

Measuring an Ultra-Low-Noise 100 MHz OCXO with Cross-Correlation

A 100 MHz OCXO measured on the 7000 Series with two-channel cross-correlation: how the correlation count lowers the analyzer's own floor, how the external references and the DUT are connected, and the -187 dBc/Hz floor reached in this example.

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1 Measuring an Ultra-Low-Noise 100 MHz OCXO with Cross-Correlation

Ultra-low-noise reference oscillators can push a phase noise analyzer to its own residual floor. This note walks through how the BNC 7000 Series uses two-channel cross-correlation, which is standard on every model, to measure a 100 MHz OCXO below that floor.

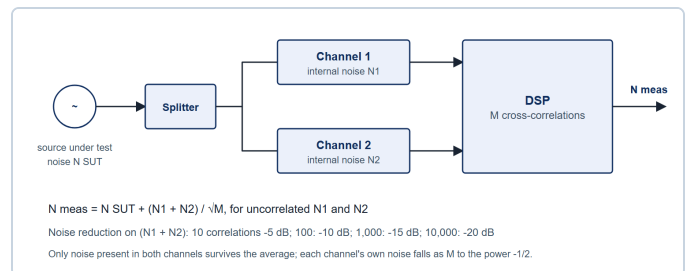
[Download the full note \(PDF\)](#)

2 Introduction

This application note describes the phase noise measurement of very low noise reference sources. It applies to every 7000 Series model (7070, 7300 and 7340), on which two-channel cross-correlation is a standard function.

This note describes how to best use the 7000 Series to measure ultra-low single sideband (SSB) phase noise of devices under test (DUT). In the following example, commercial 100 MHz OCXOs are measured using the two-channel cross-correlation technique.

3 Overview of the Two-Channel Cross-Correlation Technique



- **SCHEMATIC** **Figure 1.** A two-channel cross-correlation system. The source under test is split into two independent measurement channels, each with its own internal noise, and the DSP cross-correlates the two channel outputs over M correlations.

The cross-correlation technique uses two single-channel measurement systems. Only the coherent noise present in both channels averages to a finite value. The time average of the incoherent noise approaches zero as $M^{-1/2}$, where M is the number of correlations. The measured phase noise of the system is given by the equation shown in Figure 1:

$N_{\text{meas}} = N_{\text{S.U.T.}} + (N_1 + N_2) / \sqrt{M}$ (assuming N_1 and N_2 are uncorrelated).

Table 1.

M (number of correlation)	10	100	1,000	10,000
Noise reduction on (N_1+N_2)	-5dB	-10dB	-15dB	-20dB

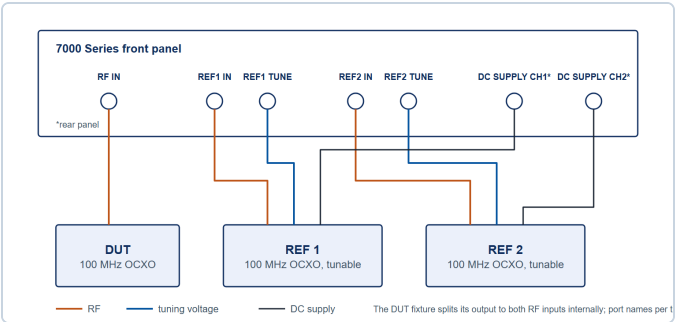
4 Measurement Setup

For this example, three 100 MHz OCXOs of the same commercial type are used: one as the DUT and two as tunable references. The measurement setup is shown in Figure 2.



PHOTO Figure 2. The 7000 Series signal source analyzer, with the REF1 and REF2 inputs, tuning outputs and the RF input on the front panel.

The connectivity schematic is shown in Figure 3. The RF output and the tuning port of each reference are connected to the REF and TUNE ports of one channel of the 7000 Series, and the DC supply of each reference fixture to the corresponding SUPPLY output. The DUT signal is split by a power splitter on the test fixture and fed to the RF inputs of both channels.



SCHEMATIC Figure 3. Connections for a DUT measurement with two external references on the 7000 Series. Red lines are RF, blue the tuning voltage and black the DC supply, for the DUT and the two reference oscillators.

Before starting the measurement, the following configuration is required. For details, please refer to the user manual.

1. **Select the measurement configuration:** DUT with Cross-correlator
2. **Set the number of correlations per decade.** In this example, the correlations are set to 100 for 10 Hz to 1 kHz offset, 1,000 for 1 kHz to 10 kHz offset, and 10,000 for 10 kHz to 1 MHz offset.
3. **Set the tuning range of external references.** In this example, the tuning range for the reference OCXOs are set at 0 to +8.0V.

Note

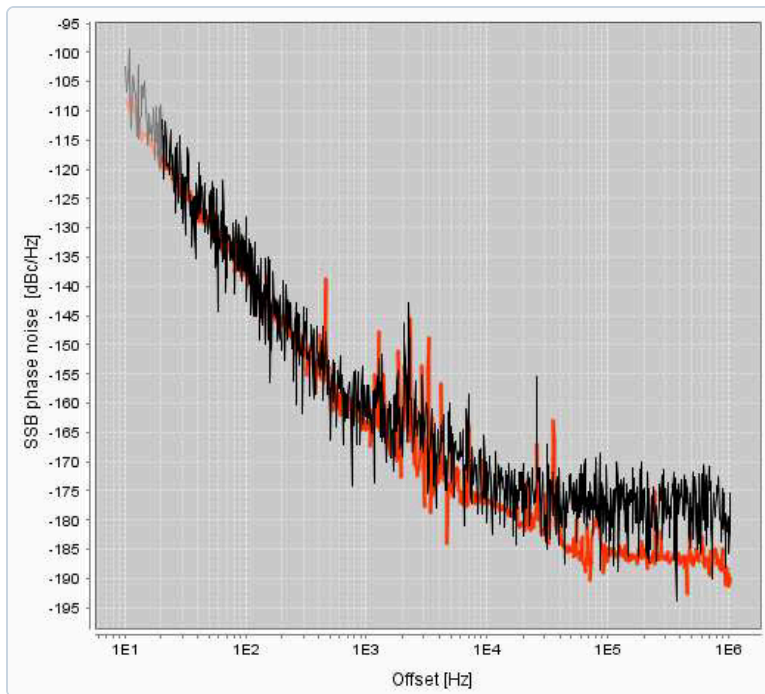
This range depends on the tuning range of your reference and must be set accordingly to avoid damaging your reference.

4. **If the sensitivity of the external sources is not known,** the auto button can be selected to apply auto-detection of the tuning sensitivity.

To start the measurement, press the Start button.

5 Measurement Results

Figure 4 below shows the measurement results.



■ **MEASURED** **Figure 4.** SSB phase noise of the 100 MHz OCXO on the 7000 Series, offset 10 Hz to 1 MHz. Black: one correlation. Red: 100, 1,000 and 10,000 correlations in the three decades from 10 Hz, reaching -187 dBc/Hz above 100 kHz.

In Figure 4, the black curve shows the measurement after one correlation and approximately two seconds of measurement time. For offsets above 1 kHz the result is limited by the analyzer's residual noise at approximately -177 dBc/Hz. Further correlations lower that limit.

The red curve shows the result after 100 correlations and approximately 100 sec of measurement time (to be precise, 100 correlations are measured for 10 Hz to 1 kHz offset, 1,000 for 1 kHz to 10 kHz offset, and 10,000 for 10 kHz to 1 MHz offset, respectively). As expected, the phase noise at lower offsets (<1 kHz) has not improved substantially further and the curve shows little variance, indicating there will be no further noise improvement with additional correlations.

For offsets above 1 kHz the improvement is up to 10 dB, and a noise floor of -187 dBc/Hz was measured for this 100 MHz OCXO.

6 Conclusion

The BNC 7000 Series is a two-channel cross-correlation phase noise measurement system. In this example it measured a 100 MHz OCXO to a floor of -187 dBc/Hz with 10,000 correlations; the datasheet sensitivity reaches -190 dBc/Hz at high offsets after more than 1,000 correlations.

7 Talk to an application engineer

If you are characterizing a low-noise OCXO or another quiet reference and want to confirm which 7000 Series model and options fit your measurement, our engineers can help scope the configuration. Request a quote or a demo and we will follow up with the right setup. You can also reach us at info@berkeleynucleonics.com or 800-234-7858.

Ask now →

Chat with our assistant and get an answer in seconds.

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