VCO & PLL Problems

In this sheet I have put two simple analysis for two common VCO & PLL problems.

Yellow = input, Green = output

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PLL Charge Leakage Calculation from level of Phase Reference Spurs

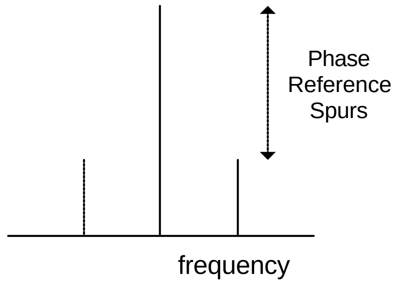
In a PLL the VCO generates sidebands which are commonly referred to a the Phase Reference Spurs. These are generated by modulation on the VCO control line caused by the PLL charge pump. This modulation on the VCO tune line cannot be seen on a scope as the level is too low.

This sheet calculates the 'modulation' voltage assuming low index FM moluation.

$\text{spur\_level} := -60$ -dBc

$\text{VCO\_gain} := 20\,\frac{\text{MHz}}{\text{volt}}$ $\text{unwanted\_freq} := 10\cdot\text{MHz}$

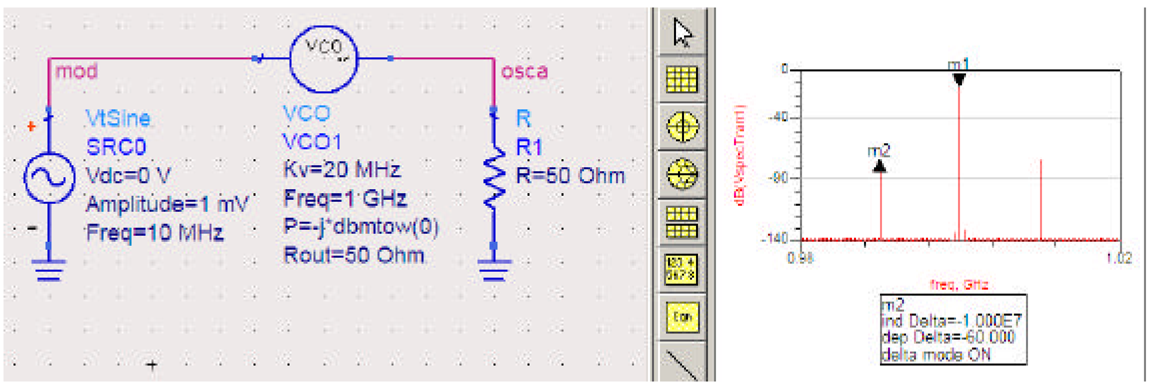
$$\text{Vmodulation\_equivalent} := \frac{\left(10^{\frac{\text{spur\_level}}{20}}\right)\cdot\text{unwanted\_freq}\cdot 2}{\text{VCO\_gain}}$$



$\text{Vmodulation\_equivalent} = 1\cdot\text{mV}$

Phase Reference Spurs Simulation

It is always nice to have a simulation, here is ADS simulating the setup above, VCO gain = 20MHz/V, unwanted frequency = 10MHz and the modulation level is 1mV, giving sidebands at -60dBc.



VCO Noise from a Resistor Voltage Noise

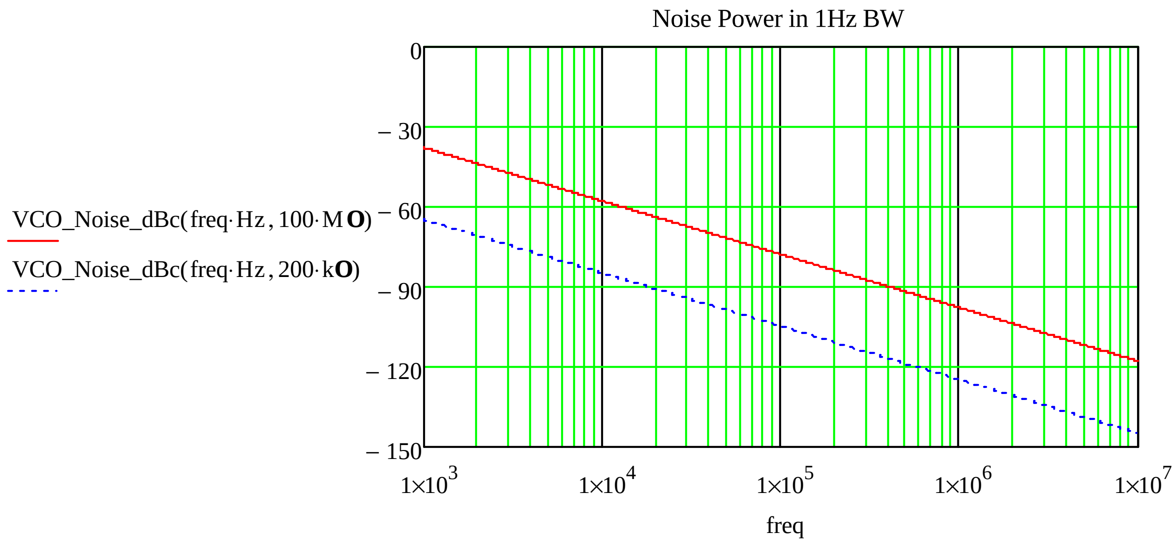
The next analysis is to show the affect of resistor noise on the VCO. The resistor could be part of the loop filter. The resistor noise is flat, but this modulates the VCO to give a 1/f spectrum. The ResBW used in this calculation is the fourier resolution, set in the spectrum analyser function on ADS.

This shows that if 200kOhm is used, then at 1kHz the noise from this is likely to be dominant at -60dBc/sqr(Hz), depending on the noise within the loop.

$k_b := 1.380658 \cdot 10^{-23} \cdot m^2 kg \cdot s^{-2} K^{-1}$ $\qquad$ $T := 300 \cdot K$

$$\text{NoiseVoltage}(\text{res}) := \sqrt{4 \cdot k_b \cdot T \cdot \text{res}}$$

$$\text{VCO\_Noise\_dBc}(\text{freq}, \text{res}) := 20 \cdot \log\left(\frac{\text{NoiseVoltage}(\text{res}) \cdot \sqrt{Hz} \cdot \text{VCO\_gain}}{\text{freq} \cdot 2}\right)$$



VCO Noise Simulation

Again a simulation is required using ADS. A resistor of 100Mohm is connected to a VCO with gain set to 20MHz/V, and the spectrum is shown below.

I have filtered the noise from the resistor using a three pole C-L-C passive filter.

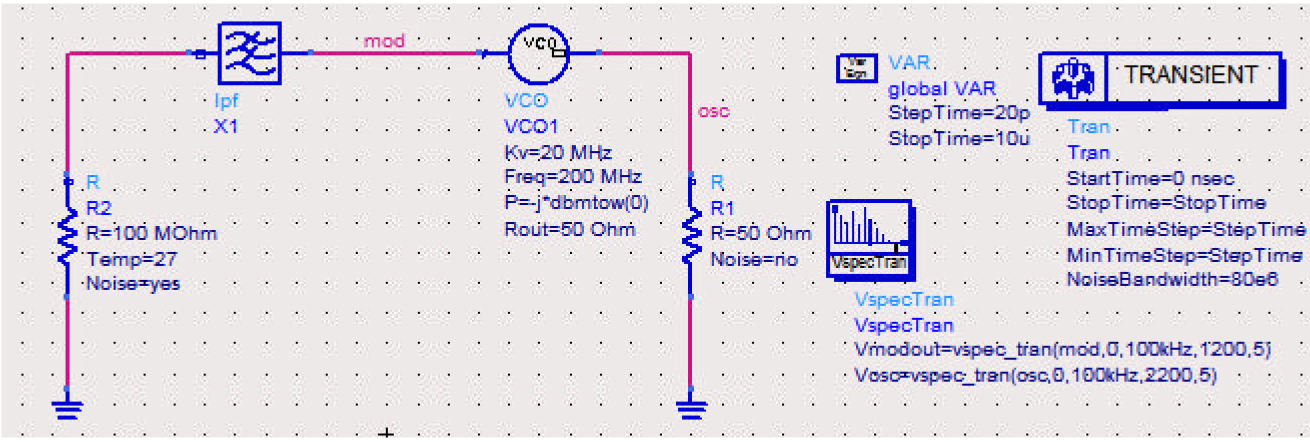
The simulated rms noise voltage at 9.85mV, agrees reasonably closely with the calculated value of 9.101mV, and is expected to be higher as the noise BW of a filter is usually higher than the 3dB BW.

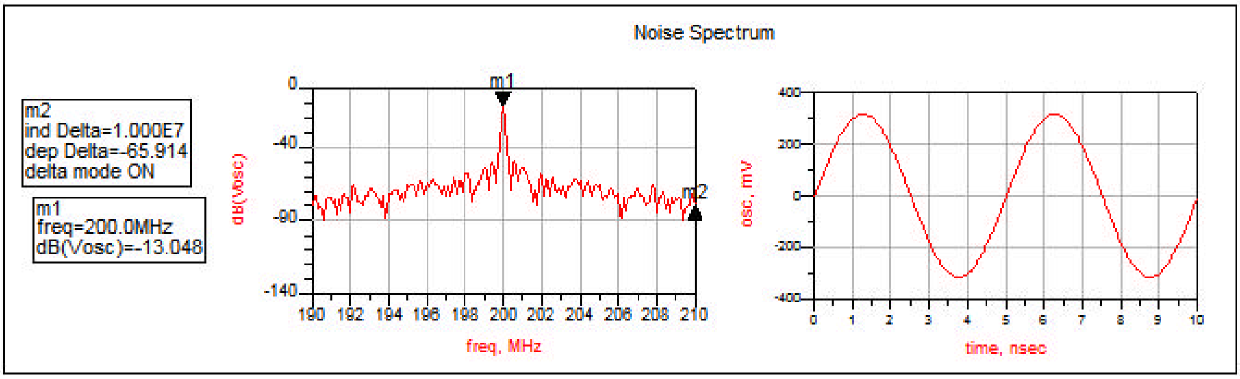
The noise power spectrum is calculated using same FM equation as in the first section and assumes the modulation is at a low level. The simulated noise sidebands at -65.9dBc agree reasonably well with the calculated value of -67.8dBc.

$\text{ResBW} := 100000$

$\text{NoiseVoltage}(100M\mathbf{O}) \cdot \sqrt{50MHz} = 9.1016 \cdot mV$

$\text{VCO\_Noise\_dBc}(10MHz, 100 \cdot M\mathbf{O}) + 10 \cdot \log(\text{ResBW}) = -67.807$





The Noise Modulation is seen below, the transient is in the center, the frequency response on the right.

Eqn Size=sweep_size(mod)

Eqn RMS=sqrt((sum(sqr(mod))/(Size)))

RMS
9.850E-3