Observations by Mr. JoJakNap in Cadence Forum Post in [1]


cadence

PLL Verification

Rapid Adoption Kit (RAK)

Product Version IC 6.1.8, MMSIM 21.1, XCELIUM 21.09
May, 2022

- I've been going through the PLL Verification RAK[2].
  ...
  ...
- Question:

  1. Strangely the VCO Phase noise looks like it is 1/f and white not 1/f^3 and 1/f^2 and white. Why?
  2. In the section where the total phase noise is summed, all noise sources appear to be summed together directly - as opposed to summing their squares and taking square root at each frequency.

- Are these two correct? And if so can someone explain

[1] https://community.cadence.com/cadence_technology_forums/f/mixed-signal-design/58557/pll-verification-rak---total-phase-noise

[2] "PLL Verification Rapid Adoption Kit (RAK)", Product Version IC 6.1.8, MMSIM 21.1, XCELIUM 21.09 May, 2022

Response to Question 1 from Cadence Forum Post in [1]

- Question:
  1. Strangely the VCO Phase noise looks like it is 1/f and white not 1/f^3 and 1/f^2 and white. Why?

I am not positive, but I believe the plot shown in reference [2] on page 58 as "Action 75" (link to plot in Action 75) is the figure to which Mr. JoJakNap is referring.

Mr. JoJakNap's question refers to "the VCO phase noise", but the plot on page 58 is the total noise result from an AC noise analysis of the phase-locked loop phase domain model at the output node "ph_out" (i.e., the output node of its 2.5 GHz VCO noise model).

There is a VCO noise analysis section of reference [2] starting on page 33, but the plot of its output noise[3] shown in "Action 46" on page 36 (link to plot in Action 46) does not include a 1/f sloped region. Refer to its slope analysis on Slide 9.

[3] Output noise derived from an HB noise analysis

Response to Question 1 from Cadence Forum Post in [1] (continued)

Phase noise describes the short and long term variations in the marks of a periodic signal. From Section 2 of reference [4]:

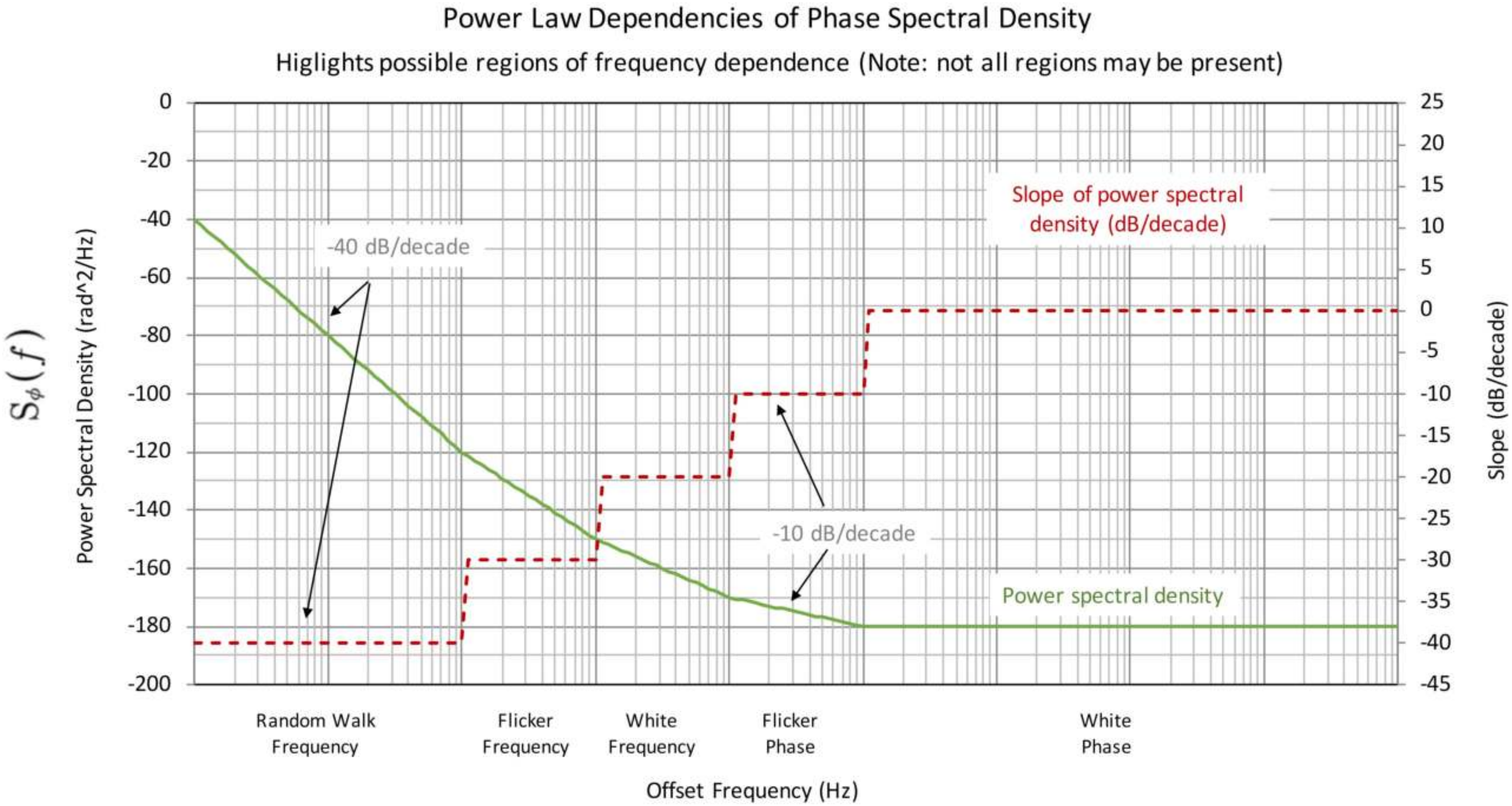
$$\mathcal{L}(f) \approx 10\text{Log}10\left[\left(\frac{1}{2}\right)\text{S}_{\phi}(f)\right] \quad \phi \ll 1 \text{ radian} \qquad [1]$$

As discussed in [4], its units are in dBc/Hz. When plotted on a logarithmic scale, the characteristics of the noise terms that contribute to phase noise may be identified by the slope of the curve as a function of frequency. This is shown in Figure 1 of reference [4] derived from a Figure in reference [5] and included on the following page (page 4).

[4] Logan, S.M., “Observations of the use of the Cadence Spectre® Simulator Phase Noise Analyses to Characterize Oscillators”, August 14, 2022, v1.0 available at: https://www.dropbox.com/s/5za1ilay6sqa06b/phase_noise_response_081422v1p0.pdf?dl=0

[5] Walls, F. and Ferre-Pikal, E. (1999), Frequency Standards, Characterization, Wiley Encyclopedia of Electrical and Electronics Engineering.

Power Spectral Density of a Frequency Reference Illustrating Different Sloped Regions



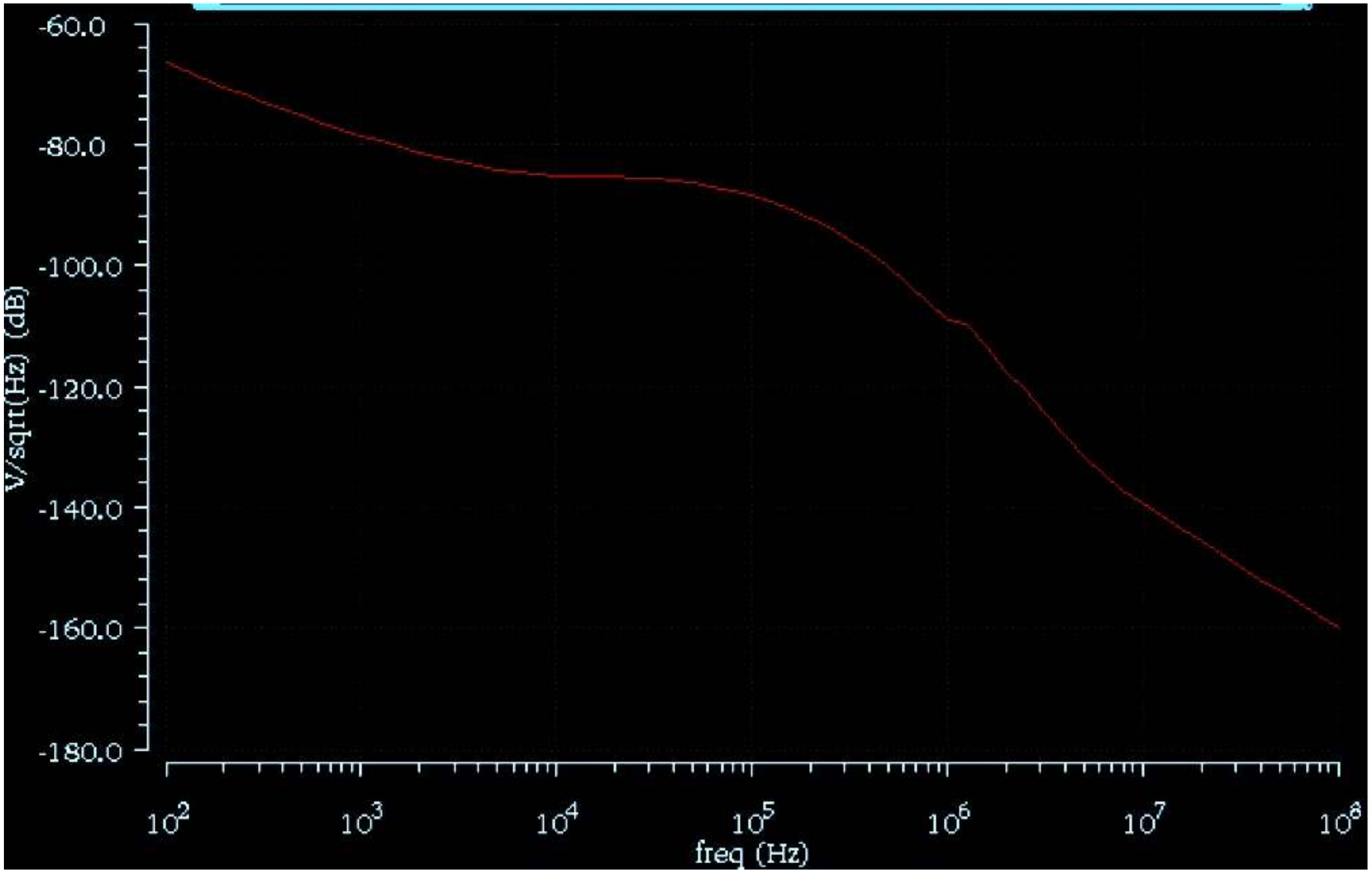
Response to Question 1 from Cadence Forum Post in [1] (continued)

If you examine the plot of total output noise for the phase-locked loop contained in Action 75, the units of the y-axis are in dB with units V/√Hz. Unless the decibel computation used for the y-axis is 20*log10(V/√Hz), its slopes will not correspond to those commonly used to identify noise sources in a conventional phase plot whose units are dBc/Hz.

Assuming the y-axis was computed as 20*log10(V/√Hz), the data from the plot in Action 75 (page 6) was extracted and its slope computed. The extracted data and its slope are shown on page 7 . It is evident that the frequencies between 100 Hz and 2 kHz show a slope of about -10 dB/decade corresponding to a 1/f sloped region.

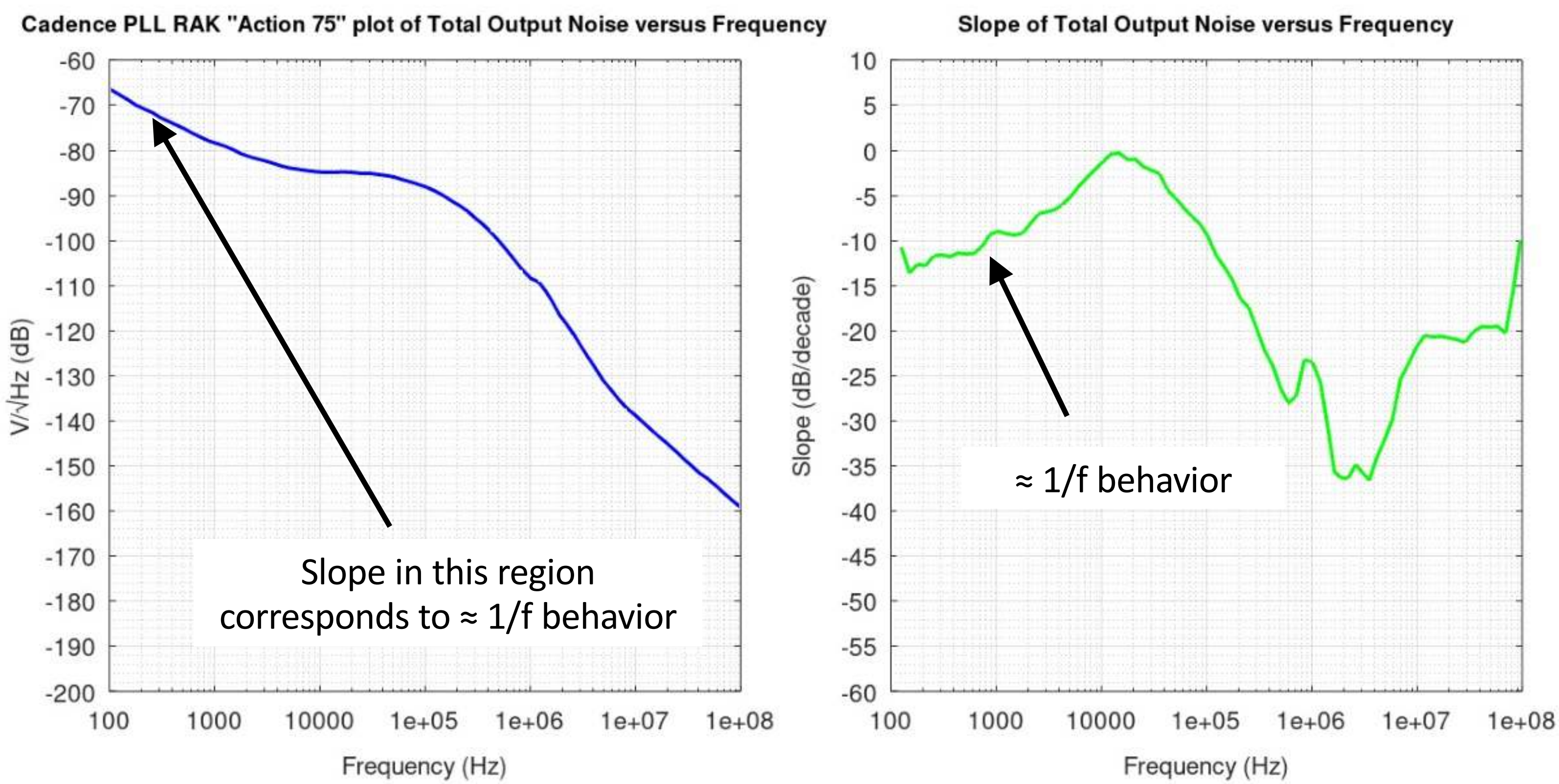
Since this is a closed-loop response and its bandwidth was simulated as 224 kHz (page 14), the output slope in the 100 Hz to 2 kHz region should be dominated by the slope of the reference clock noise, phase detector/charge pump noise, and attenuated VCO noise over this same frequency range. Inspection of the noise contributions to the total noise shown under Action 78 on page 60 in Slide 10 and its expanded view in Slide 11 shows that the total output noise in this region is dominated by the phase detector/charge pump noise with its slope of -10 dB/decade.

From Action 75 on page 58 of reference [2]

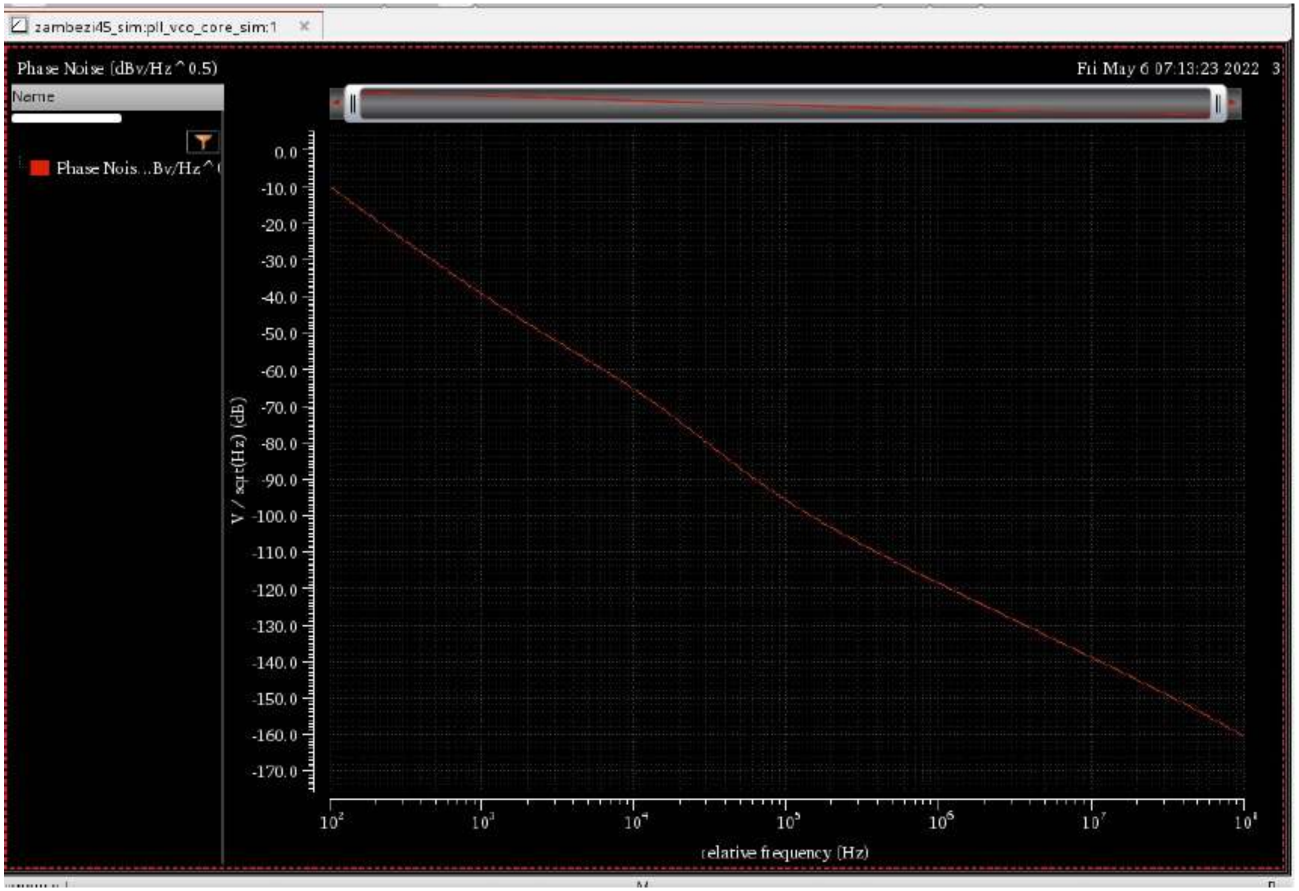


Slope Analysis of Total Output Noise on page 58 of reference [2]

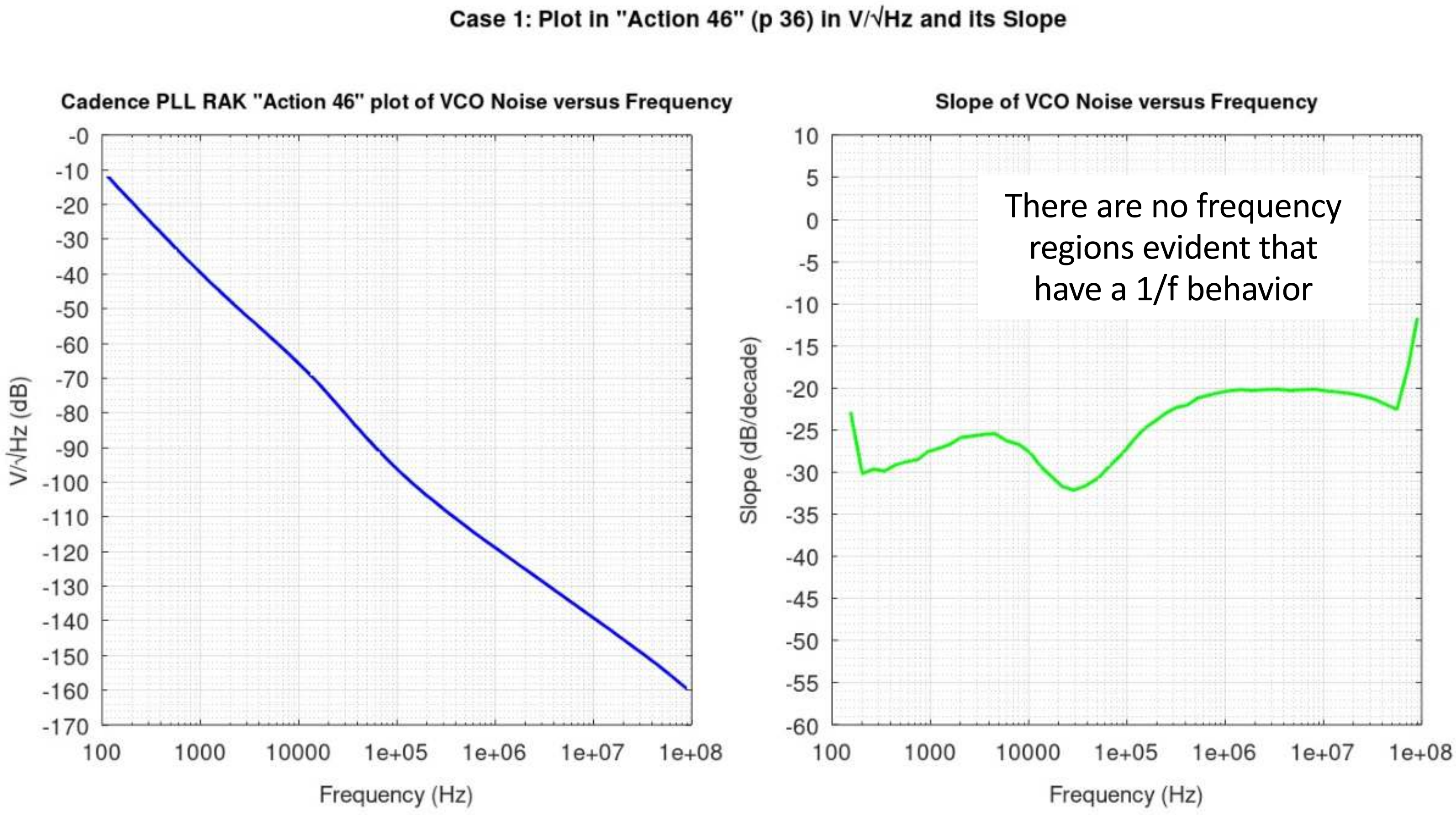
Case 1: Original Plot in V/√Hz and Slope of Original Plot



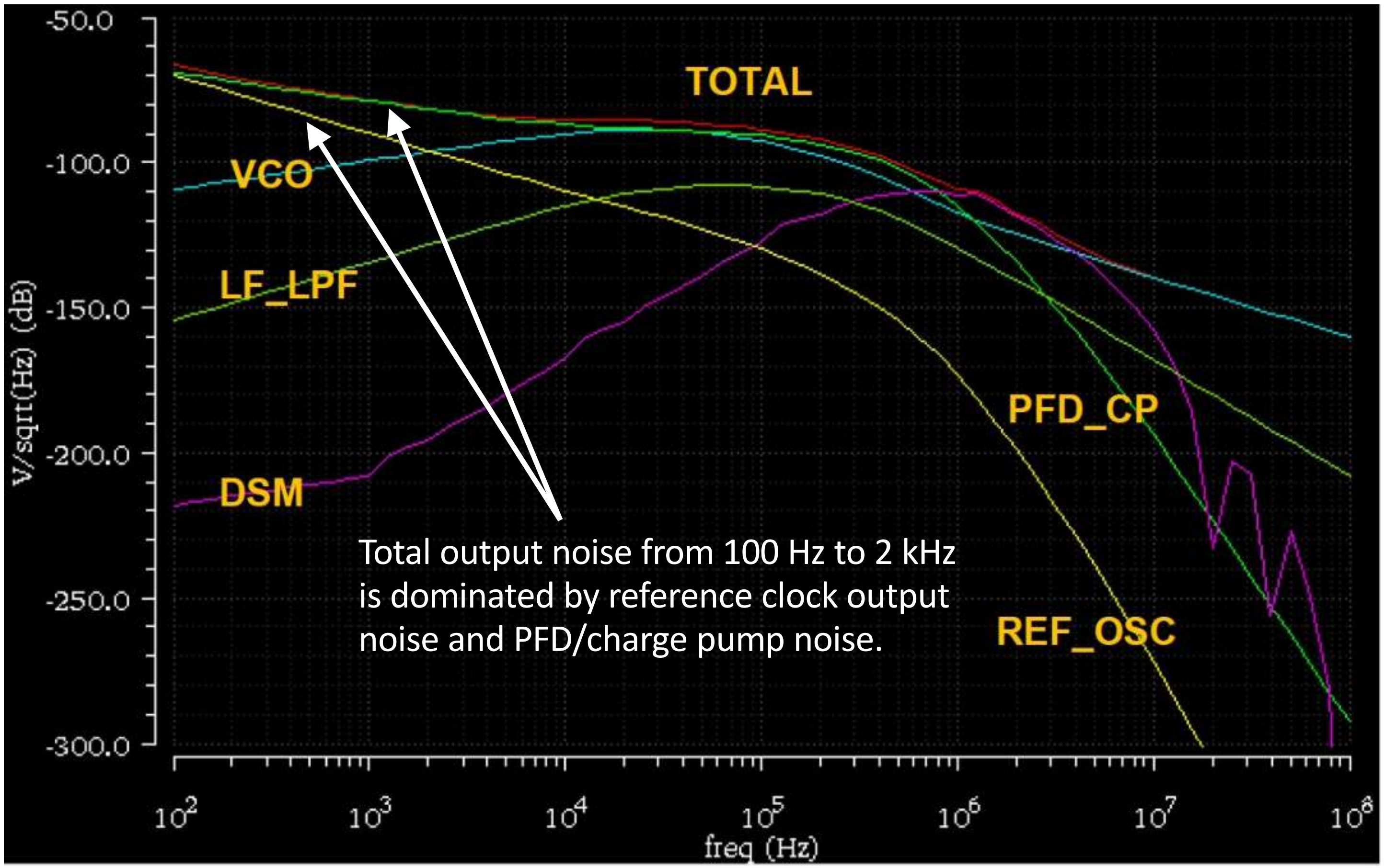
From Action 46 on page 36 of reference [2]



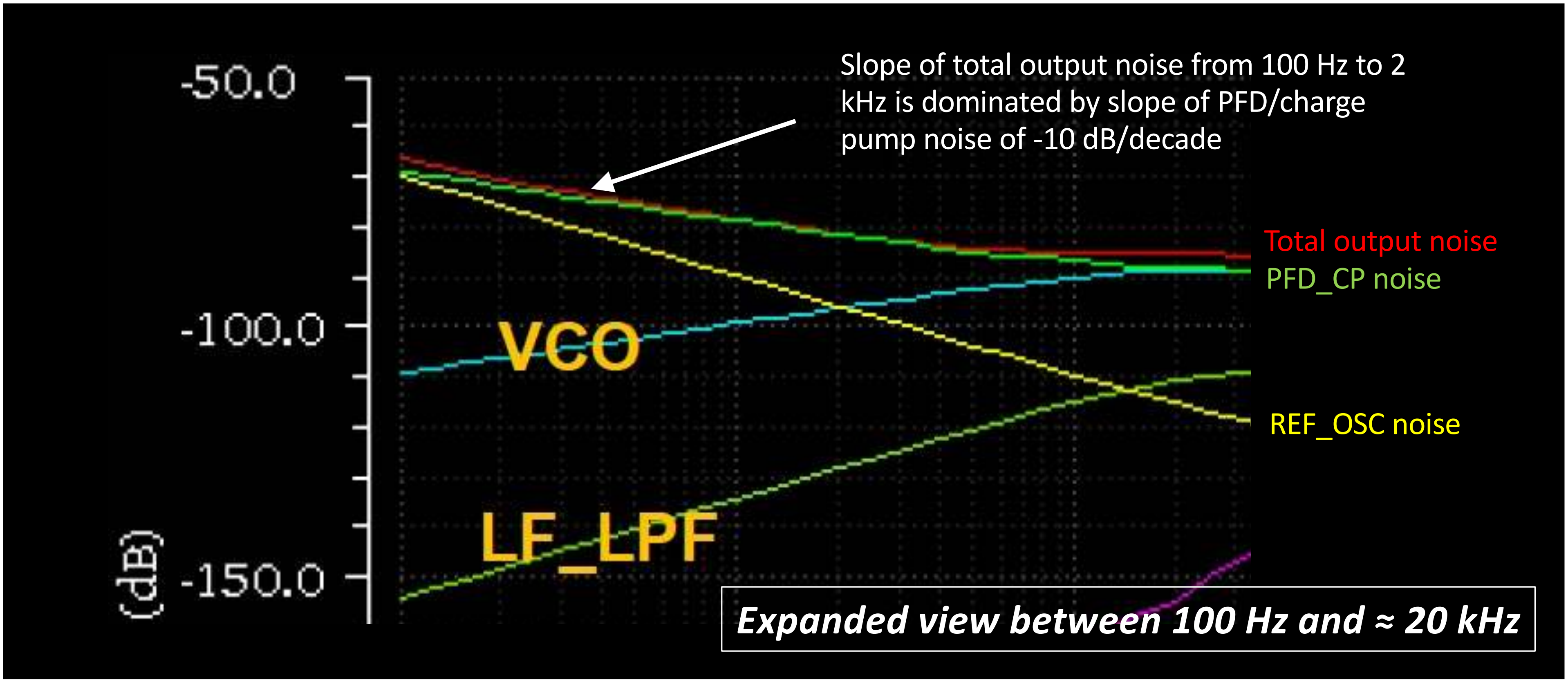
Slope Analysis of VCO Noise on page 36 of reference [2]



From page 60 of reference [2]



From page 60 of reference [2]



Response to Question 2 from Cadence Forum Post in [1]

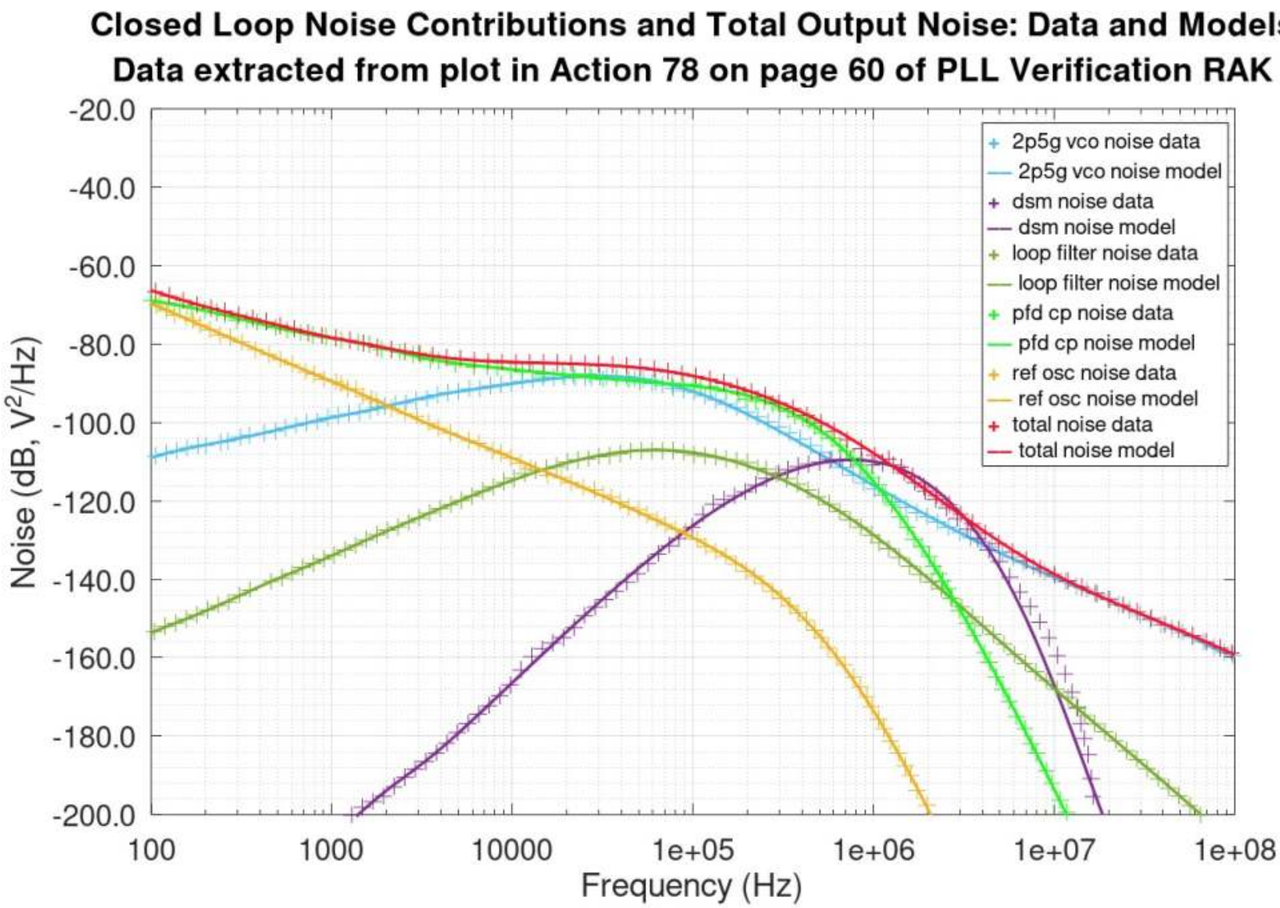
- Question:
  2. In the section where the total phase noise is summed, all noise sources appear to be summed together directly - as opposed to summing their squares and taking square root at each frequency.

The data for each of the PLL individual noise contributors from the plot on page 60 of reference [2] was extracted. The data for each contributing noise source was fit to create a model for each source. A comparison of the extracted data points with its respective model is shown on page 13.

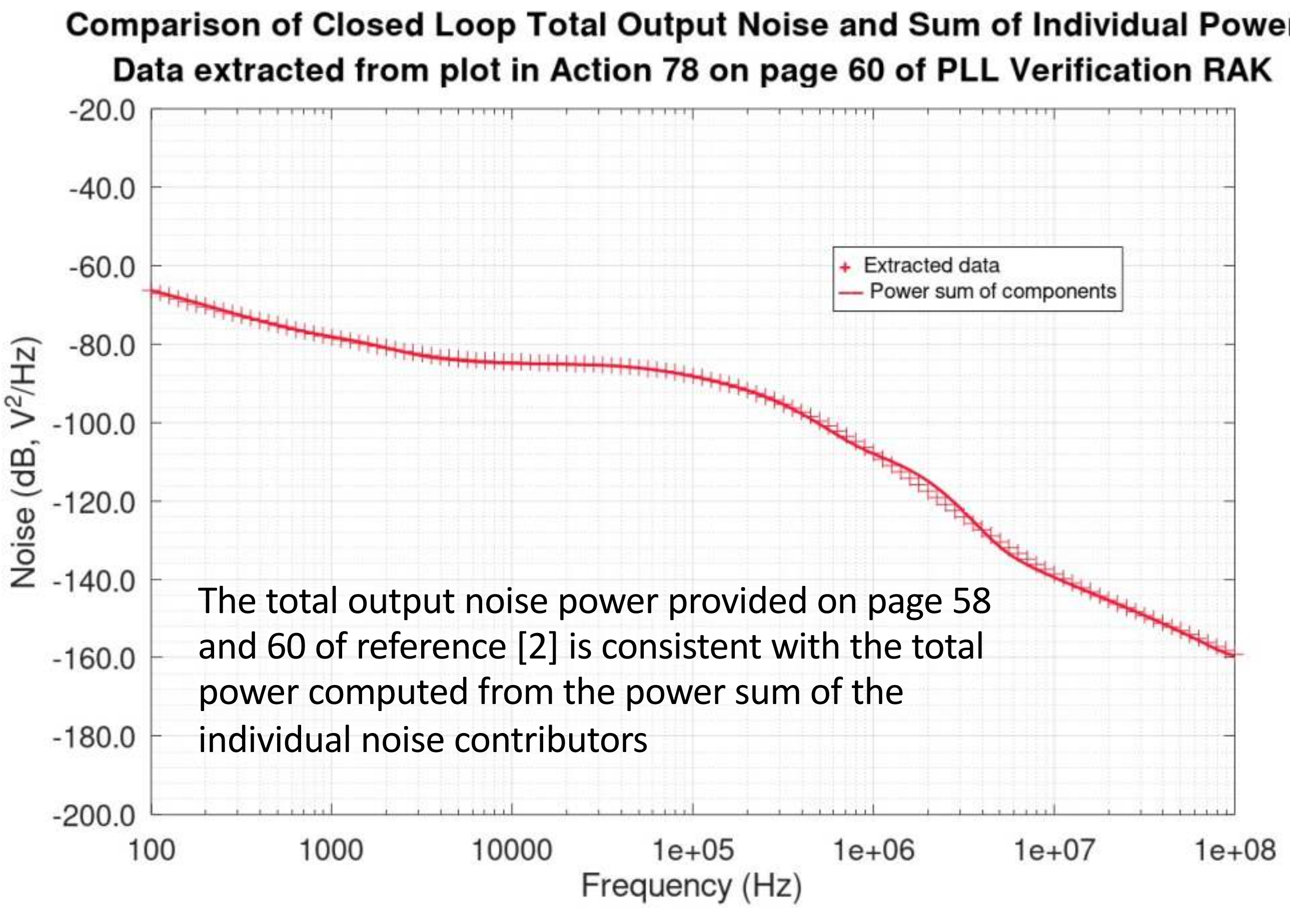
Using the model curve fits for each contributing noise source, the sum of the total output noise power was computed to compare with the total output noise provided on page 58 of reference [2]. The expression used to compute the total power is shown as Equation 2 and the comparison is provided on page 14.

$$P_{total} = 10\log 10\left[\sum_{i=1}^{i=N} 10^{\frac{P_i}{10}}\right] \qquad [2]$$

PLL Noise Contributors and Total Output Noise from page 60 of ref. [2]: Extracted Data Points and Resulting Models



Comparison of Sum of PLL Noise Contributors with Total Output Noise



The total output noise power provided on page 58 and 60 of reference [2] is consistent with the total power computed from the power sum of the individual noise contributors