

## Introduction

In order to discuss RMS Phase Jitter, some basics phase noise theory must be understood. Phase noise is often considered an important measurement of spectral purity which is the inherent stability of a timing signal. Phase noise is the frequency domain representation of random fluctuations in the phase of a waveform caused by time domain instabilities called jitter. An ideal sinusoidal oscillator, with perfect spectral purity, has a single line in the frequency spectrum. Such perfect spectral purity is not achievable in a practical oscillator where there are phase and frequency fluctuations. Phase noise is a way of describing the phase and frequency fluctuation or jitter of a timing signal in the frequency domain as compared to a perfect reference signal.

## Generating Phase Noise and Frequency Spectrum Plots

Phase noise data is typically generated from a frequency spectrum plot which can represent a time domain signal in the frequency domain. A frequency spectrum plot is generated via a Fourier transform of the signal, and the resulting values are plotted with power versus frequency. This is normally done using a spectrum analyzer.

A frequency spectrum plot is used to define the spectral purity of a signal. The noise power in a band at a specific offset ( $F_o$ ) from the carrier frequency ( $F_c$ ) compared to the power of the carrier frequency is called the dBc Phase Noise.

$$\text{dBc Phase Noise} = \frac{\text{Power Level of a 1Hz band at an offset } (F_o)}{\text{Power Level of the carrier Frequency } (F_c)}$$

A Phase Noise plot is generated using data from the frequency spectrum plot. Refer to [Figure 1A](#). Using the dBc phase noise definition and calculating the dBc values for a continuous moving 1Hz band over the frequency offset range of interest generates a phase noise plot. A phase noise plot is simply these dBc values plotted versus the offset frequency ( $F_o$ ). Refer to [Figure 1B](#). To summarize, phase noise is specified as the ratio of the noise power present in a 1Hz band at a specified offset from the carrier frequency to the power value of the carrier. Generally, a phase noise plot is single side, only one side of the frequency spectrum is plotted. This is due to the assumption that the frequency spectrum plot has a Gaussian profile and that both sides of the distribution are equal. For phase noise measurements which contain deterministic components, special consideration must be taken. Typically, a phase noise plot has the domain axis is in logarithmic format and the range in linear format. Refer to [Figure 1B](#).

A phase noise plot can now be used to relate the time domain RMS jitter specification to the frequency domain spectral purity. The area under the plot is proportional to the RMS jitter squared. An application may only be interested in a range of the phase noise plot and typically will specify that range or apply a mask to identify the area of interest and maximum dBc values permitted. This mask is often called a Jitter Mask. Refer to [Figure 2](#).

Figure 1. Generating a Phase Noise Plot from the Frequency Spectrum Plot

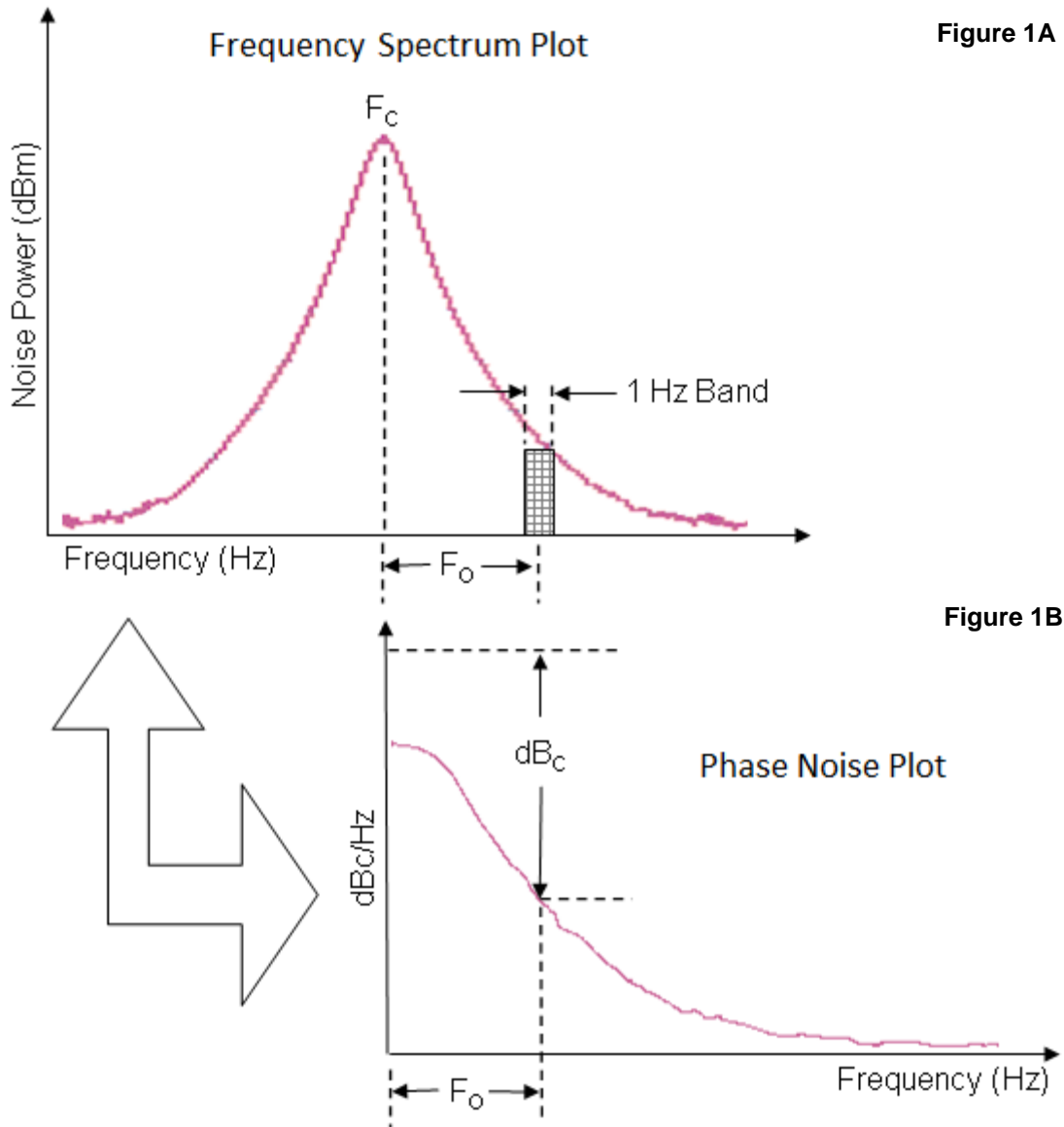
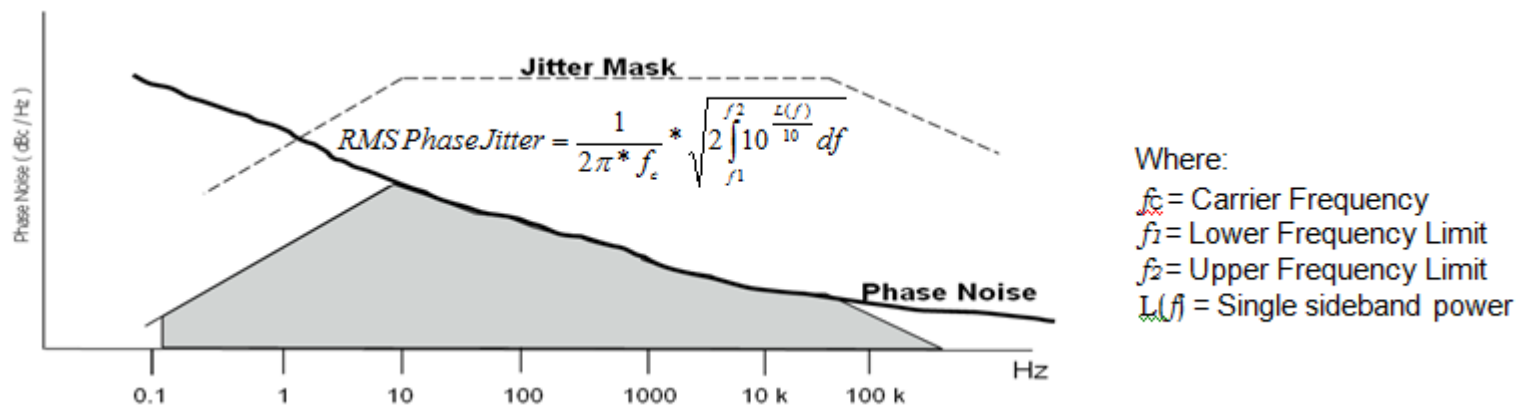
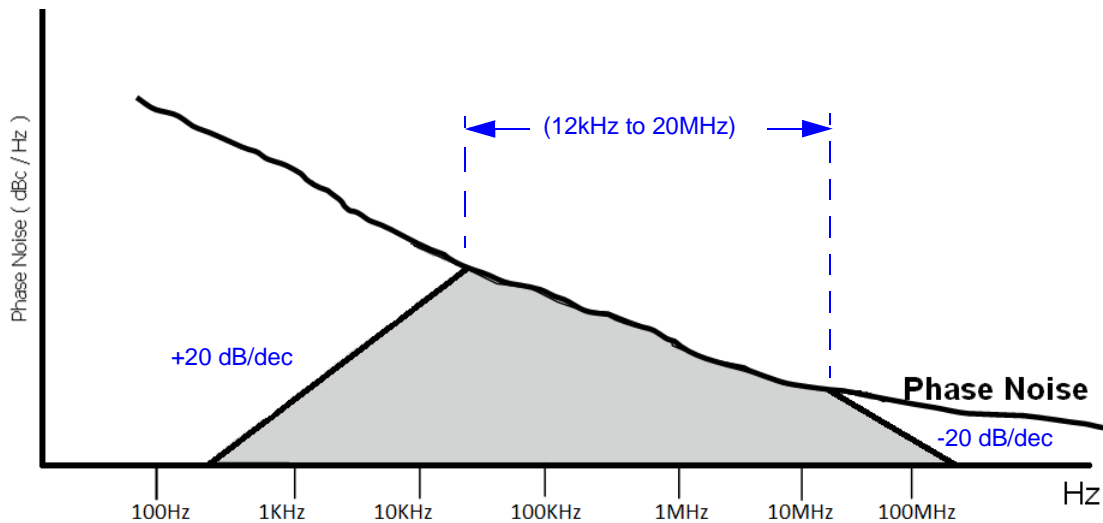


Figure 2. Applied Jitter Mask



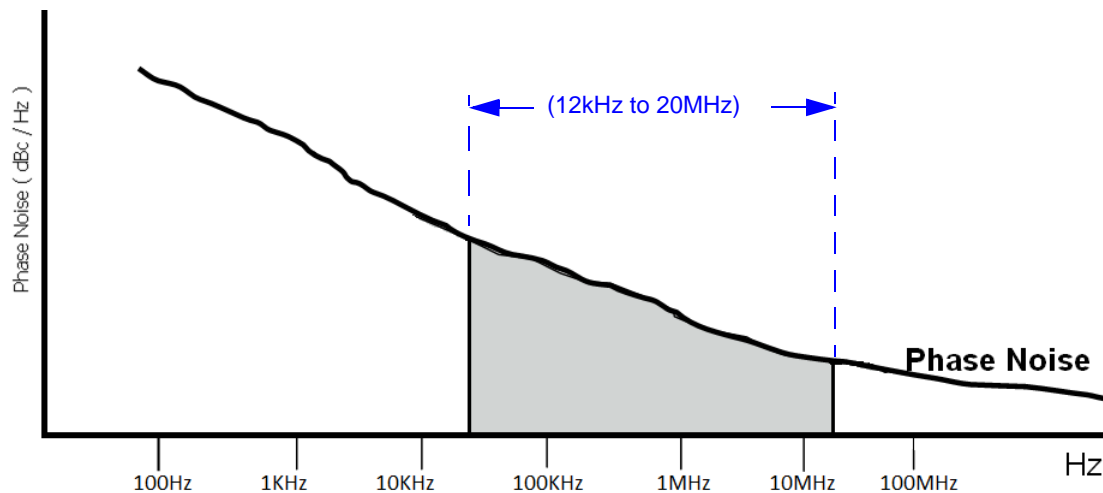
In order to specify a Jitter Mask, a systems transfer function must be analyzed. The jitter mask specifies the clock performance in ways that actually affect the system and will help avoid over-specification of the clock performance. In addition, the jitter mask will provide different weighting of different jitter frequencies. Many of these jitter masks have been predetermined by industry protocols. The most common being the SONET, 12kHz to 20MHz, OC48 Jitter Generation specification for Telcordia GR-253-CORE. Though many of the clocking devices using this specification are not SONET, this jitter mask has become an industry standard of merit for comparing performance. A jitter mask can have a profile of a band-pass, low-pass or high-pass filter with roll offs that vary in dB/decade. Refer to [Figure 3](#).

**Figure 3. Filtered Jitter Mask**



A jitter mask can also have a “brick-wall” profile. Refer to [Figure 4](#). A brick-wall profile does not have the typical filter response with a gradual roll-off of a few dB/decade slope, but rather has an infinite sloped roll-off. Brick-wall jitter masks are more common due to measurement equipment limitations. Currently, some of the industry standard Phase noise measurement equipment does not have the capability to add a roll-off to the filter, but it can be done with additional software. In most cases, the difference between filtered and brick-wall jitter is negligible, but as RMS jitter requirements continue to become more stringent, this could become an issue in the future.

**Figure 4. “Brick-Wall” Jitter Mask**



As with most timing specifications, special considerations must be taken when measuring phase noise. The primary issue is the noise floor capability of the measurement system. The noise floor can be defined as the measure of the signal created from the sum of all the noise sources and unwanted signals within a measurement system. If the measurement system does not have the necessary noise-floor performance required by the device under test (DUT), the results will be inaccurate. The phase noise plot will track the noise floor of the equipment instead of the true performance of the DUT. In addition, all precautions must be taken to avoid any additional noises from coupling into the measurement system. Proper shielding must be in place to ensure an accurate measurement. RMS Phase jitter measurements are becoming increasingly important in the characterization and qualification of high-speed computing and communication systems. It is crucial that the proper equipment and procedure be followed.

RMS phase jitter has now become a widely accepted industry standard. In the past, it was most commonly seen in Telecommunication applications, but with the expansion of Ethernet and PCI Express, both phase noise and RMS phase jitter has migrated into Networking and consumer applications. It is important to have a practical and conceptual understanding of Phase noise.



## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
  - "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
  - "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
- Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

## Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

## Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:  
[www.renesas.com/contact/](http://www.renesas.com/contact/)