Noise Measurement Techniques

Introduction

Accurate measurement techniques must be used when measuring phase noise on differential signals. This application note describes best practices to obtain optimal measurements.

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1. Measuring Differential Signals

One of the advantages of using differential signaling is the rejection of common-mode noise. However, today's high-end phase noise systems require a single-ended input, thus, a differential signal must be converted to single-ended in order to interface it with the phase noise system.

The recommended method for converting the differential signal to single-ended is to use a “balun”, which is a transformer that converts a **balanced** signal (differential about ground) to an **unbalanced** signal, hence the name “bal-un”. It's important to know the bandwidth of the balun. A balun with a bandwidth of 30–3000 MHz will not be able to provide an accurate measurement for signals of 25MHz and below. This application note describes other methods that may be used to provide an accurate measurement.

2. Ideal Setup when SMA Connectors are Available

Figure 1 illustrates the recommended setup for measuring phase noise of a differential signal. Ideally, the device under test will have SMA connectors available. Cables with 50Ω impedance are connected to the output SMA of the device on one end. The other end of each cable is connected to a 50Ω series terminator and then a DC-block into the balun. The 50Ω terminators provide a matched load impedance. The DC blocks then AC-couple the signal into the balun. The single-ended output of the balun is then AC-coupled into the phase noise system. The AC-coupling in the last stage is important because phase noise systems do not support signals with DC offsets. Typically, phase noise systems provide an internal 50Ω termination. If the phase noise system does not have an internal 50Ω termination, then it is recommended to use a 50Ω series terminator.

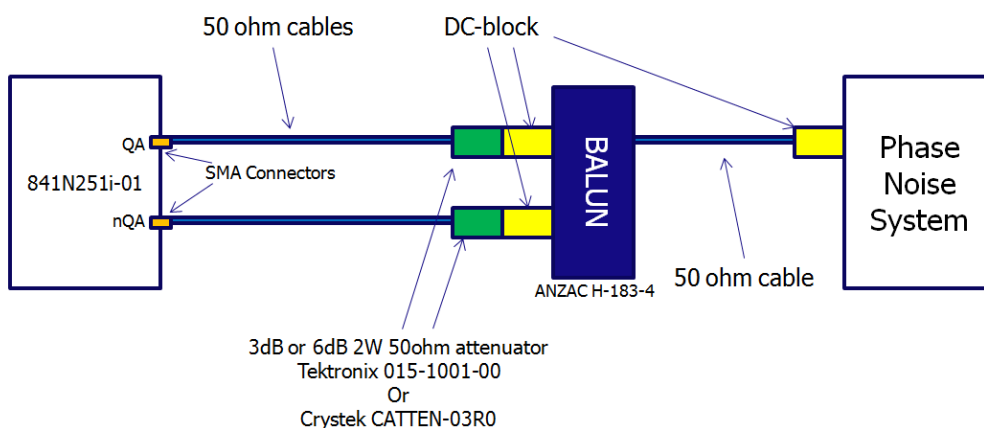


Figure 1. Recommended Setup for Measuring Phase Noise of a Differential Signal

Figure 2 shows the setup using the ANZAC H-183-4 balun which has a bandwidth of 30–3000 MHz. The 50Ω series terminator can be a 3dB or 6dB, 2W, 5Ω attenuator (commonly available). Two models that can be used are the Tektronix 015-1001-00 or the Crystek CATTEN-03R0. Two models of the DC-block that can be used are the MCL15542 BLK-89-S+ or the MCL 15542-BLK-18.

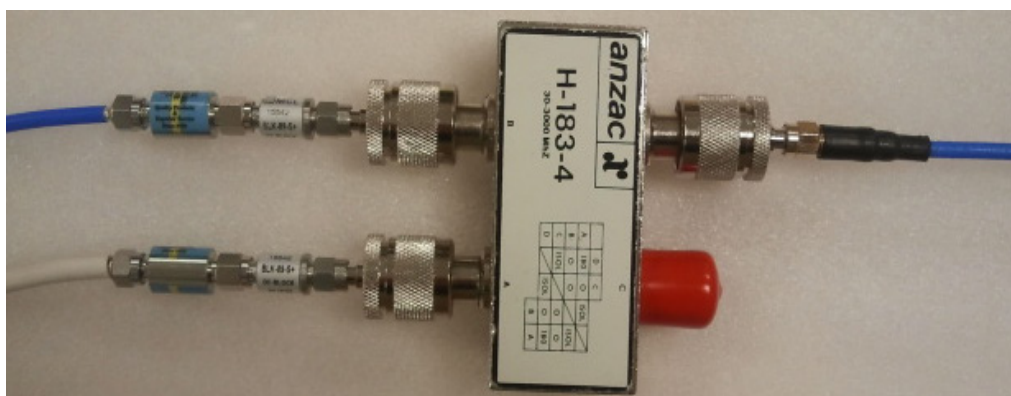


Figure 2. ANZAC H-183-4 Balun Setup

3. Non-Ideal Setup when SMA Connectors are not Available

When probing a system, SMA connectors may not be available. In this case, it is recommended to obtain the best possible connection. Often, a custom probe that interfaces with the phase noise system may not be available, thus, a custom-made probe will have to suffice.

Use the following steps and refer to Figure 3 for one method of constructing a custom-made probe.

1. Take a 50Ω impedance cable that has SMA connectors and cut the cable in half to create two separate cables.
2. Place the cables in parallel with the cut ends on the same side.
3. Remove some of the outer plastic casing and strip back some of the shielding to reveal the center wires. Then, cut back some more of the shielding.
4. Solder the shielding of the two cables together. This provides a strong mechanical connection as well as a common ground for both. If possible, solder pins onto the ends of the exposed wires to provide a strong, sharp probe.
5. Tape the two wires together to provide additional stability. The other ends of the cables can then be interfaced into the balun.

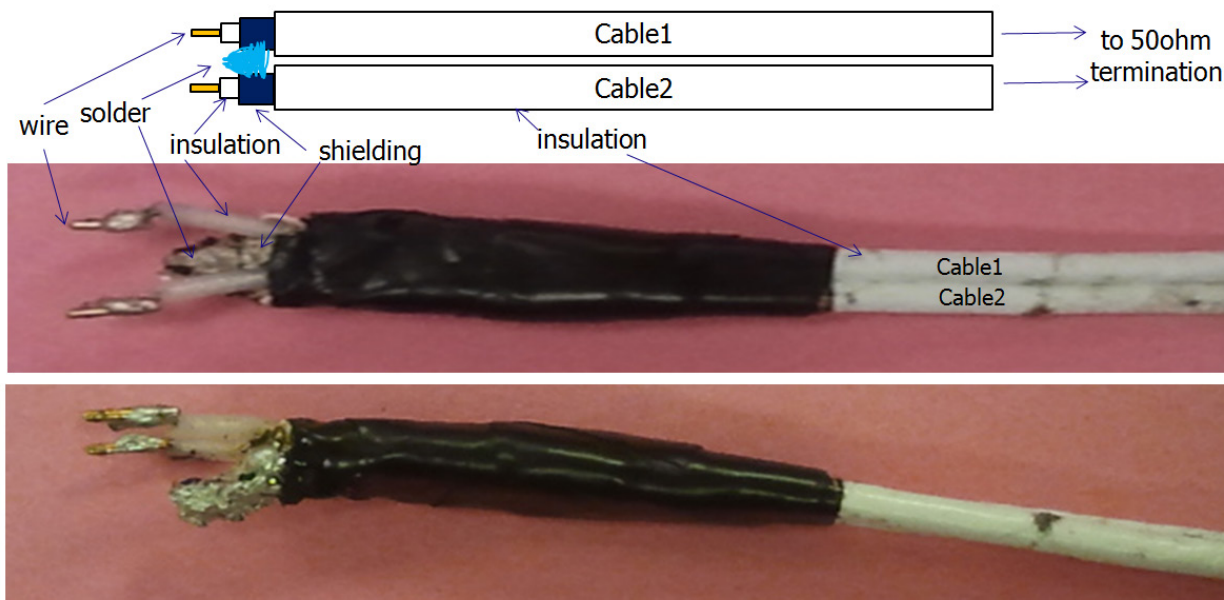


Figure 3. Construction of a Custom-Made Probe

4. When a Balun is not Available

When probing a system, a balun may not be available. In this case, the measurement can be performed using a single-ended measurement or using a differential-to-single-ended buffer.

Figure 4 shows the setup for a single-ended measurement. This setup, however, is susceptible to common-mode noise. If a signal has a lot of spurious content, or if there is common-mode noise present, this single-ended phase noise measurement will prove less effective than if a differential measurement is used. The single-ended measurement setup may be sufficient for an evaluation of the typical performance of the system.

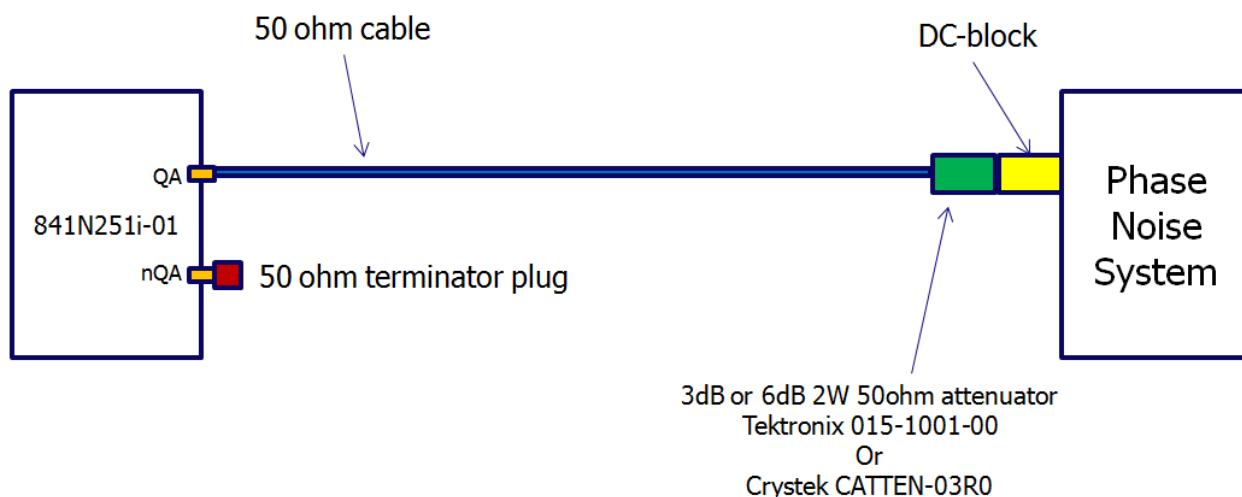


Figure 4. Single-Ended Setup for Phase Noise Measurement

Figure 5 shows the setup where the balun has been replaced by a differential-to-single-ended buffer. The Renesas 83026i-01 evaluation board provides a CMOS output and can be used for these measurements.

Important: The measurement will be limited to the noise floor of the buffer, plus the phase noise system, and may mask the true performance of the device under test. Refer to the [83026i-01 Datasheet](#) for phase noise specifications.

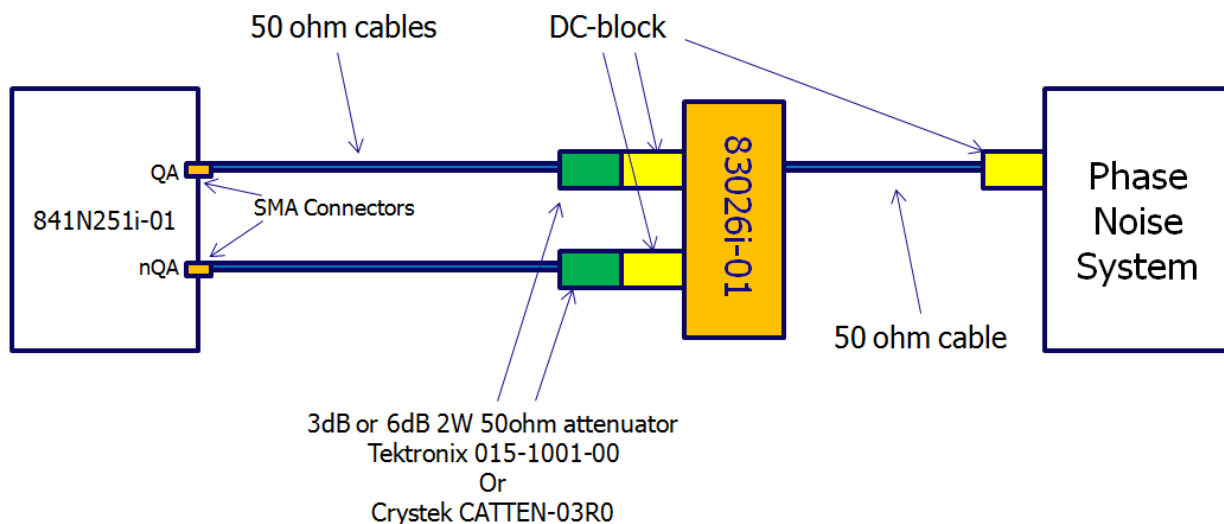


Figure 5. Differential-to-Single-Ended Buffer Setup for Phase Noise Measurement

5. When a Balun and SMA Connectors are not Available

When probing a system, a balun and SMA connectors may not be available. In this case, the measurement can be obtained using a single-ended measurement.

Use the following steps and refer to Figure 6 for the process of constructing a single-ended probe.

1. Solder a pin to an SMA ground and center pin.
2. Screw the SMA into the cable. This provides a low-impedance probe.
3. Connect the other end of the cable to the 50Ω series termination and DC-block.
4. Alternately, use a cable and solder it directly to the board and then connect to the 50Ω terminator and AC-coupler.

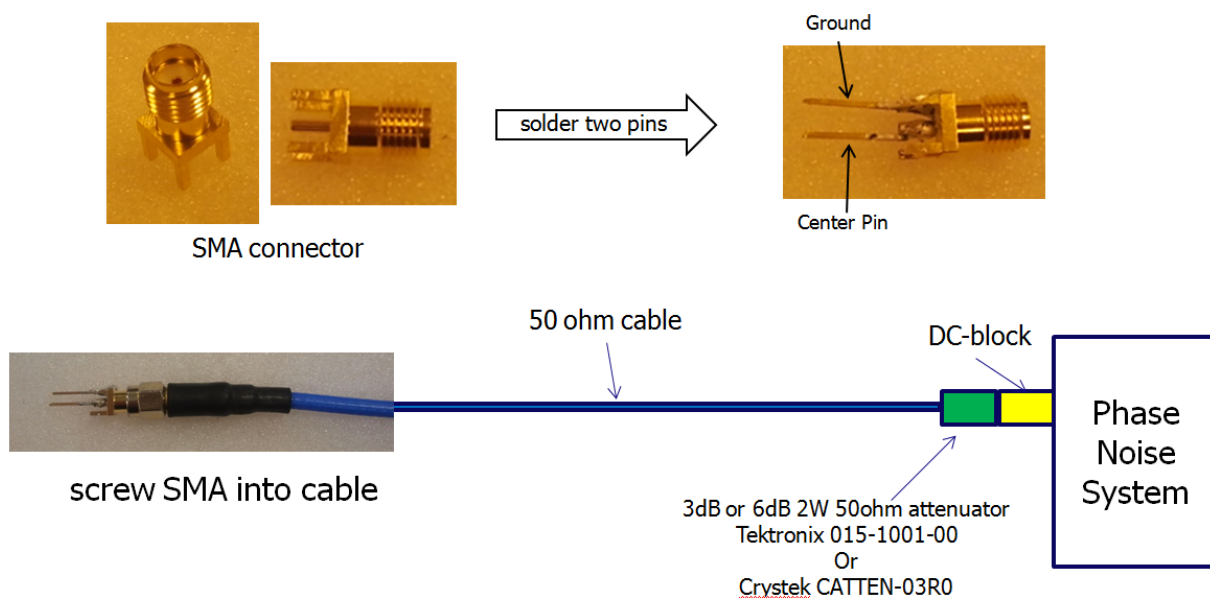





Figure 6. Constructing a Single-Ended Probe

6. Recommended Baluns

Table 1 lists Renesas recommended baluns for phase noise measurements.

Table 1. Renesas Recommended Baluns for Phase Noise Measurements

Manufacturer	Model	Bandwidth (3dB)	Insertion Loss	Propagation Delay	Common Mode Rejection Ratio	Port Impedance	Image
Prodyn	BIB-100G	250kHz–10GHz	8 dB	0.6ns	20dB	50Ω	
Macom	H-183-4	30MHz–3GHz	1.5dB (maximum)	-	-	50Ω	
Marki	BAL-0050	300kHz–50GHz	3dB (30MHz–35GHz) 7dB (35GHz–50GHz)	0.52ns	28dB	50Ω	

7. Revision History

Revision	Date	Description
1.01	Apr 15, 2025	<ul style="list-style-type: none"> Updated to latest document template. Added section 6.
1.00	Jul 11, 2025	Initial release.

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