

Simulations on VCO

Using Cadence SpectreRF Simulator

PSS, Pnoise, ... analyses

OSCILLATORS

Phase Noise analysis using PSS and Pnoise

Autonomous PSS Analysis

- ◆ PSS analysis lets you simulate both **driven** and **autonomous** circuits
- ◆ Driven circuits; amplifiers, filters, or mixers,
 - require a **stimulus** to create a time-varying **response**
 - Analysis period is a multiple of drive signal period
- ◆ Autonomous circuits: oscillators,
 - have time-varying responses even though the circuits are time-invariant.
 - No analysis period due to unknown oscillation period
 - specify an **estimate** of the oscillation period
 - PSS analysis uses this estimate to compute the precise period
 - ◆ PSS analysis monitors the voltage of the specified nodes and refines its estimate of the period

Phases of Autonomous PSS Analysis

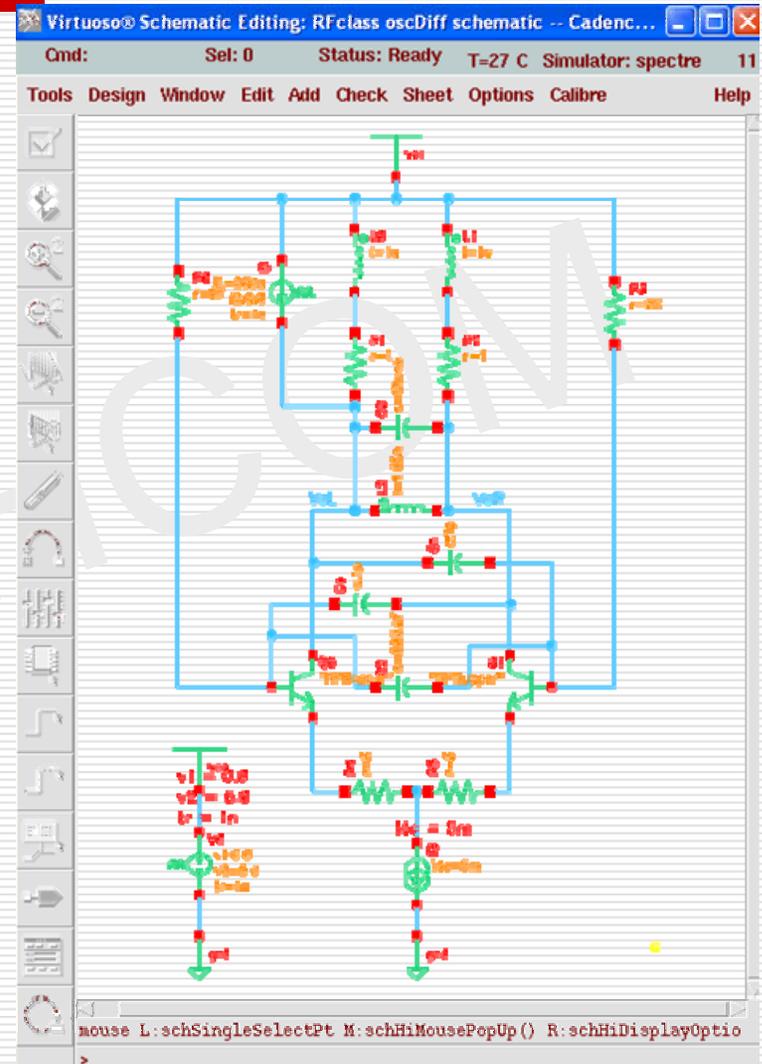
- ◆ A transient analysis phase to initialize the circuit
 - A beginning interval
 - A second, optional stabilization interval of length *tstab*
 - A final interval (that is four times the estimated oscillation period).
 - During the final interval, the PSS analysis monitors the waveforms in the circuit and improves the estimate of the oscillation period.
- ◆ A shooting phase to compute the periodic steady state solution.
 - During this phase, the circuit is simulated repeatedly over one period.

Starting and Stabilizing the Oscillator

- ◆ To simulate an oscillator using PSS analysis, you must first start it.
- ◆ Start an oscillator by supplying either
 - A brief impulse stimulus
 - A set of initial conditions for the components of the oscillator's resonator
- ◆ Allow the oscillator to run long enough to stabilize before you start the steady state solution.
- ◆ Adjust the *tstab parameter to supply the additional stabilization period.*

Differential Bipolar Oscillator

This example is from
rfExamples library of Cadence



Analog Environment

- ◆ Set model library (rfModels.scs)

The screenshot displays the Cadence Analog Design Environment (ADE) interface. The main window shows the 'Design' and 'Analyses' tabs. The 'Analyses' tab is active, showing a table of analysis configurations:

#	Type	Arguments	Enable
1	pnoise	7 1 100M 5	no
2	pas	1.96 5 /VoR /VoL	no

The 'Design Variables' tab is also visible, showing a table with one variable:

#	Name	Value
1	Ctune	3.5p

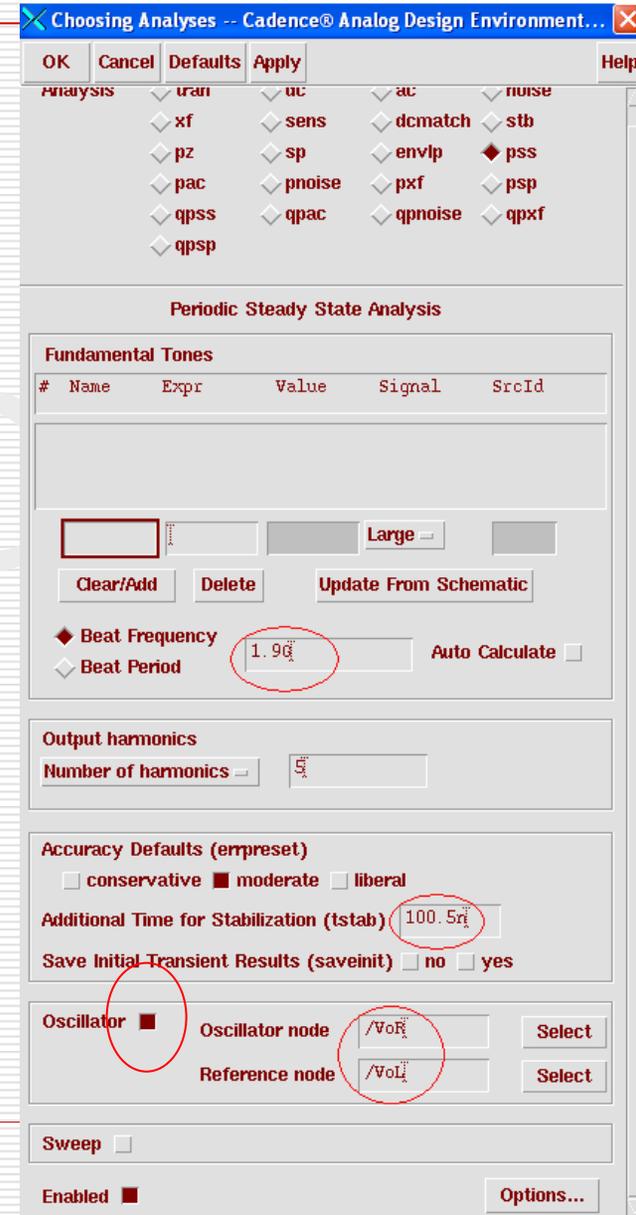
The 'spectre0: Model Library Setup' dialog box is open, showing the following configuration:

- #Disable|Model Library File**: `...ools.lnx86/dfII/samples/artist/models/spectre/rfModels.scs`
- Model Library File**: (Empty text field)
- Section (opt.)**: (Empty text field)

The dialog box includes buttons for 'OK', 'Cancel', 'Defaults', 'Apply', 'Enable', 'Disable', 'Up', 'Down', 'Add', 'Delete', 'Change', 'Edit File', and 'Browse...'. The 'Enable' button is currently selected.

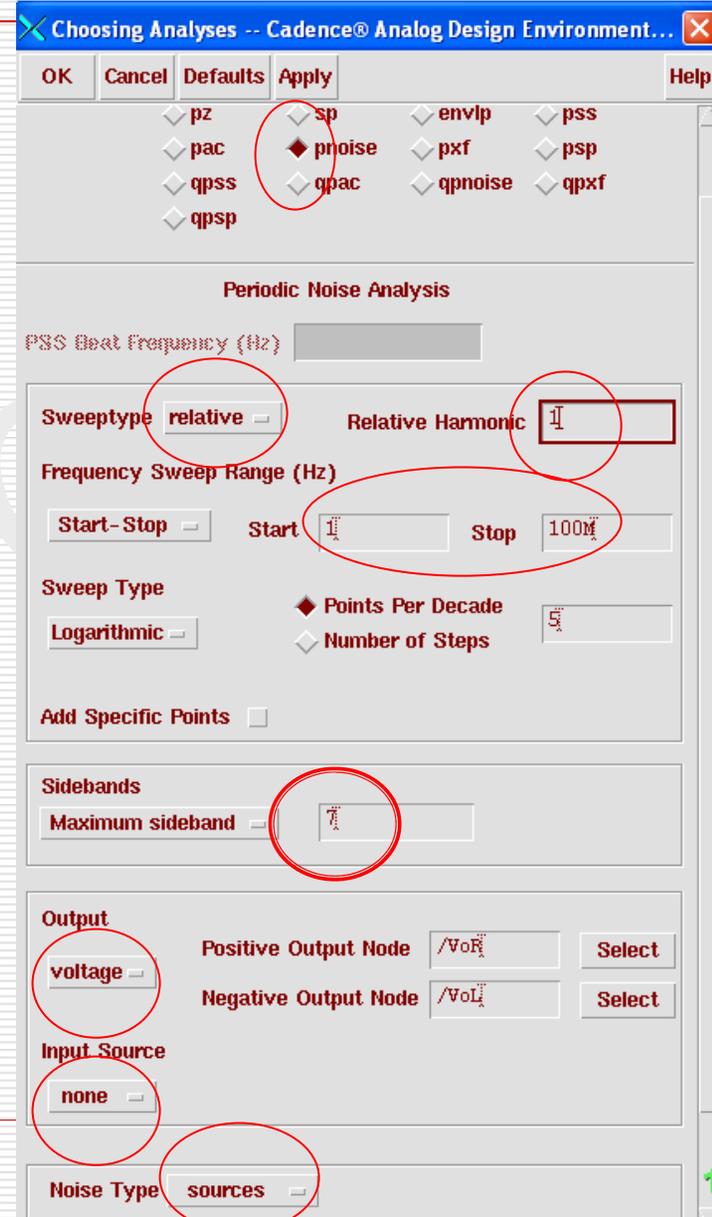
Setting Up PSS Analysis

- ◆ Specify an estimate frequency
- ◆ Specify an additional time for stabilization, *tstab* (optional for more accuracy)
- ◆ Highlight *Oscillator*
- ◆ Select the oscillator nodes on schematic



Setting Up Pnoise Analysis

- ◆ Choose relative sweeptype and harmonic 1
 - Shows frequency values relative to the fundamental frequency.
- ◆ *Maximum sideband = 7*
 - Increase the *Maximum sideband value until the output noise stops changing*
 - *Maximum sideband must be at least 1 to see any flicker noise up conversion.*
- ◆ Output: voltage
- ◆ Input: none



Simulation Results

- ◆ After running the simulation
- ◆ You can see the fundamental frequency
 - Results → direct plot → main form
 - → pss, Harmonic Frequency
- ◆ In this example:
 $f = 1.93875 \text{ GHz}$

The image shows a software dialog box titled "Direct Plot Form". It has a blue title bar with a close button (X) in the top right corner. Below the title bar are three buttons: "OK", "Cancel", and "Help".

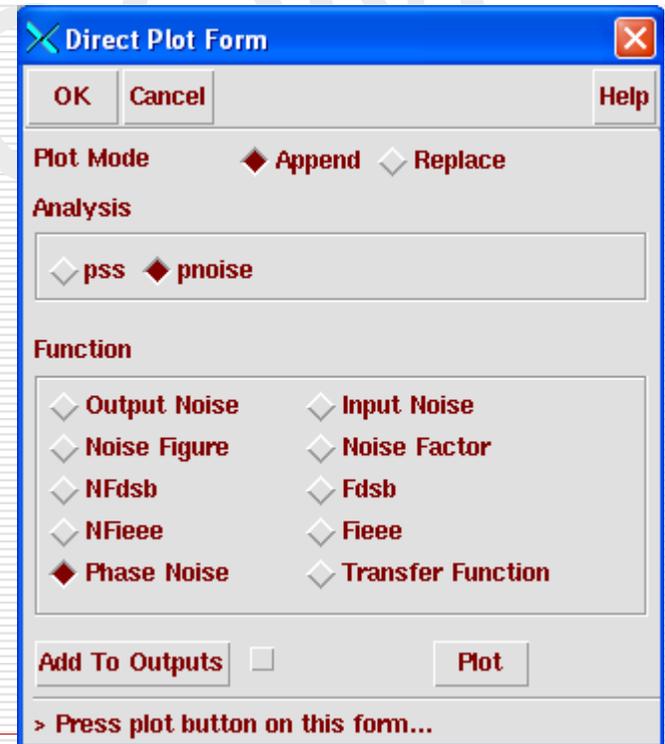
The dialog is divided into several sections:

- Plot Mode:** Contains two radio buttons: "Append" (which is selected) and "Replace".
- Analysis:** Contains two radio buttons: "pss" (selected) and "pnoise".
- Function:** A list of 16 functions with radio buttons next to them. The "Harmonic Frequency" function is selected. The other functions are: Voltage, Current, Power, Voltage Gain, Current Gain, Power Gain, Transconductance, Transimpedance, Compression Point, IPN Curves, Power Contours, Reflection Contours, Power Gain Vs Pout, Comp. Vs Pout, and Node Complex Imp.
- Harmonic Frequency:** A table with 5 rows and 2 columns. The first row has "0" in both columns. The second row is highlighted in red and contains "1" and "1.93875G". The other rows contain "2 3.8775G", "3 5.81625G", "4 7.755G", and "5 9.69375G".
- At the bottom, there are two buttons: "Add To Outputs" (with an unchecked checkbox) and "Plot".
- Below the "Plot" button is a text prompt: "> Press plot button on this form...".

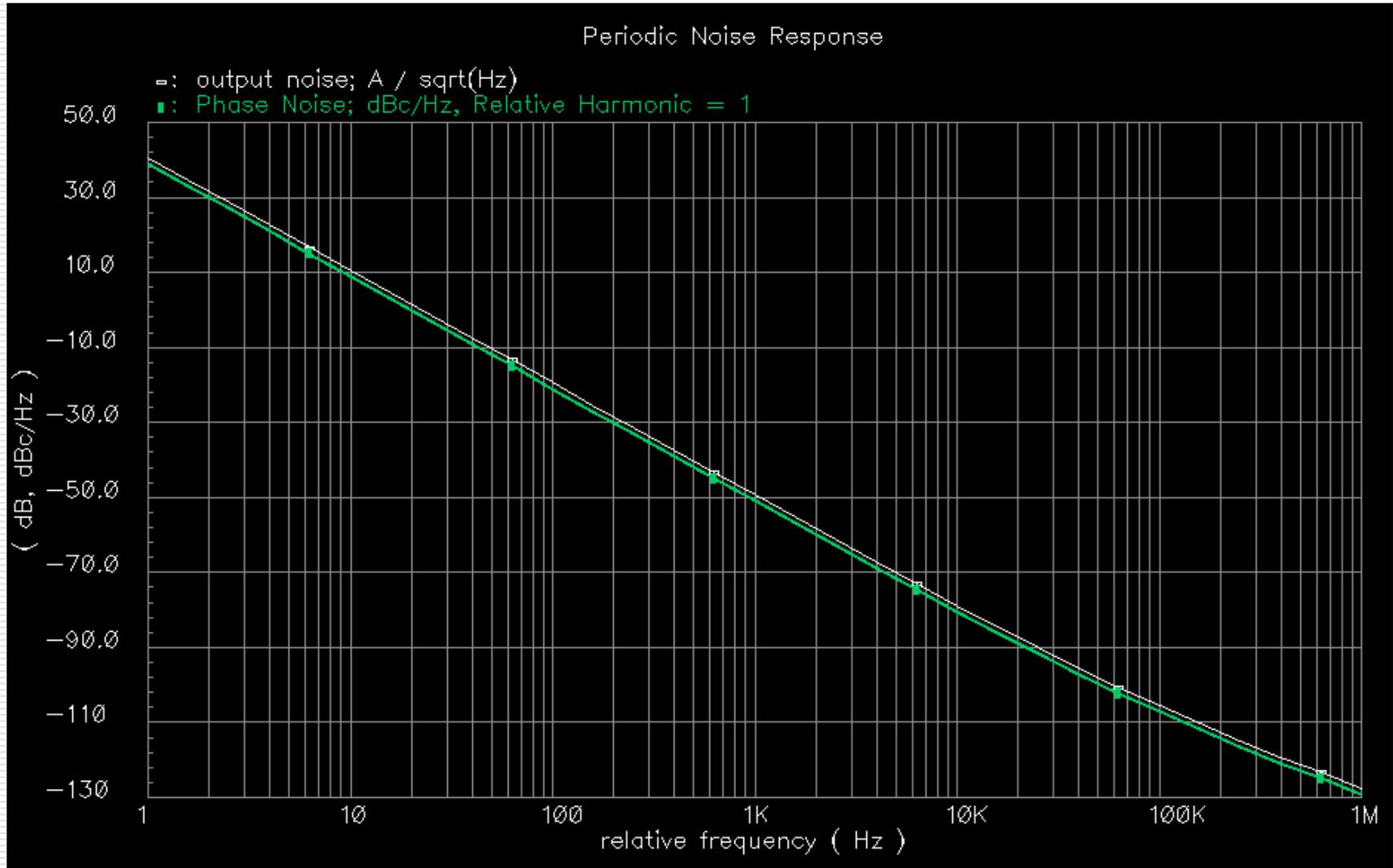
Phase Noise & Output Noise

- ◆ You can plot Phase Noise & Output Noise (dB) on the same graph
 - & see the linear relationship between them.
 - The output noise is scaled by the carrier amplitude to produce the phase noise value.

- ◆ The phase noise is:
 - -80.5 dBc/Hz @ 10kHz
 - -107.2 dBc/Hz @ 100kHz
 - -129.1 dBc/Hz @ 1MHz



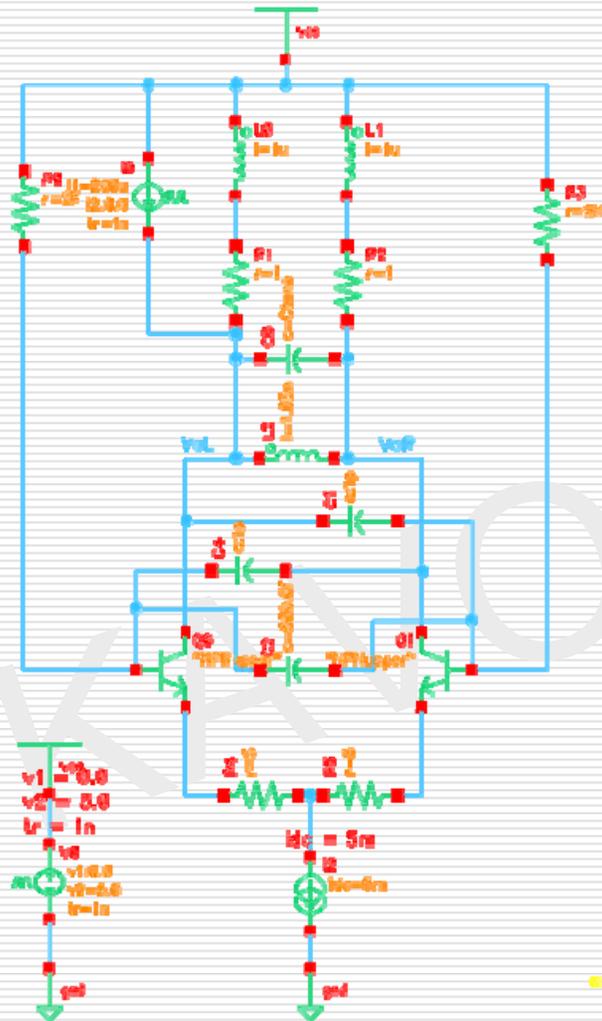
Phase Noise & Output Noise



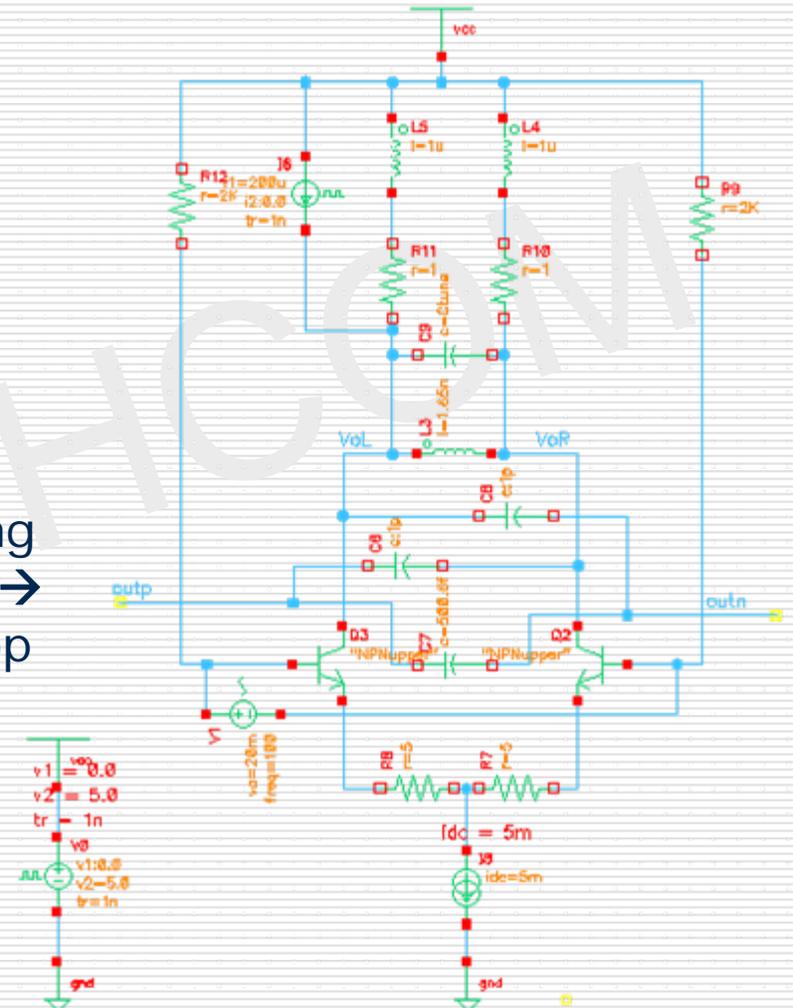
Convergence Issue

- ◆ Increase the value of the `tstab` parameter.
- ◆ Be sure that you successfully started the oscillator.
- ◆ Improve your estimate of the period.
- ◆ Increase the value of the `maxperiods` parameter to increase the maximum number of iterations
- ◆ Tighten the normal simulation tolerances by changing the values of the `maxstep`, `reitol`, `lteratio`, and `errpreset` parameters. Avoid setting *errpreset to liberal*.

Small Signal Loop Gain with AC Analysis

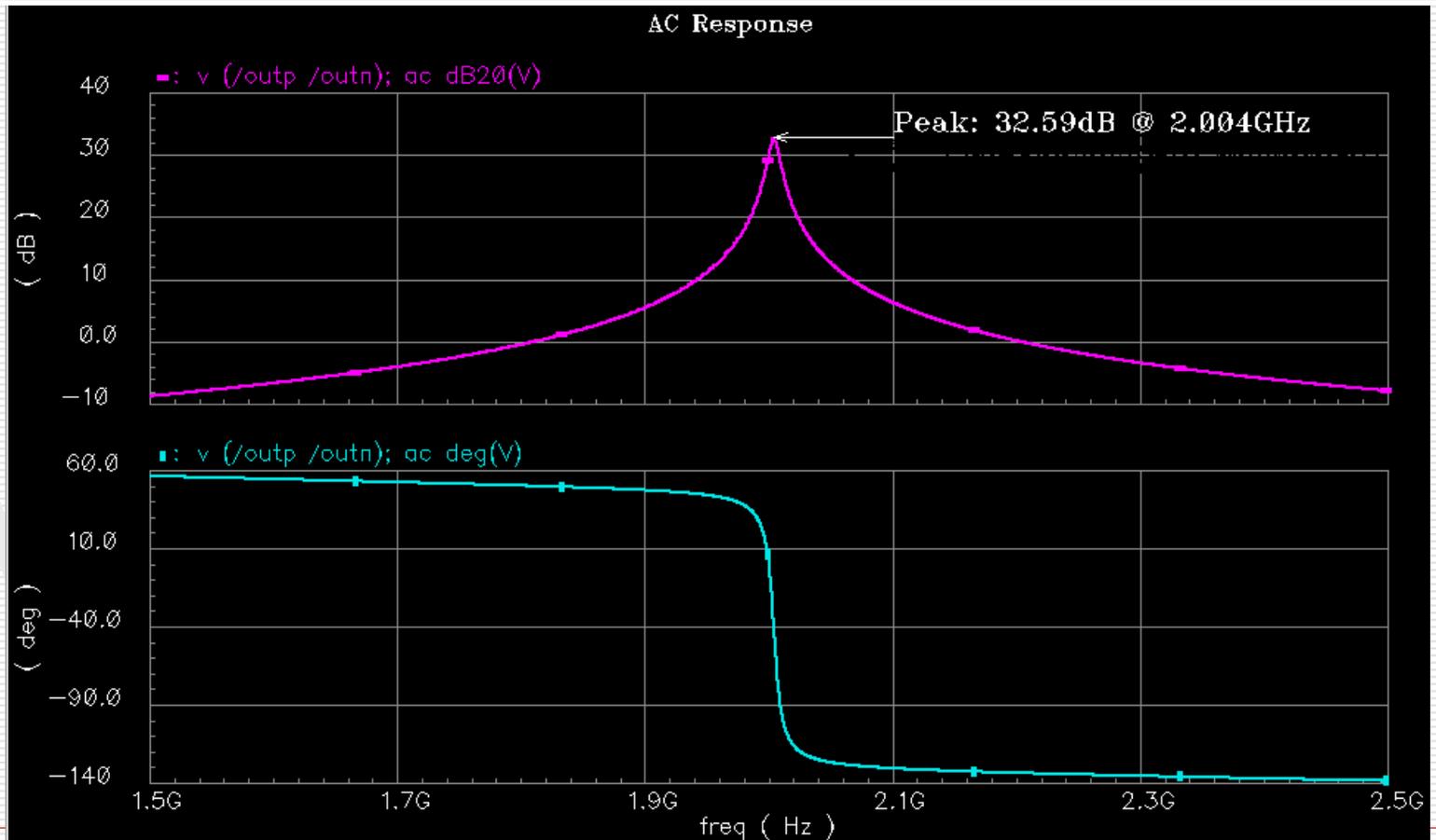


Opening
----->
the loop



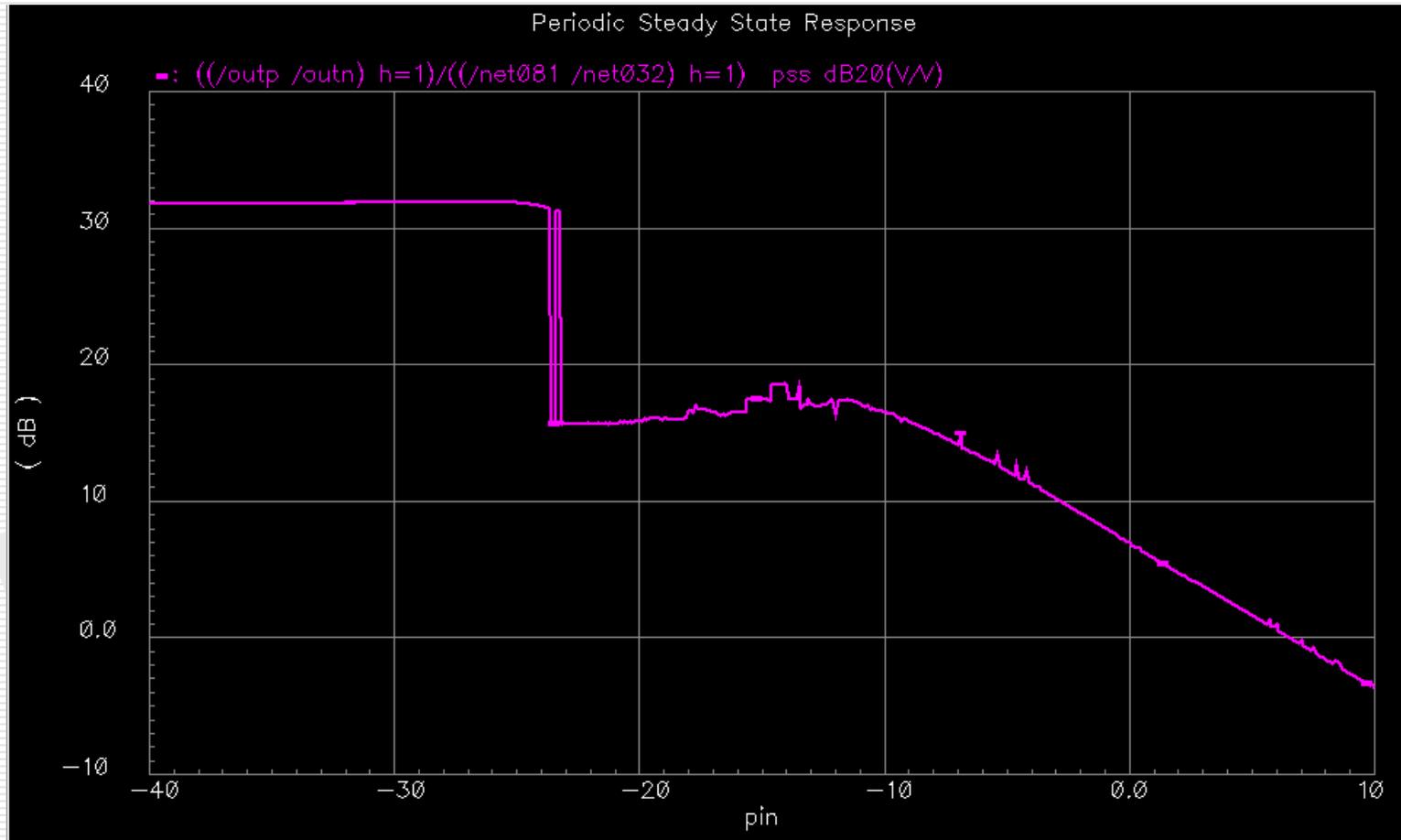
Loop Gain with AC Analysis

- ◆ Peak freq is at ~2G (higher than oscillation freq)
 - capacitive load is lower because the loop is opened



Loop gain vs. Amplitude (PSS)

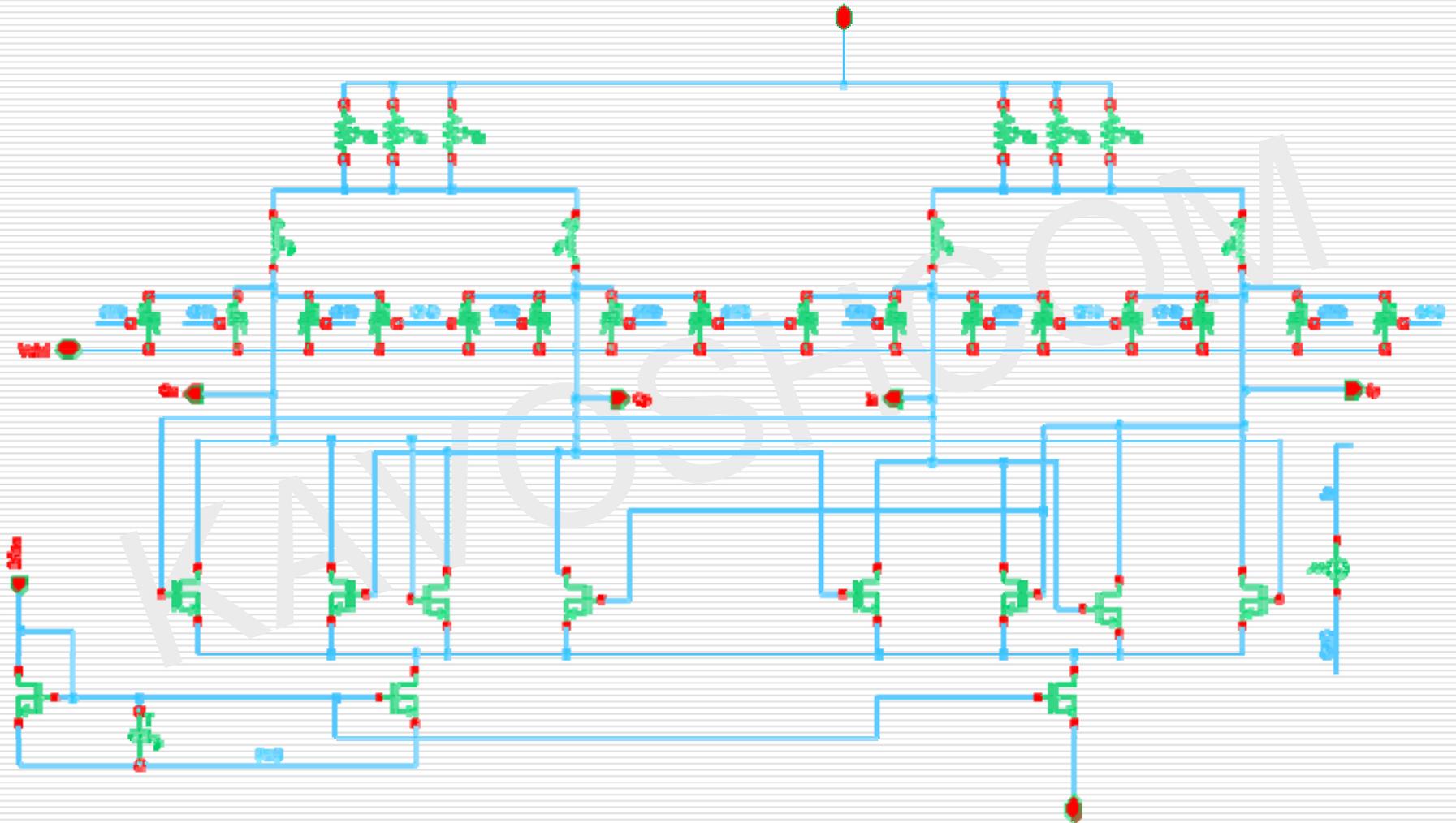
- ◆ Loop gain decreases with higher amplitudes



VOLTAGE CONTROLLED OSCILLATORS

Time-domain response using *Tran* or *PSS* analyses
Tuning range using *PSS* analysis
Phase Noise using *PSS* and *Pnoise* analyses

Quadrature CMOS VCO



Tran and PSS Analyses

- ◆ Setup and run these analyses as described before
- ◆ The oscillation frequency for $V_{cont}=0.7V$ is $\sim 1.47GHz$

Direct Plot Form

OK Cancel Help

Plot Mode Append Replace

Analysis

tran pss

Function

- Voltage
- Power
- Current Gain
- Transconductance
- Compression Point
- Power Contours
- Harmonic Frequency
- Power Gain Vs Pout
- Node Complex Imp.
- Current
- Voltage Gain
- Power Gain
- Transimpedance
- IPN Curves
- Reflection Contours
- Power Added Eff.
- Comp. Vs Pout

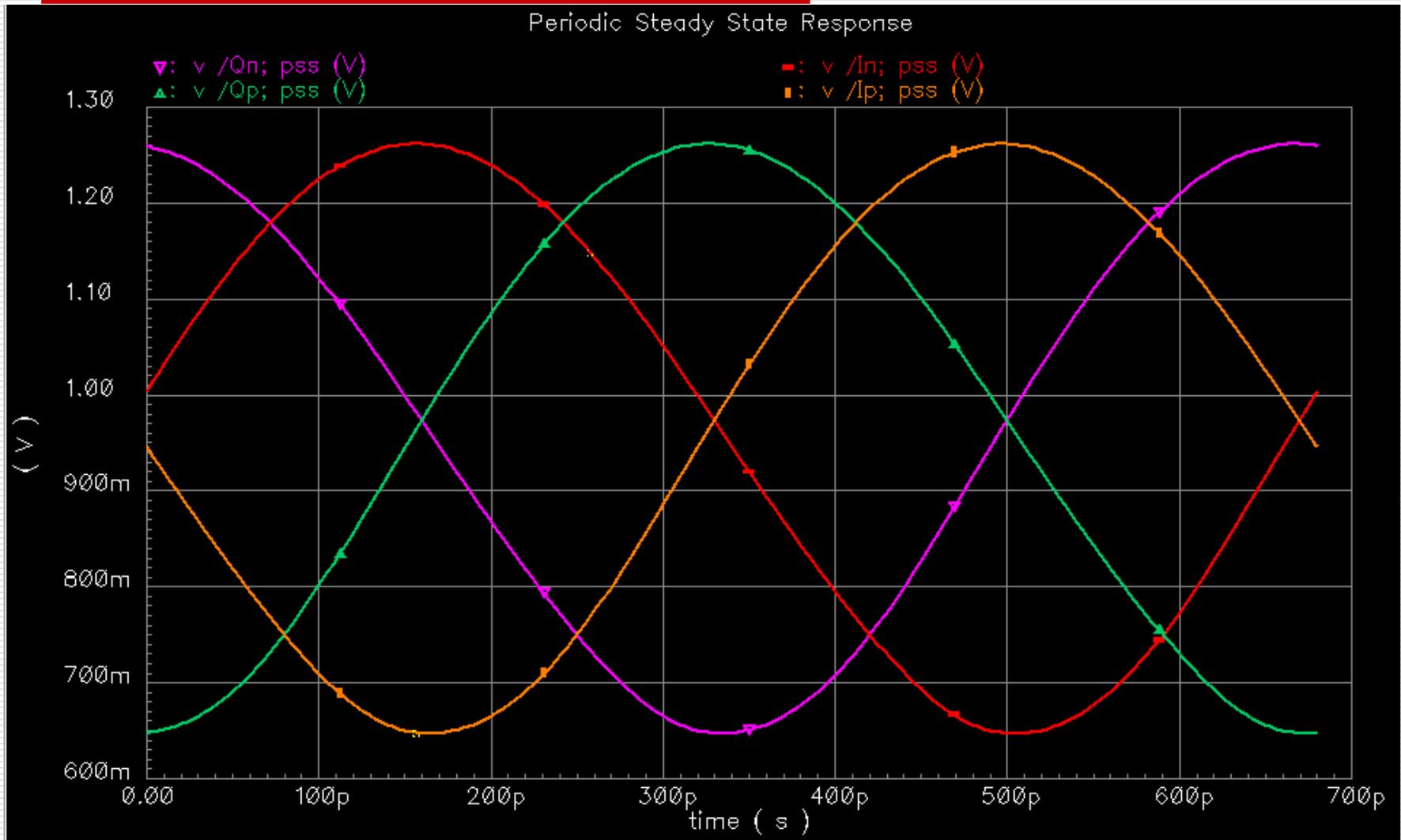
Harmonic Frequency

0	0
1	1.46993G
2	2.93985G
3	4.40978G
4	5.8797G
5	7.34963G

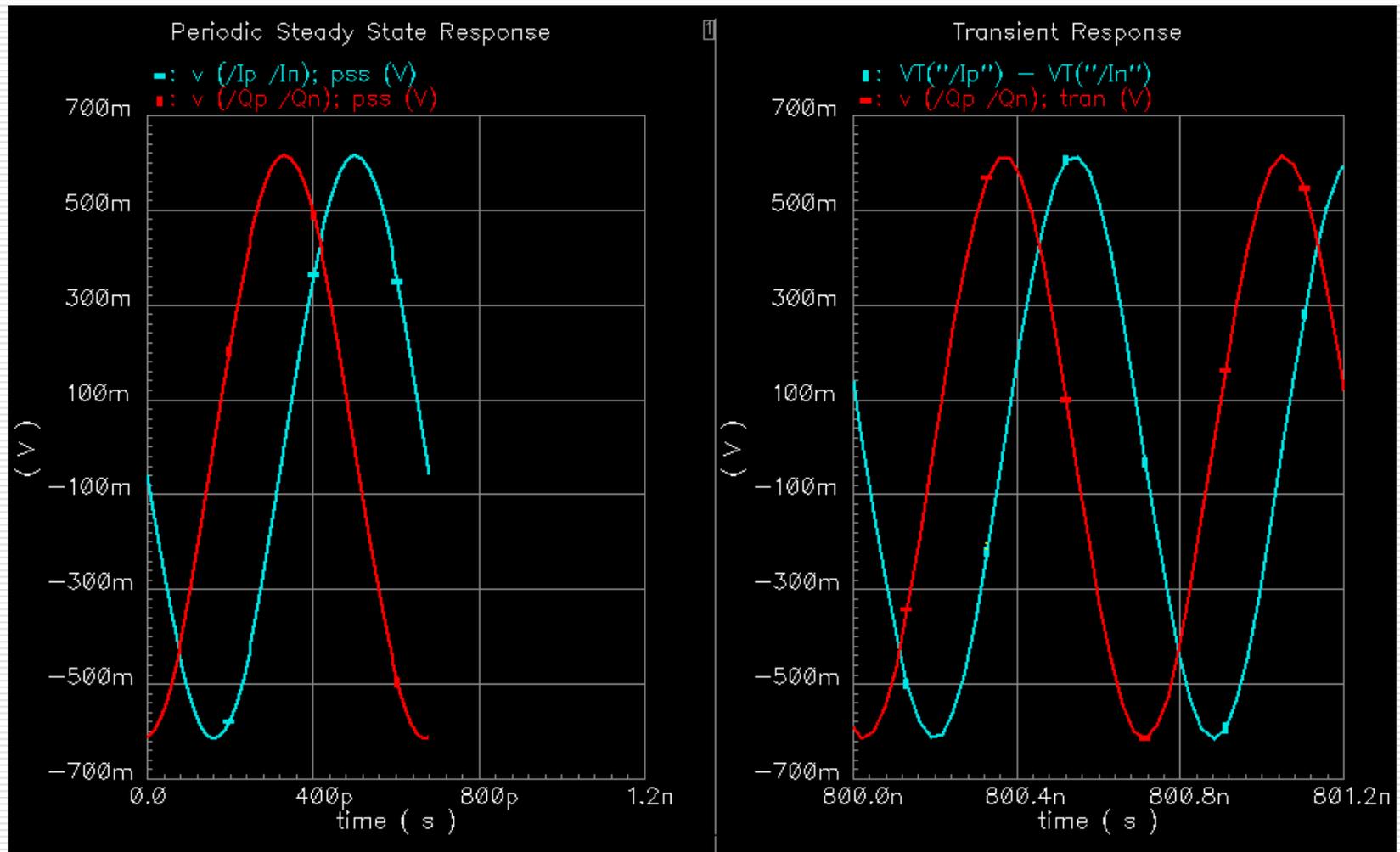
Add To Outputs Plot

> Press plot button on this form...

PSS Response in time (1 period)



PSS vs. Transient Response (diff)



Swept PSS to plot frequency vs. Vcont

- ◆ To plot oscillation frequency vs. control voltage
 - *PSS* is much faster & easier than *Tran*
- ◆ Highlight *sweep* and specify sweep variable and range

Choosing Analyses -- Cadence® Analog Design Environment...

OK Cancel Defaults Apply Help

◆ Beat Frequency 1.4 GHz Auto Calculate

◇ Beat Period 5 ns

Output harmonics

Number of harmonics 5

Accuracy Defaults (empreset)

conservative moderate liberal

Additional Time for Stabilization (tstab) 100 ns

Save Initial Transient Results (saveinit) no yes

Oscillator Oscillator node /Ip Select

Reference node /In Select

Sweep Frequency Variable? ◆ no ◇ yes

Variable Variable Name Vcont Select Design Variable

Sweep Range

◆ Start-Stop Start 0 Stop 1.0

◇ Center-Span

Sweep Type

◆ Linear Step Size .1

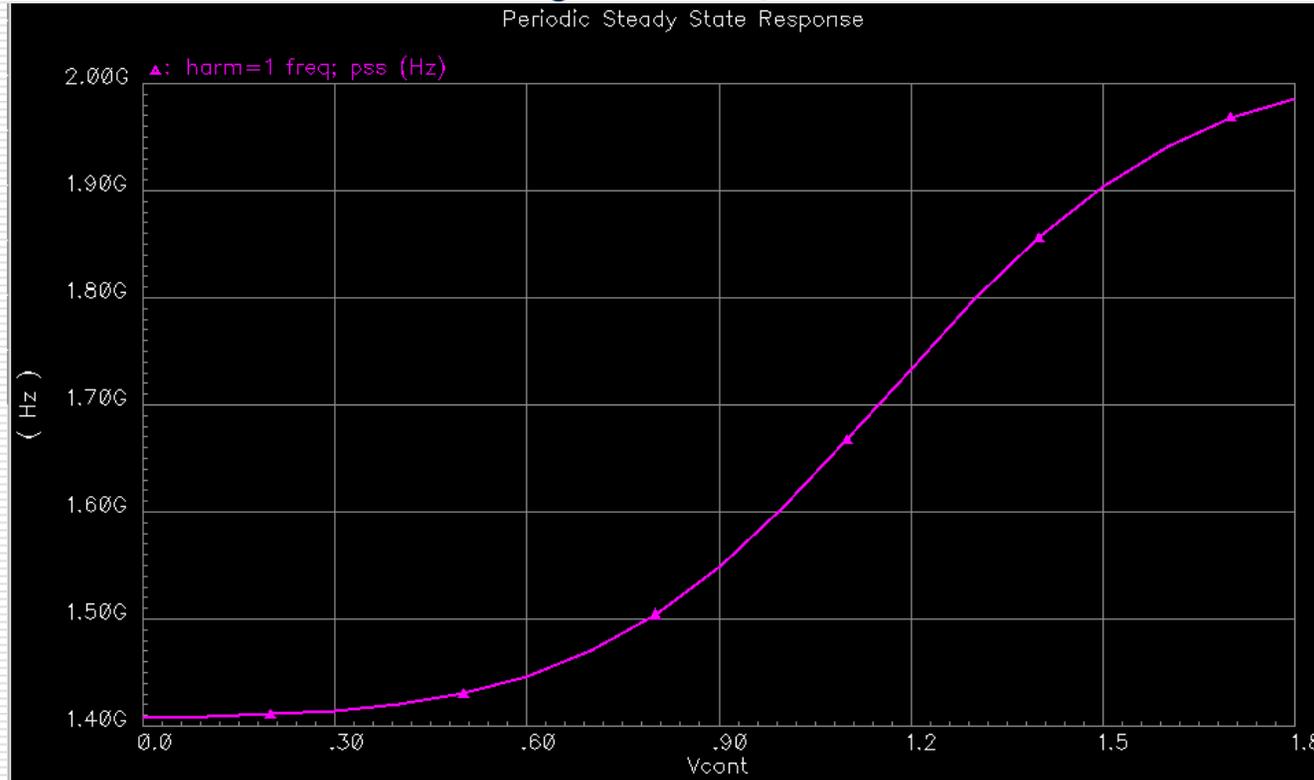
◇ Logarithmic ◇ Number of Steps

Add Specific Points

Enabled Options...

VCO frequency vs. control voltage

- ◆ $f = 1.407 \text{ GHz @ } 0\text{V}$
- ◆ $f = 1.987 \text{ GHz @ } 1.8\text{V}$
- ◆ Nonlinearity \propto slope



Direct Plot Form

OK Cancel Help

Plot Mode Append Replace

Analysis pss

Function

- Voltage
- Power
- Current Gain
- Transconductance
- Compression Point
- Power Contours
- Harmonic Frequency
- Power Gain Vs Pout
- Node Complex Imp.
- Current
- Voltage Gain
- Power Gain
- Transimpedance
- IPN Curves
- Reflection Contours
- Power Added Eff.
- Comp. Vs Pout

Harmonic Frequency

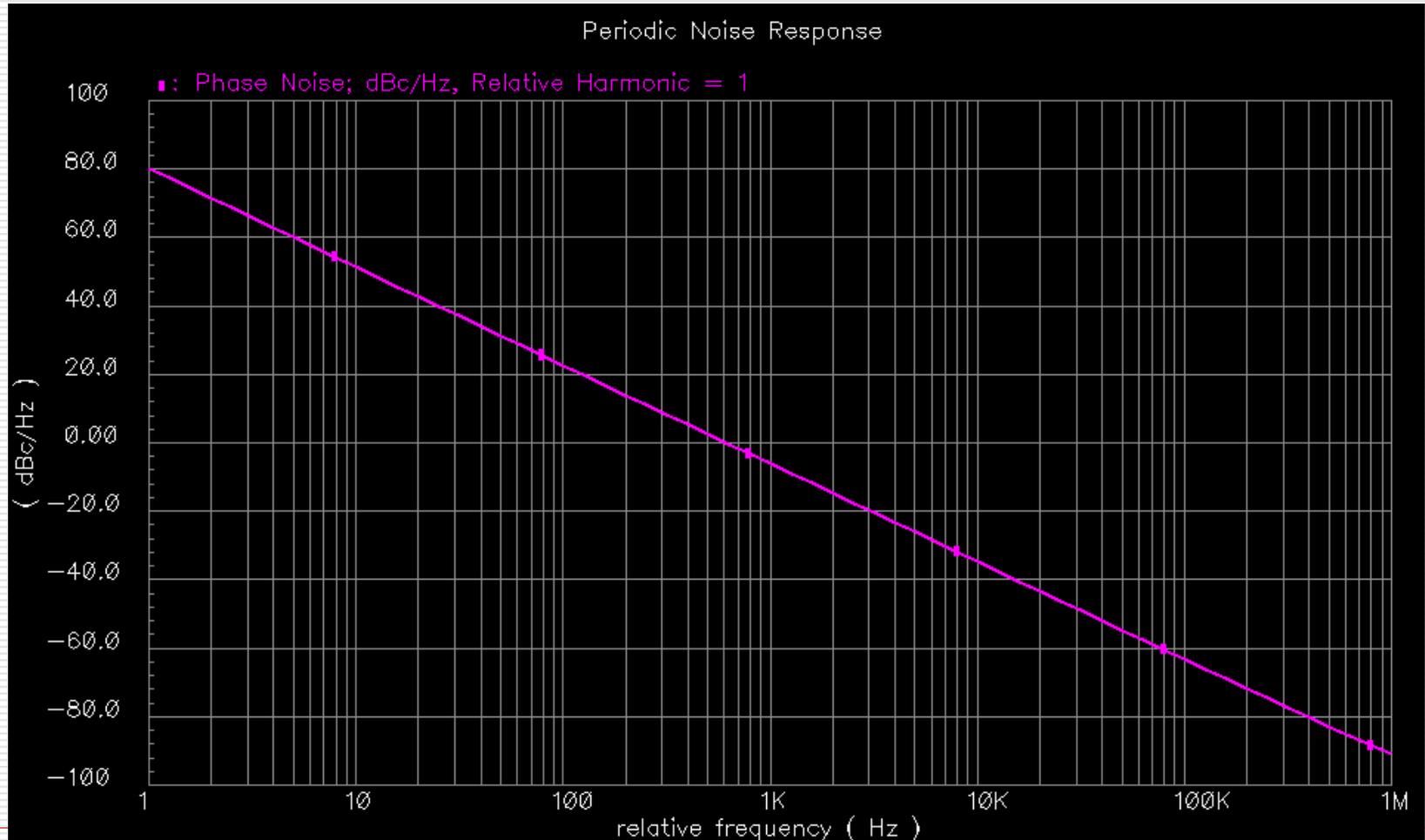
0	0	
1	1.407496	- 1.!
2	2.814986	- 3.!
3	4.222476	- 5.!

Add To Outputs Plot

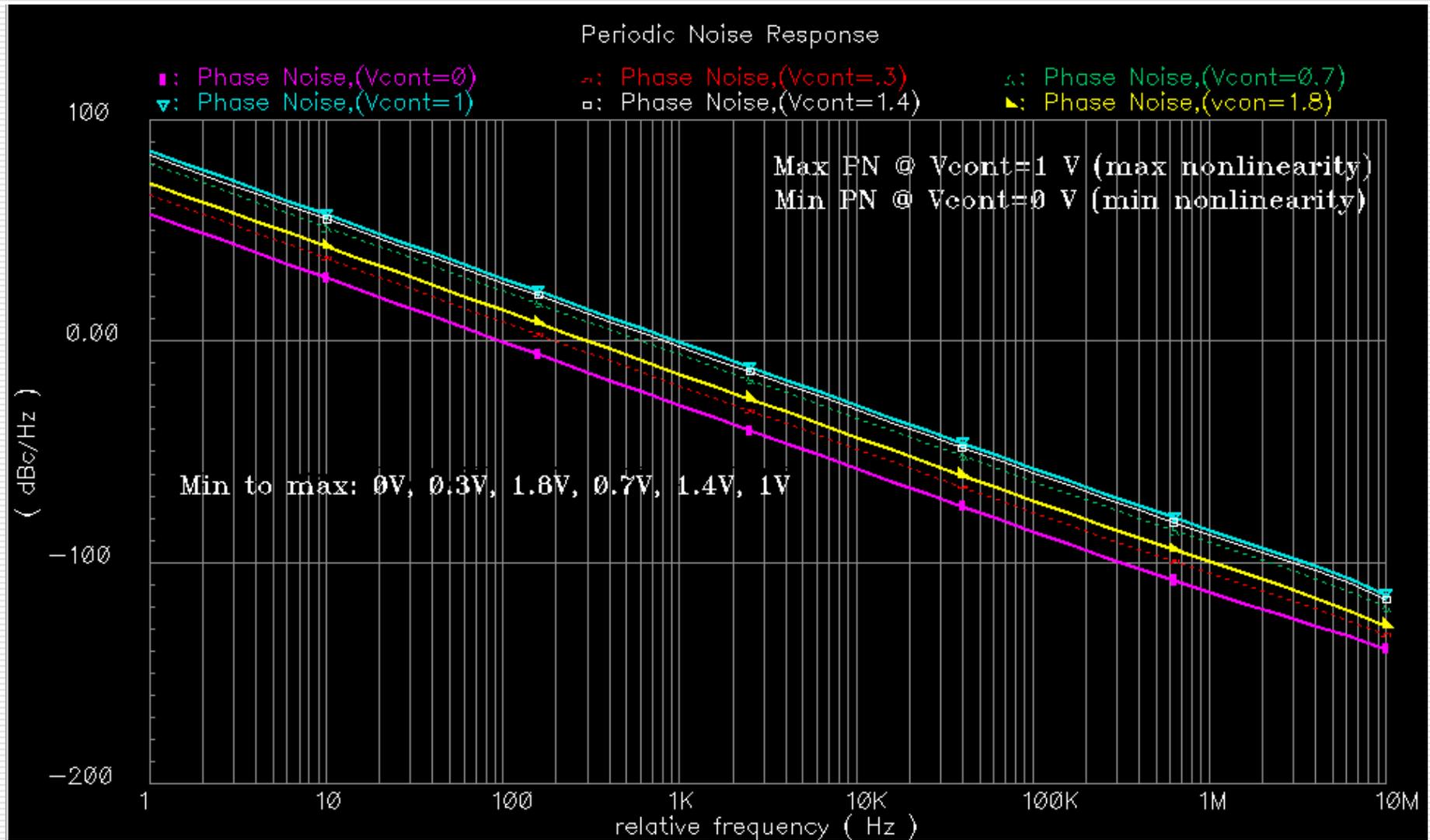
> Press plot button on this form...

Phase Noise (@ $V_{cont}=0.7V$)

- ◆ -63.3 dBc/Hz @ 100kHz -91dBc/Hz @ 1MHz



Effect of Varactor Nonlinearity



Periodic Noise Response

