Technical Article

Don't Let Bad Reference Signals Destroy the Phase Noise in Your PLL/synthesizer

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"You are what you eat" is a commonly heard saying that recommends the careful selection of food, given its ability to directly affect our health and well-being.

Although not an exact comparison, the concept applies if you think of your input reference signal as the food, ingested by the phase-locked loop (PLL)/synthesizer, which affects the well-being of the PLL/synthesizer, as evident in the output phase noise, shown in Figure 1. In this post, I'll provide some practical examples to show you what a good input reference looks like, what damage a bad input reference can do and how to analyze a given input reference.

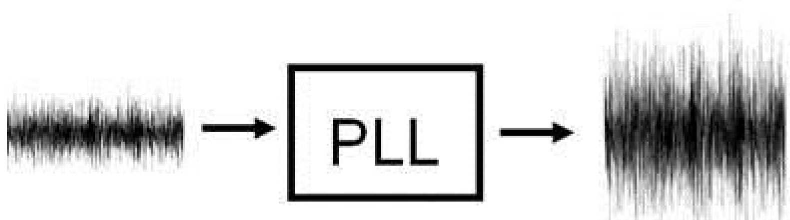

Figure 1. Input Reference Noise is also multiplied by the PLL

To back up a little, a PLL, when paired with a voltage-controlled oscillator (VCO), becomes a control-loop system that can lock on to a low-frequency signal (10MHz from a stable crystal oscillator) and multiply it to a much higher frequency (the LMX2592 can multiply up all the way to 9.8GHz).

Example 1

Figure 2 shows a single sideband phase-noise plot. The orange line is the 100MHz input reference signal, which uses a very low phase-noise crystal as the input reference. The LMX2582 synthesizer in this example multiplies the 100MHz up to 5,160.96MHz. In doing so, the input reference noise scales up as well by a factor of [20 x LOG (5,160.96/100) = 34.25dB]. The brown line shows the scaled-up result (adjusted mathematically). The red line is showing the output of the LMX2582 at 5160.96MHz.

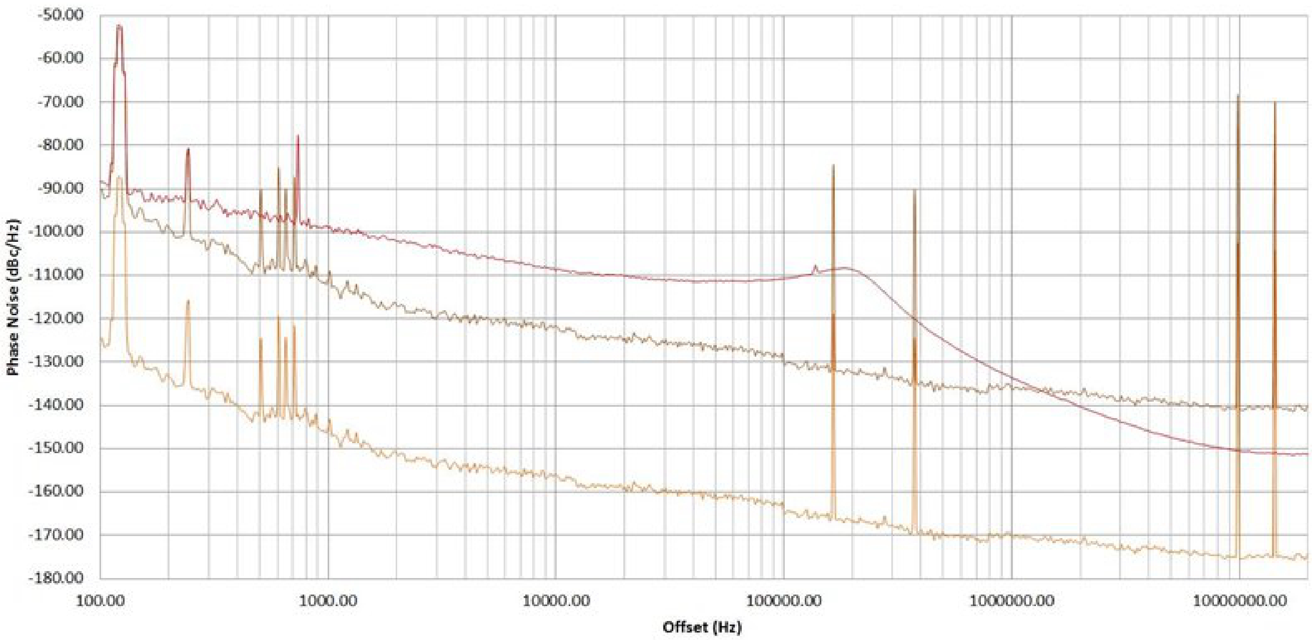

Figure 2. Low phase noise 100MHz input reference and 5160.96MHz LMX2582 output

Using an input reference like the one in Figure 2 shows the performance of the synthesizer, since the input reference phase noise is low enough. Note that the key region is under the loop bandwidth (~300kHz offset), since beyond this offset frequency the input reference noise is also filtered and will fall in the same manner as the red line (not shown in this example).

Also notice the huge spike at about 120Hz from the input reference. This directly impacts the output phase noise. You can already see the danger here. If noise is coupled somewhere into the input reference source at the lower offsets, it can damage the synthesizer phase noise.

Example 2

Figure 3 considers another input reference, this time a 122.88MHz crystal oscillator. The output frequency is again 5,160.96MHz. This time, the input reference noise is scaled by [20 x LOG (5,160.96/122.88) = 32.46dB]. Look at the phase noise portion 2kHz offset and below, and compare it to the output phase noise of Figure 2; you can see that this higher input reference noise contribution directly raises the output phase noise from the synthesizer. To achieve optimal performance from the LMX2582, you also have to feed it a good-enough input reference. And knowing how the noise scales and contributes helps in the selection of an input reference signal by its fundamental phase-noise level.

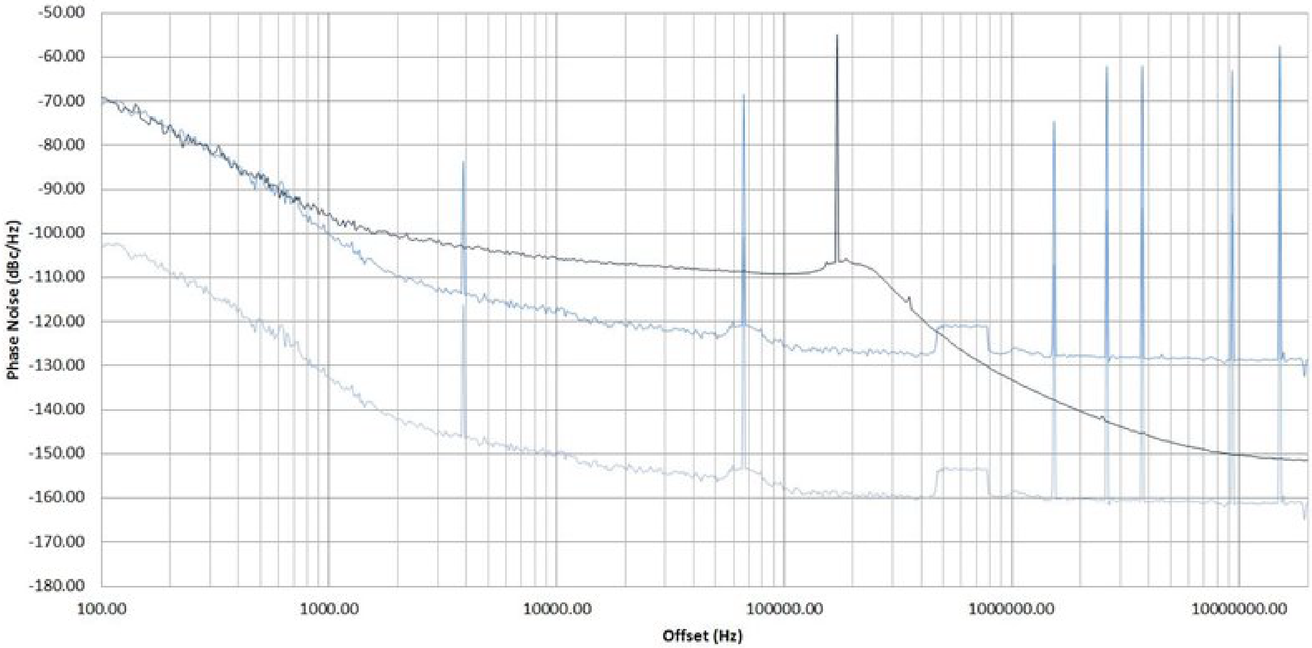

Figure 3. A 122.88MHz input reference and 5160.96MHz LMX2582 output

Example 3

Figure 4 explores a further scenario. This example also uses a 122.88MHz crystal oscillator, but this time the impact in phase noise occurred from vibration. Those clumps of spikes in Figure 4 appear when you tap your finger close to the oscillator. This is a known behavior in certain crystal-based oscillators. It does damage in the same way that bad phase noise does, but you may not know about it if you just leave it there on the bench and measure. This suggests that in picking an input reference, it is important to not only know the fundamental phase noise of the device, but to also know its response to vibration, aging, temperature variation, resilience to power-supply noise and many other influences. Having this in mind can help in part selection as well as debugging an overall signal chain.

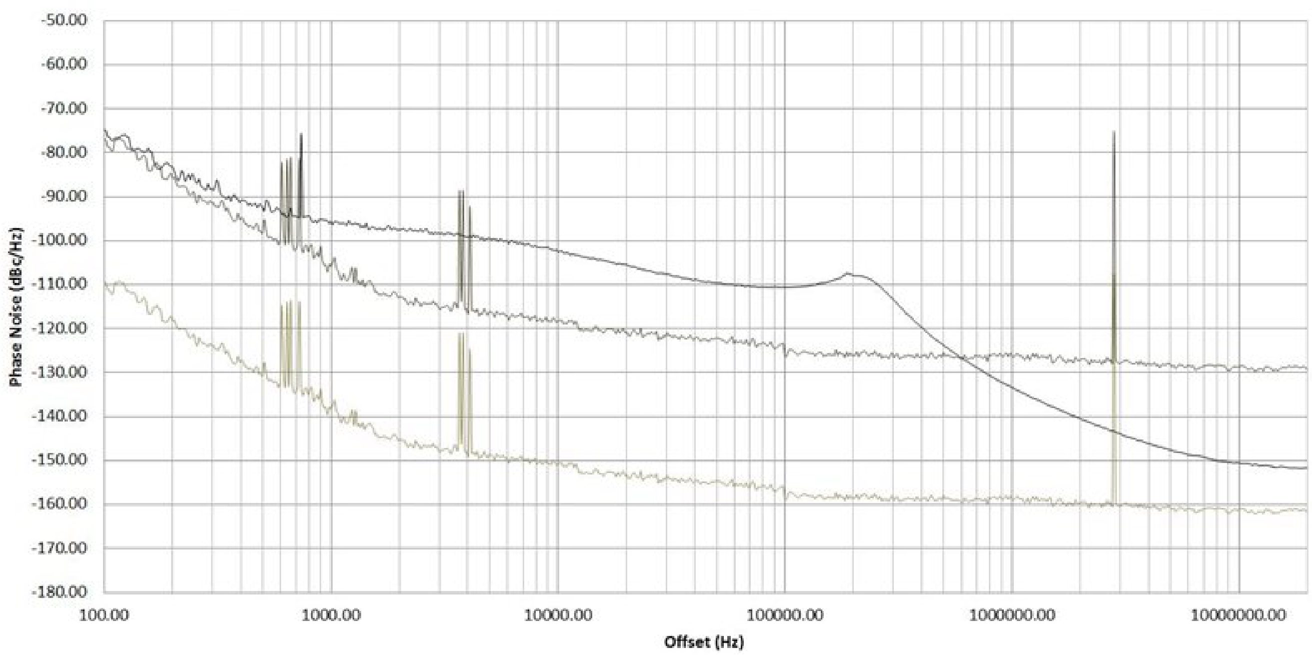

Figure 4. A noisy 122.88MHz input reference and 5160.96MHz LMX2582 output

To see how this works in an example design, check out our 9.8 GHz RF High Performance Synthesizer Operating From a Buck Converter Reference Design.

Reference Table

As a guideline, it is helpful to see the impact of calculated scaled input reference noise. In Table 1, you can see that (as expected) if the scaled input reference phase noise is the same as the PLL phase noise (0dB in Table 1), you get a 3dB addition because you are doubling the amount of noise. Likewise, if you go further down in the phase-noise level of the input reference, you get less and less of a significant contribution in phase noise.

Table 1. Phase-noise addition from the scaled input reference phase noise

Scaled input reference phase-noise level below PLL phase noise (dB)	Phase-noise addition (dB)
0	3.01
-1	2.54
-2	2.12
-3	1.76
-4	1.46
-5	1.19
-6	0.97
-7	0.79
-8	0.64
-9	0.51
-10	0.41

With these examples, I hope I've shown how a good input reference is vital to getting optimal performance from the synthesizer. A bad input reference is not only one that has too high a phase-noise level, but one that is also more susceptible to external influences (vibration, aging, temperature, power supply). With this information, you should have a better understanding and additional ideas when designing the input reference for your synthesizer. For additional information or if you have questions, visit the TI E2E™ Community High Performance RF Modulators, PLL and VCO forum.

Additional Resources

- Check out TI's entire PLL/synthesizer portfolio.
- Read the technical article, "A survival guide to scaling your PLL loop filter design."
- Start designing quickly with the LMX2582EVM high performance, wideband frequency PLLatinum™ RF synthesizer with integrated VCO evaluation module.

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