Simulations on VCO

Using Cadence SpectreRF Simulator

PSS, Pnoise, ... analyses

KAVOSHCO
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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

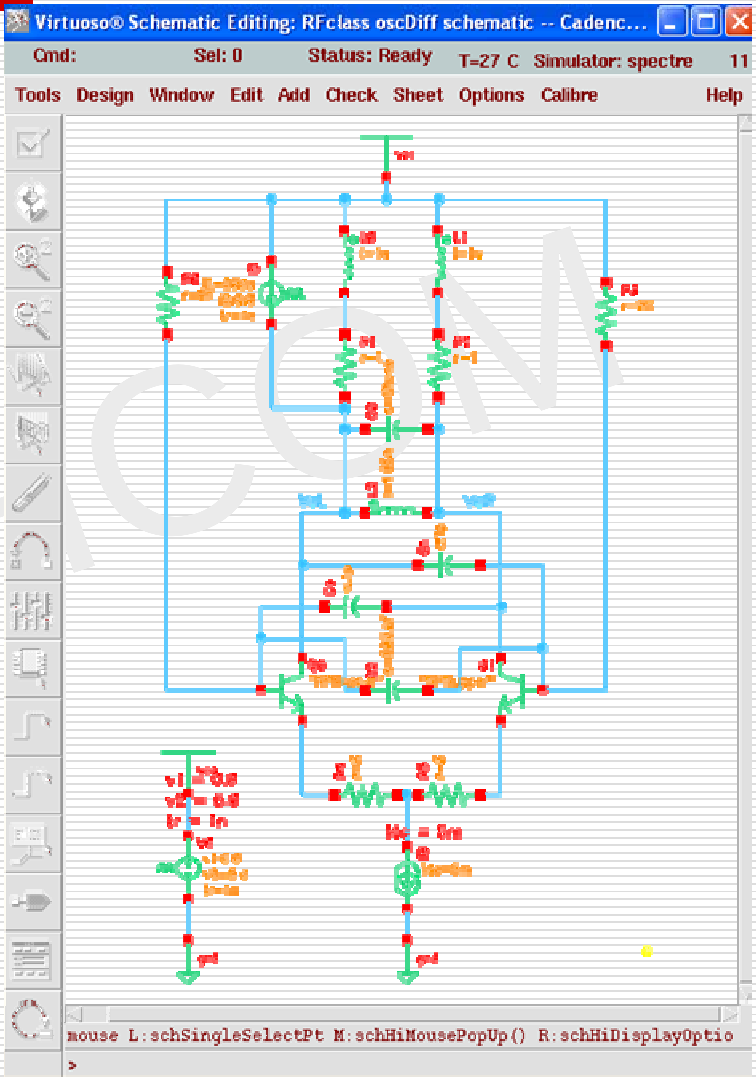
- A transient analysis phase to initialize the circuit
  - A beginning interval
  - A second, optional stabilization interval of length *tstab*
  - A final interval (that is four times the estimated oscillation period).
  - During the final interval, the PSS analysis monitors the waveforms in the circuit 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.*

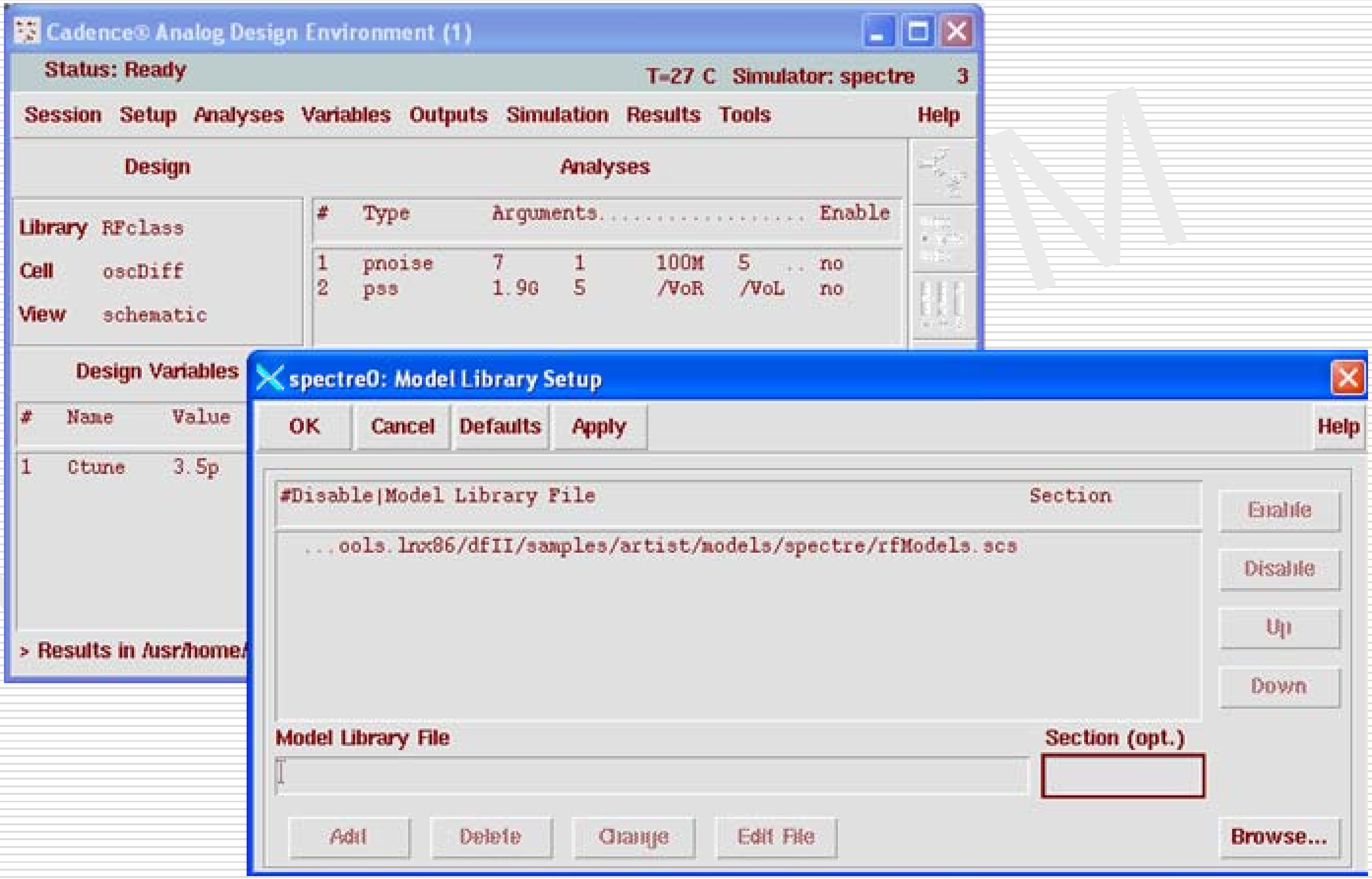
Differential Bipolar Oscillator

This example is from *rfEamples* library of Cadence



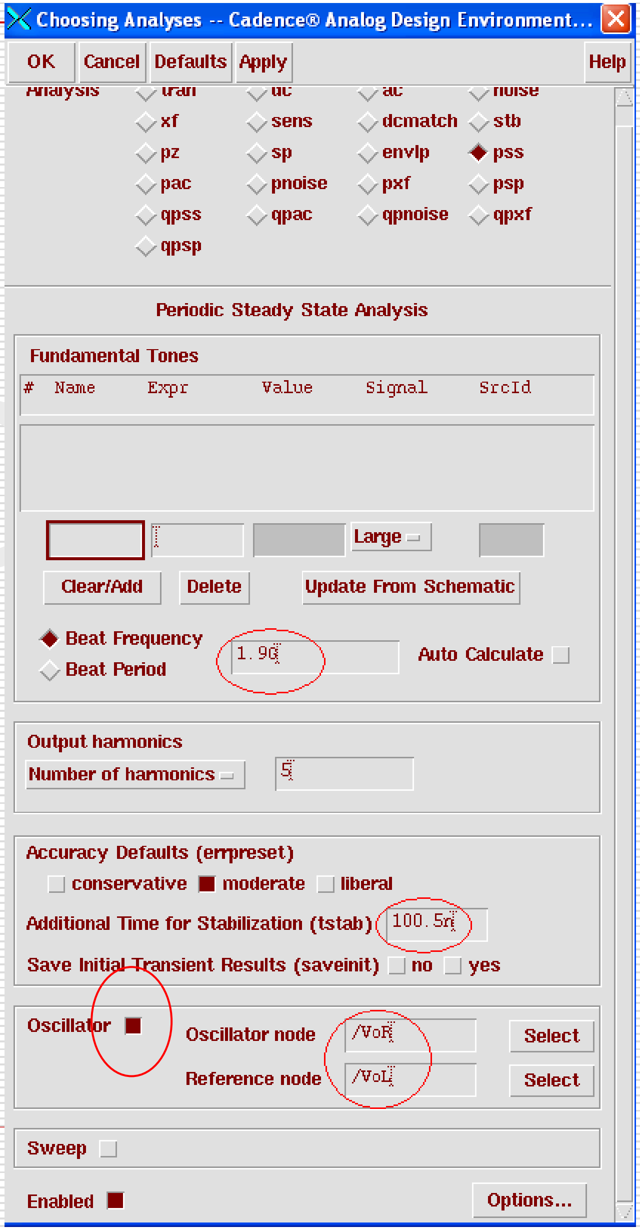
Analog Environment

- Set model library (rfModels.scs)



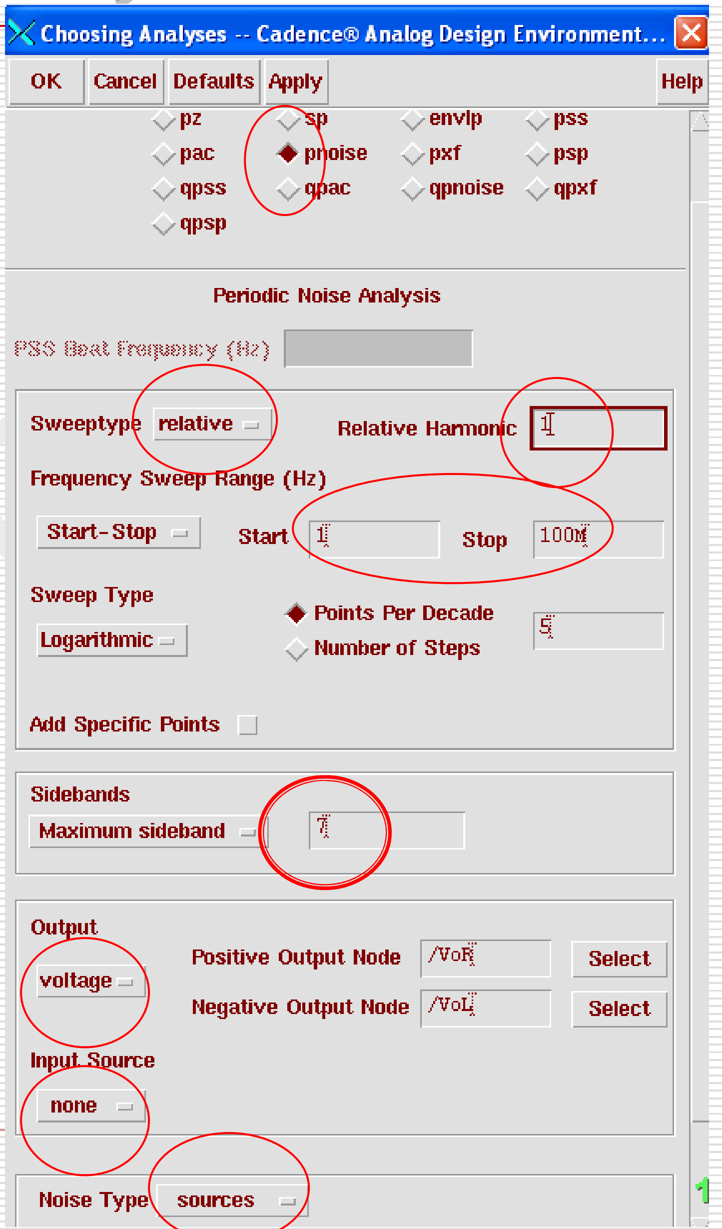
Setting Up PSS Analysis

- 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

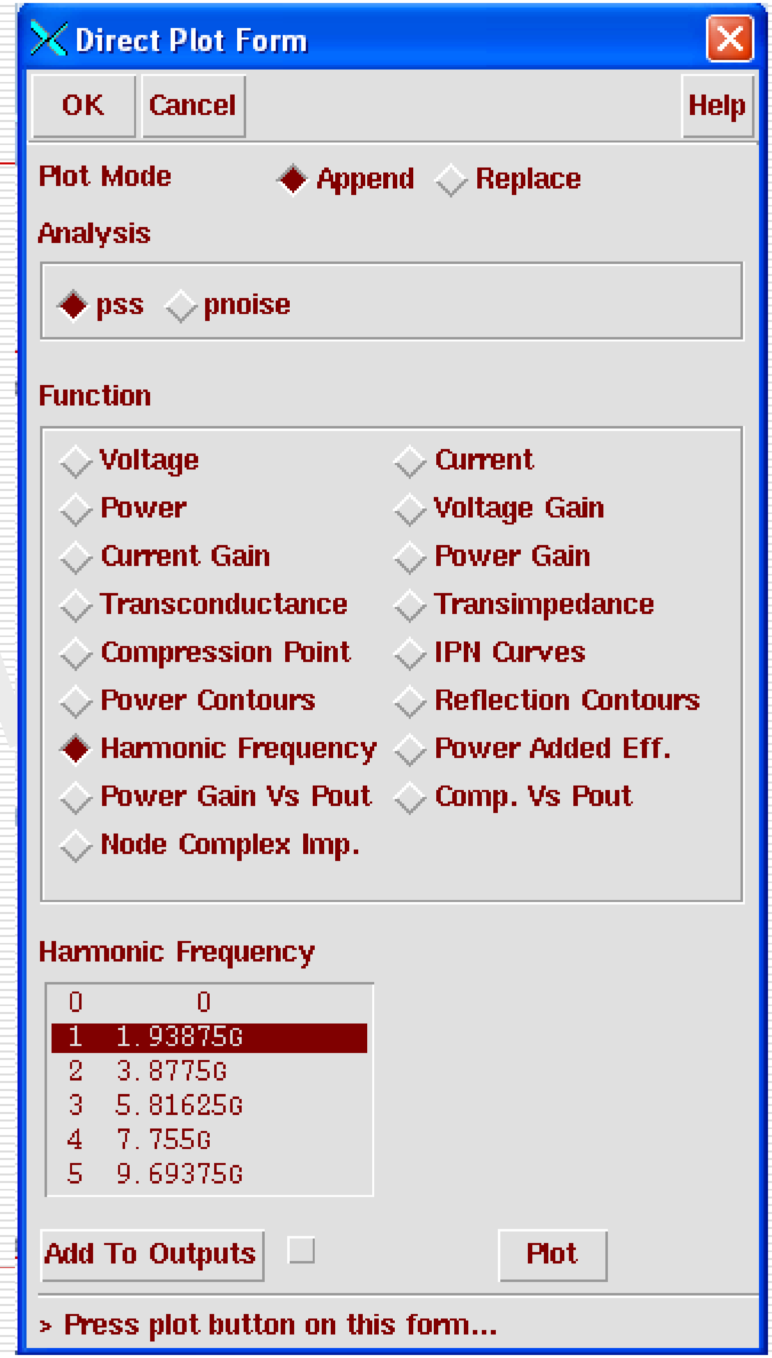
- Choose *relative* sweeptype and harmonic *1*
  - Shows frequency values relative to the fundamental frequency.
- *Maximum sideband = 7*
  - Increase the *Maximum sideband value until the output noise stops changing*
  - *Maximum sideband must be at least 1 to see any flicker* noise up conversion.
-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



Simulation Results

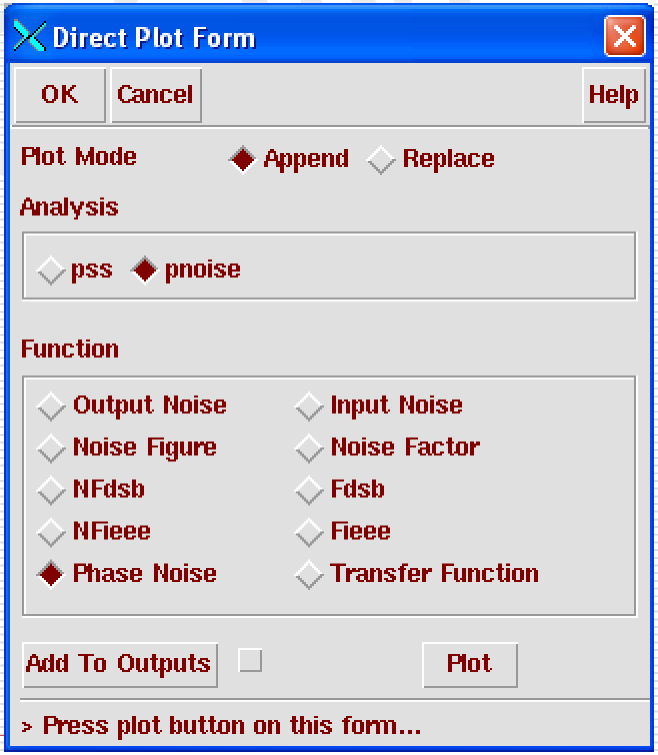
- After running the simulation
- You can see the fundamental frequency
  - Results→ direct plot→ main form
  - → pss, Harmonic Frequency
- In this example:

  f = 1.93875 GHz



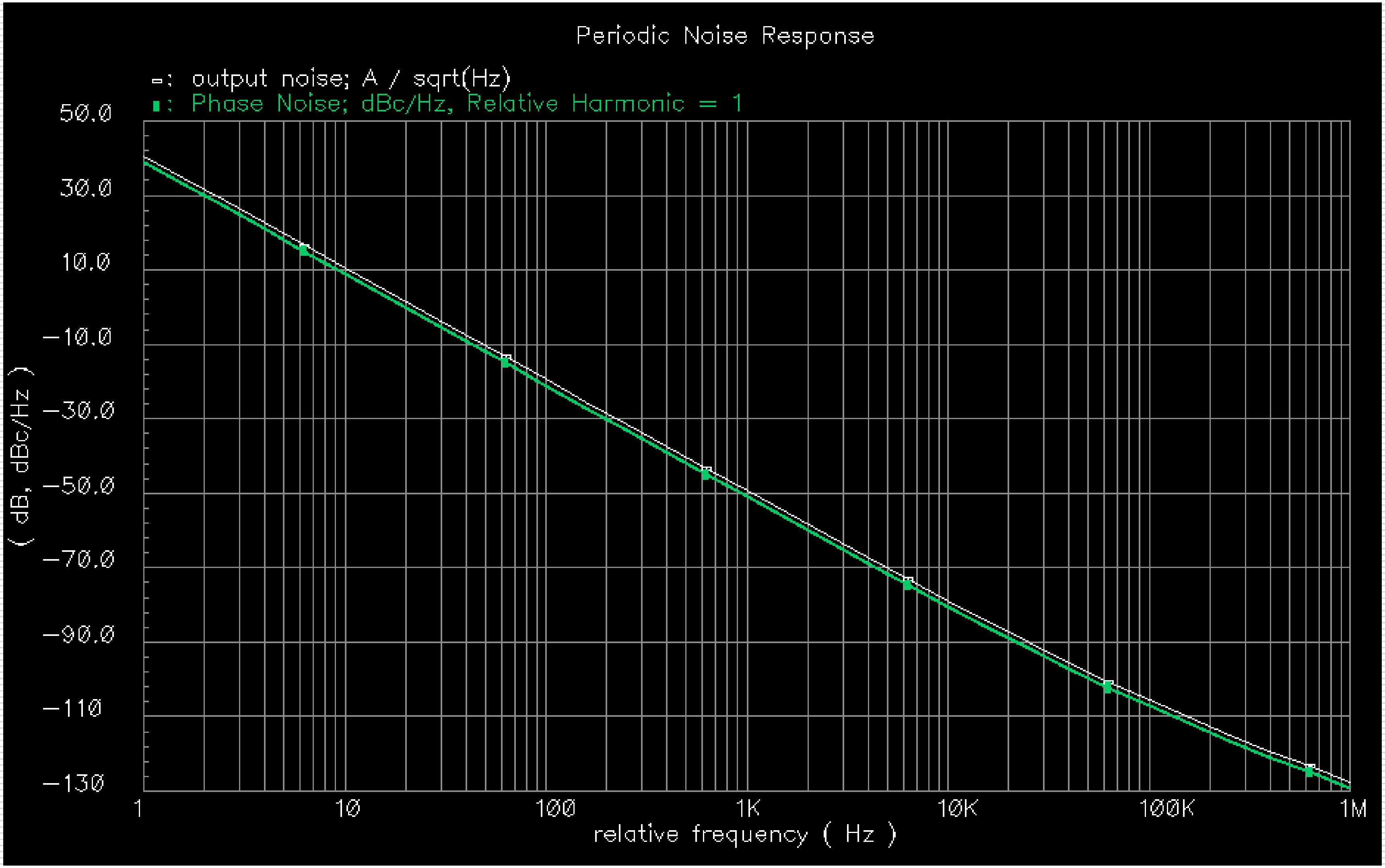
Phase Noise & Output Noise

- 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

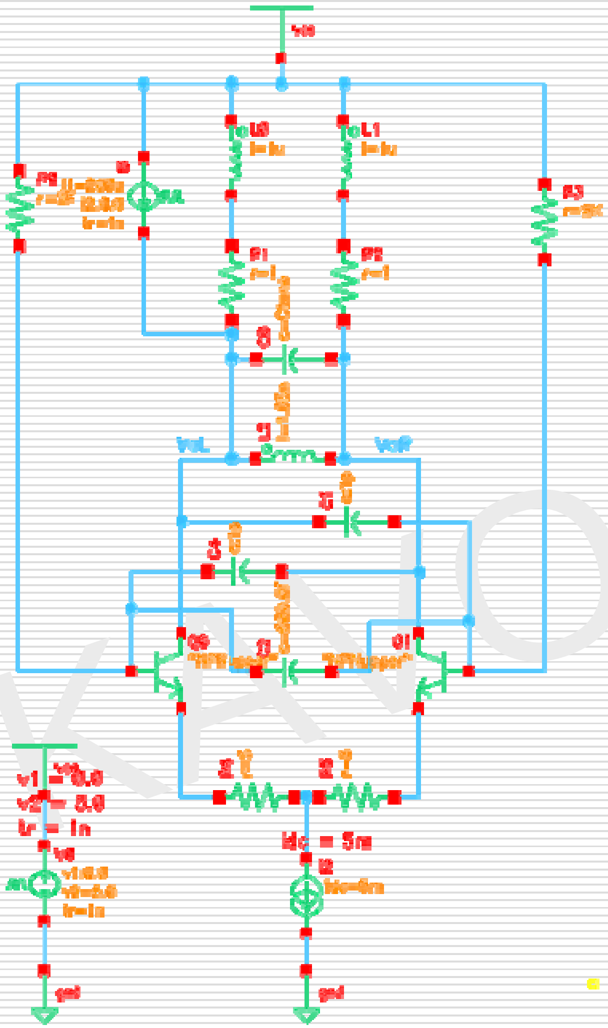
Phase Noise & Output Noise



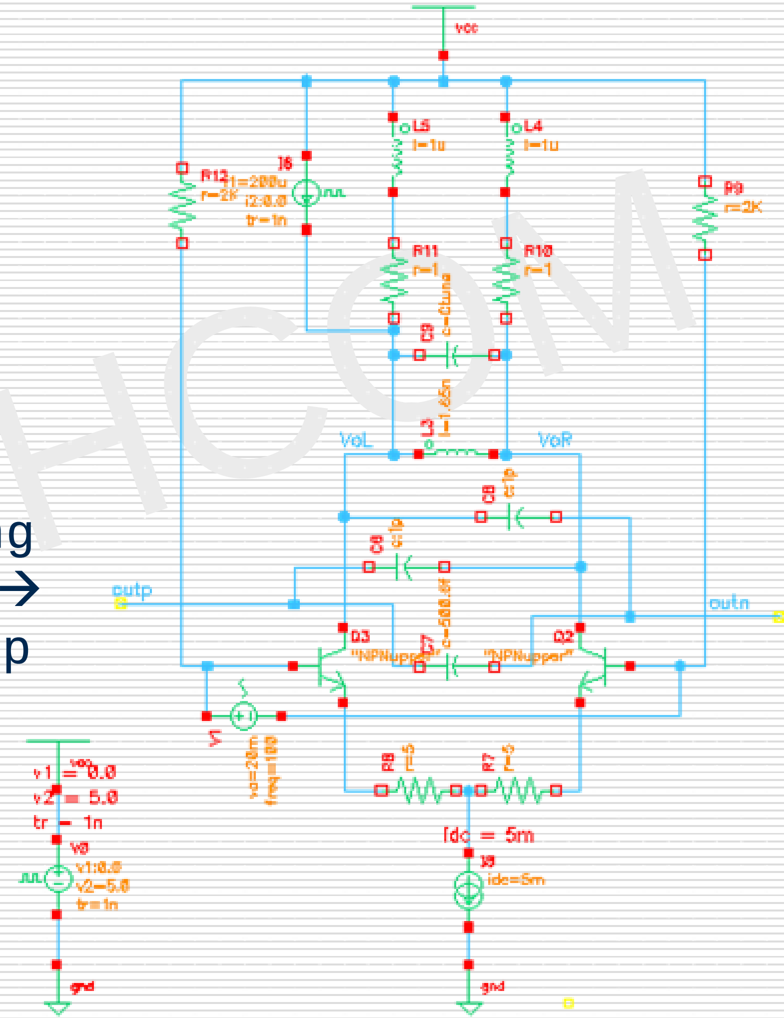
Convergence Issue

- 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, reltol, lteratio, and errpreset parameters. Avoid setting *errpreset to liberal.*

Small Signal Loop Gain with AC Analysis

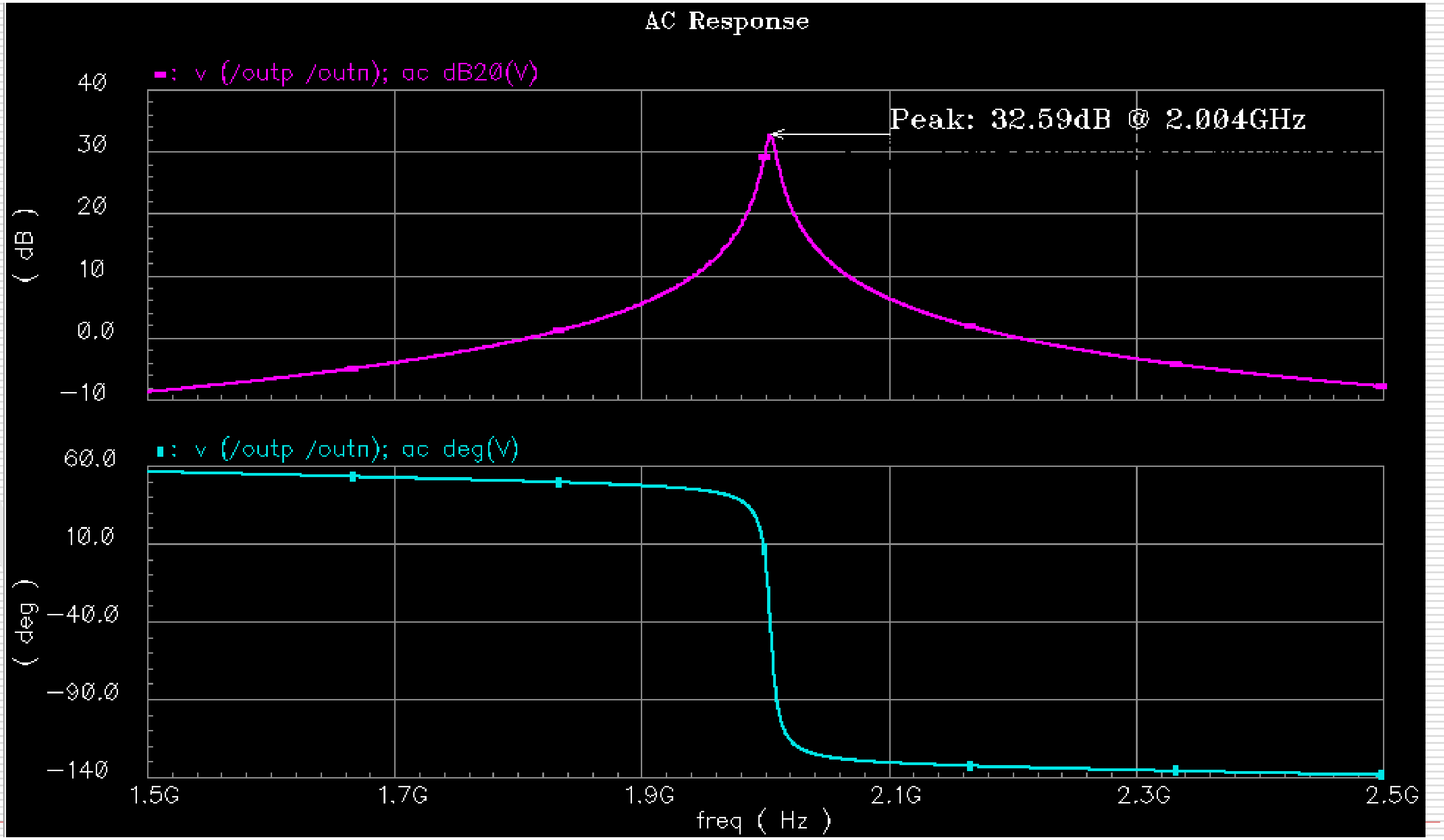


Opening
--------→
the loop



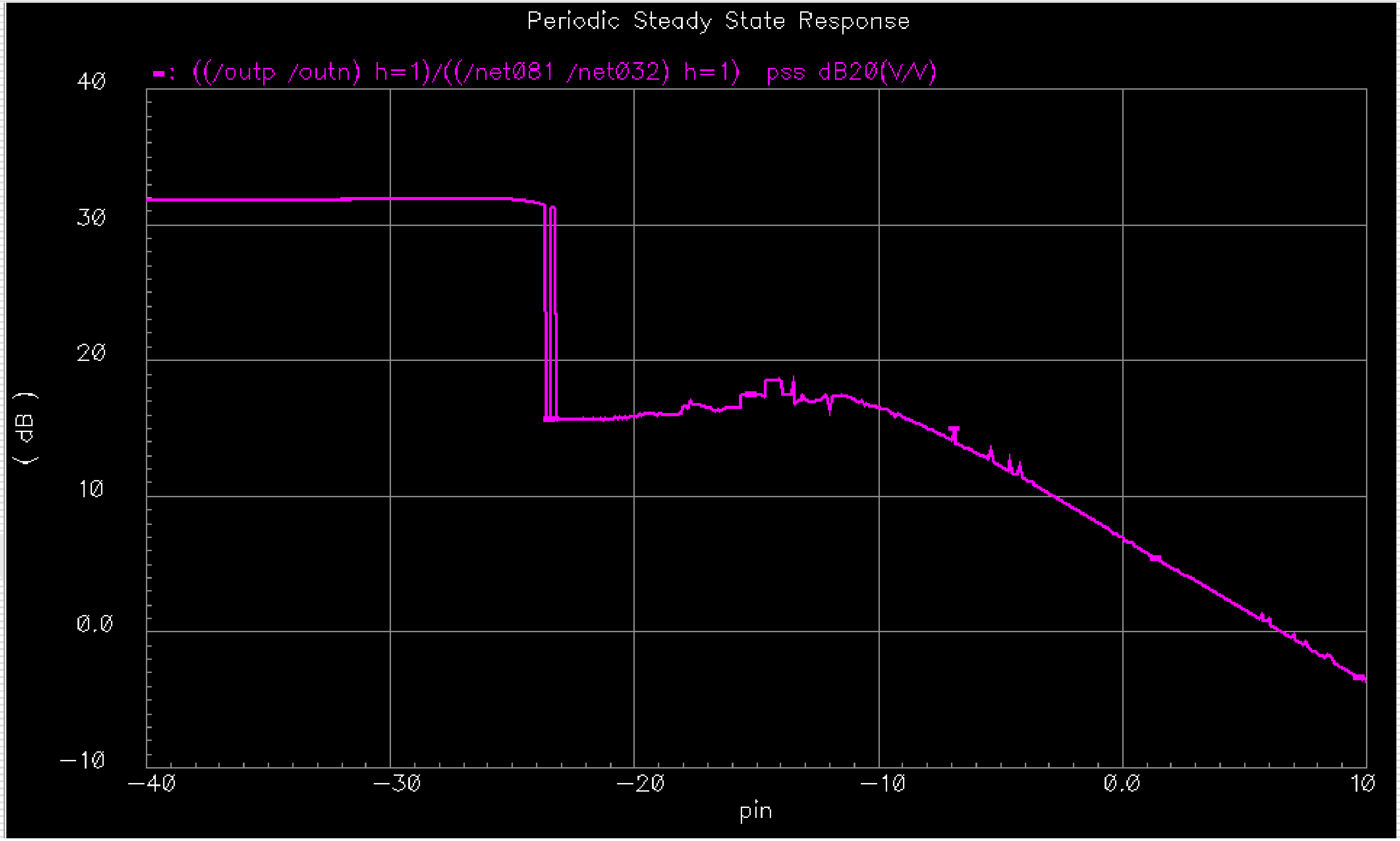
Loop Gain with AC Analysis

- 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



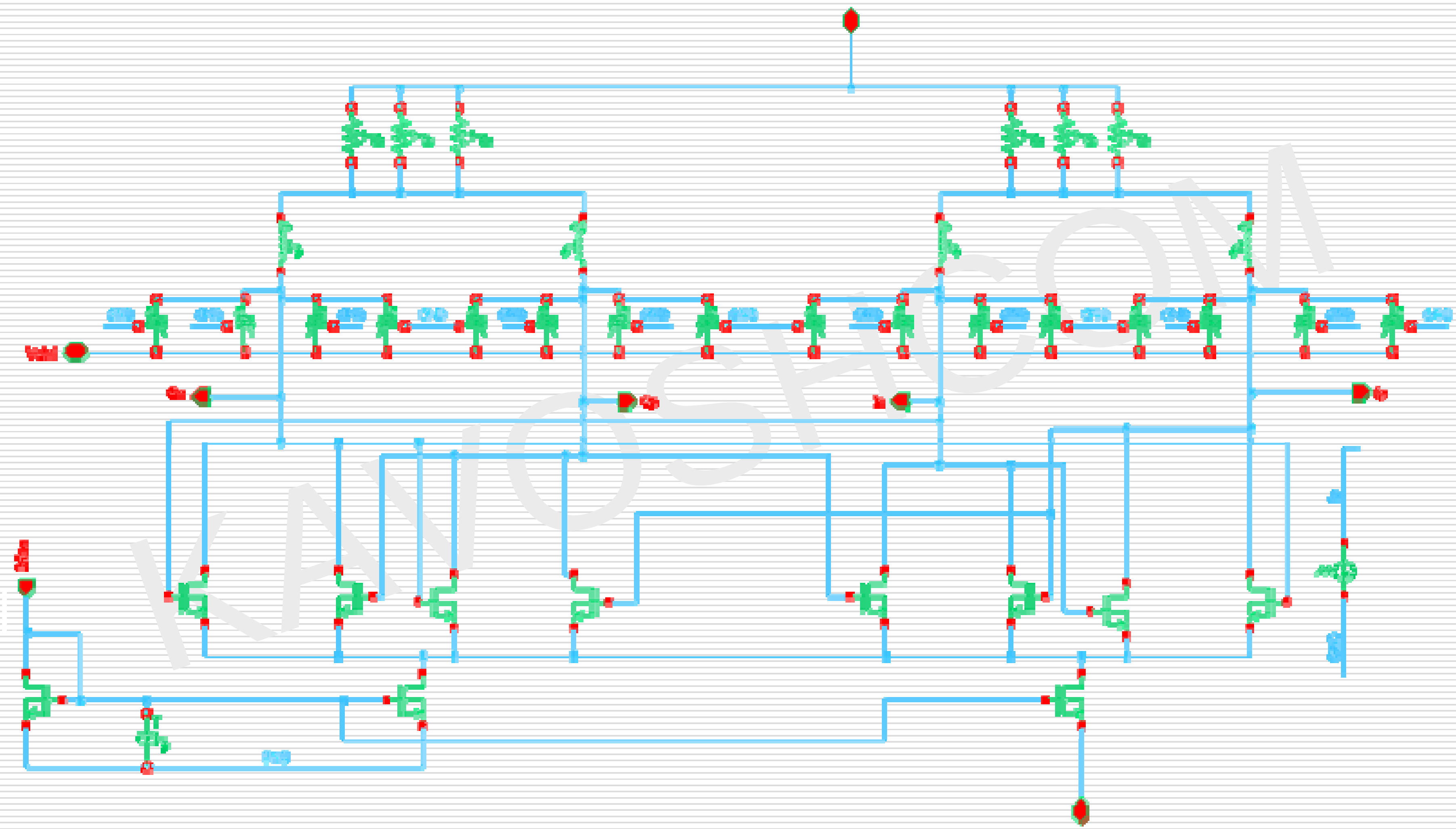
VOLTAGE CONTROLLED OSCILLATORS

Time-domain response using *Tran* or *PSS* analyses

Tuning range using *PSS* analysis

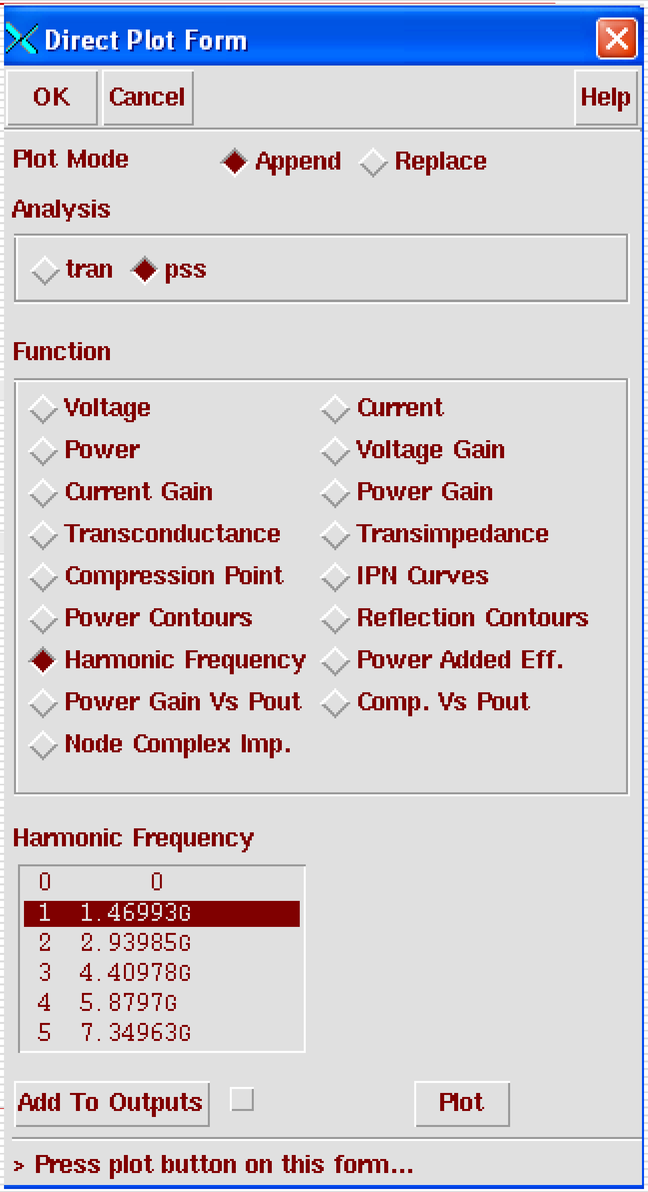
Phase Noise using *PSS* and *Pnoise* analyses

Quadrature CMOS VCO

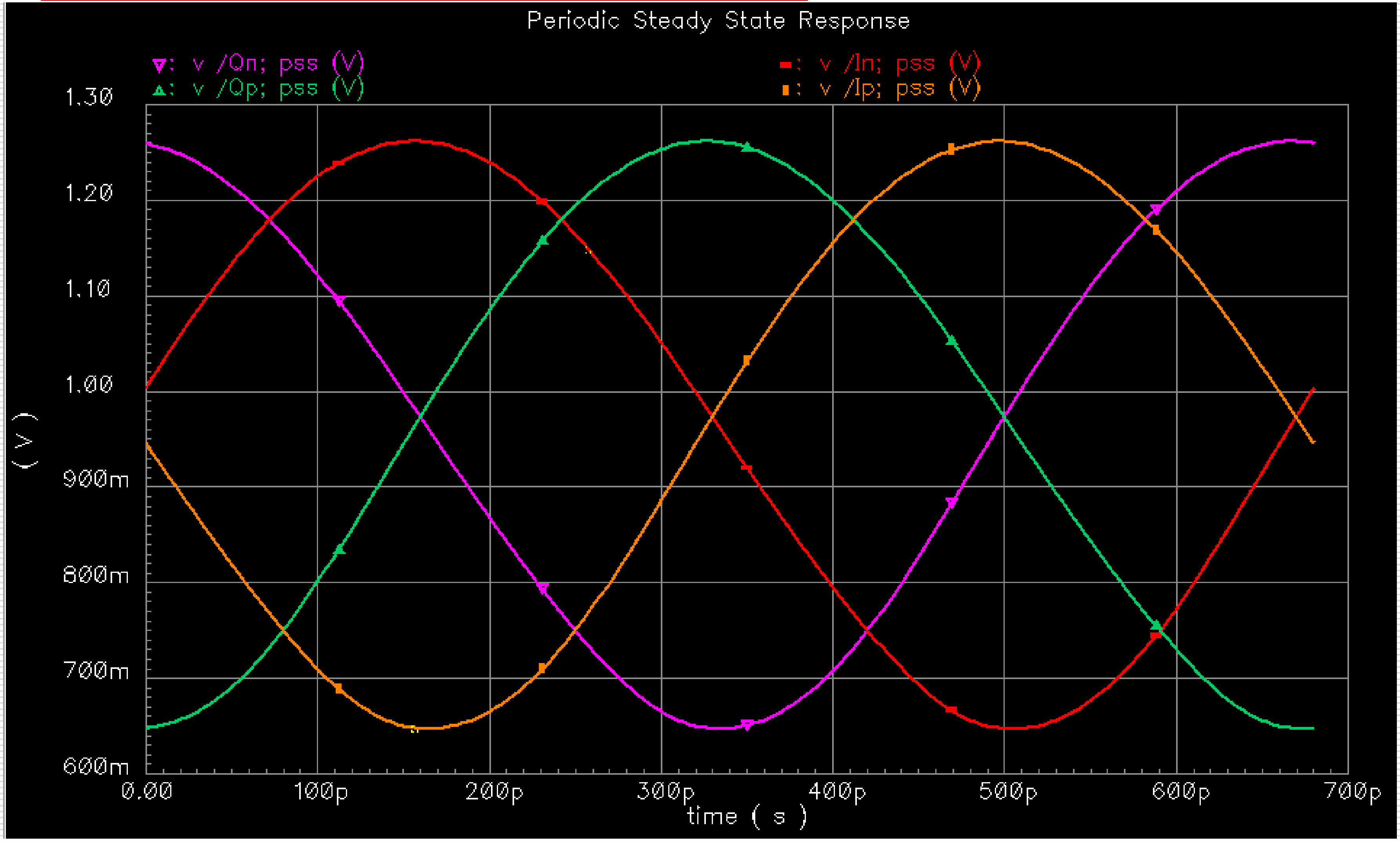


Tran and PSS Analyses

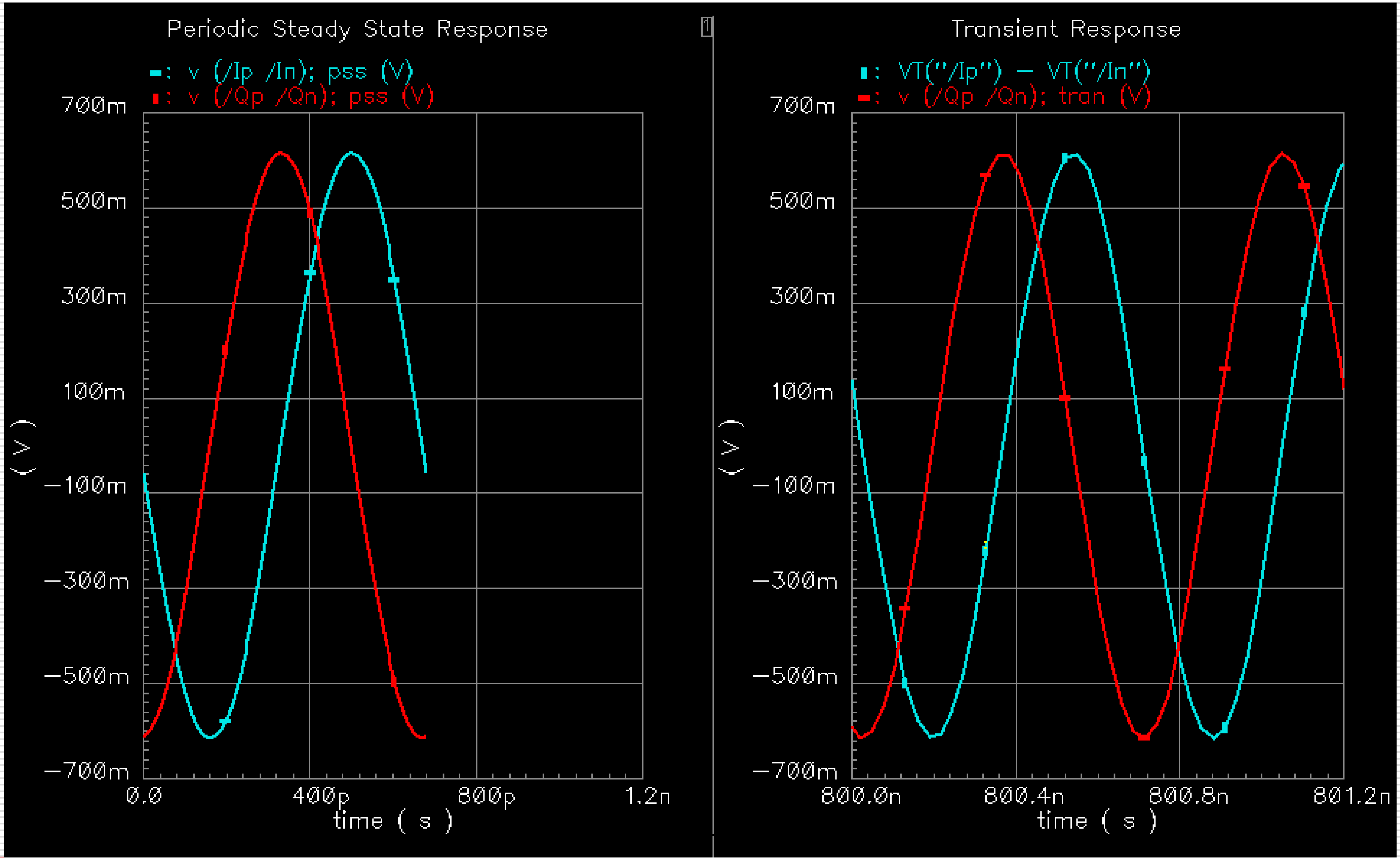
- Setup and run these analyses as described before
- The oscillation frequency for Vcont=0.7V is ~1.47GHz



PSS Response in time (1 period)

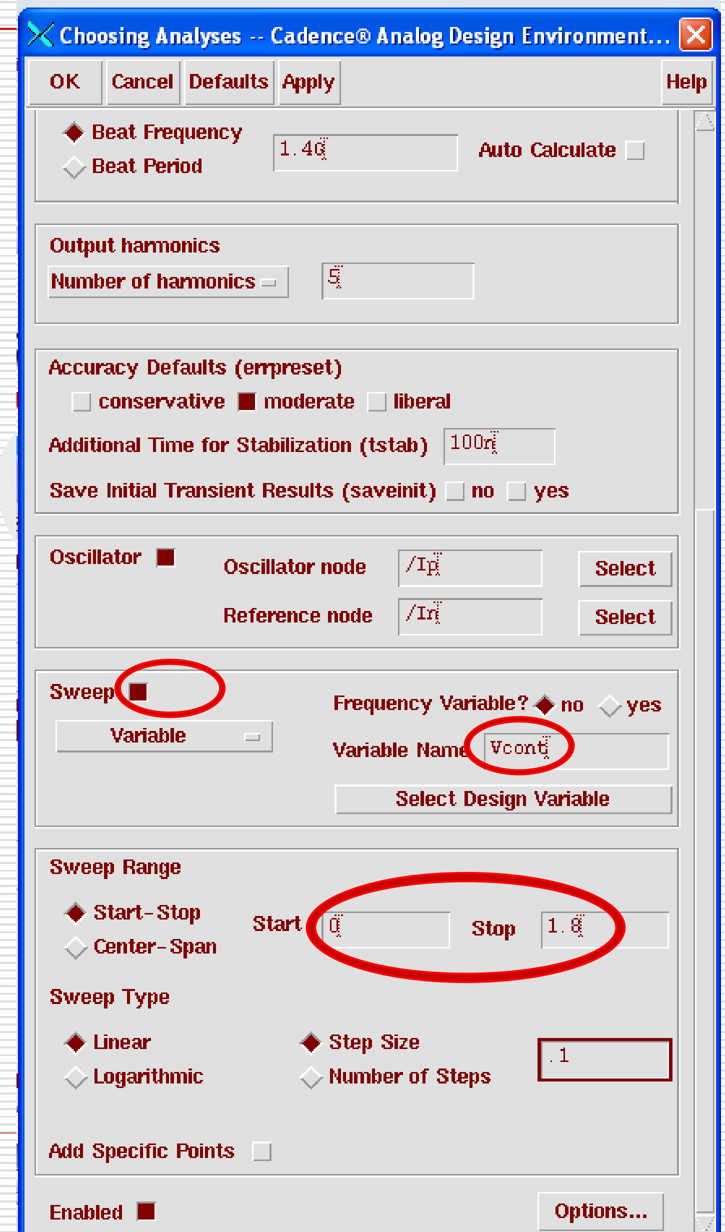


PSS vs. Transient Response (diff)



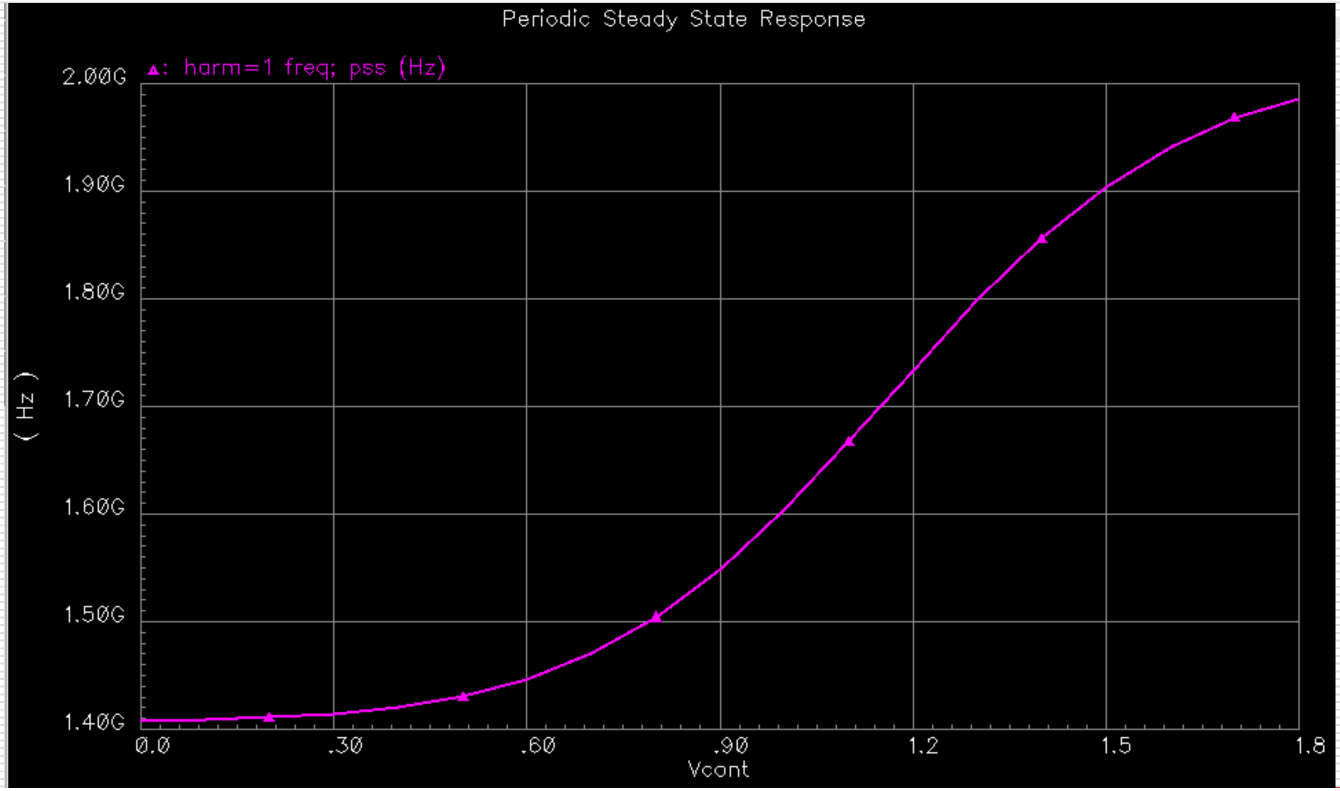
Swept PSS to plot frequency vs. Vcont

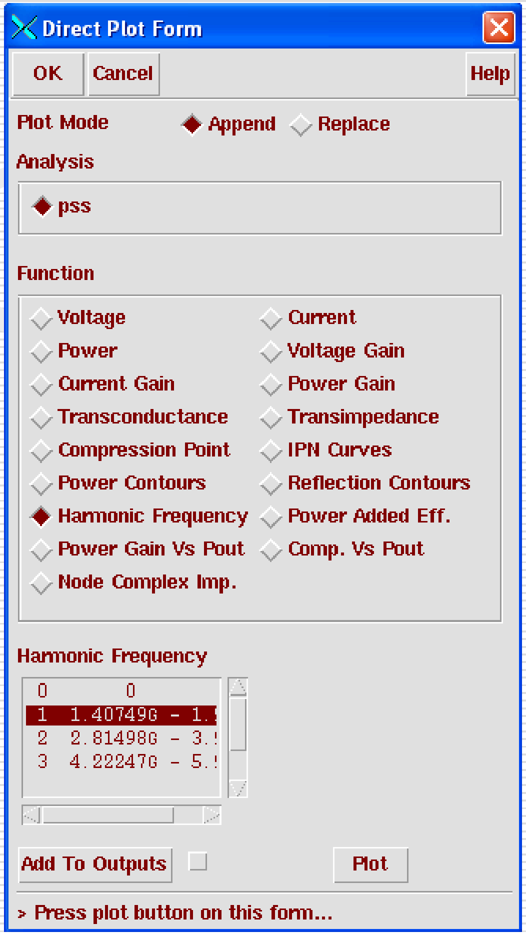
- To plot oscillation frequency vs. control voltage
  - *PSS* is much faster & easier than *Tran*
- Highlight *sweep* and specify sweep variable and range



VCO frequency vs. control voltage

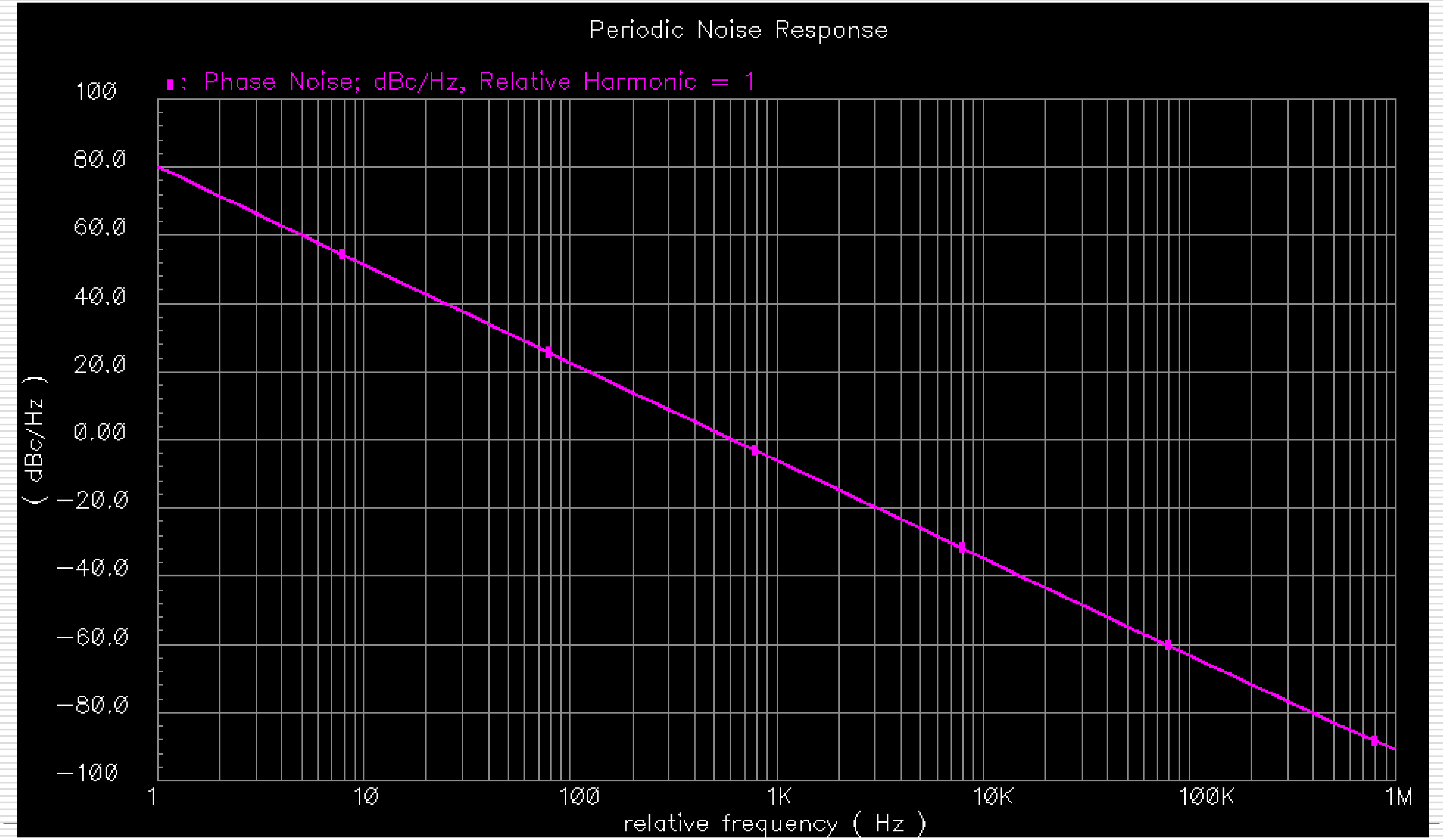
- f = 1.407 GHz @ 0V
- f = 1.987 GHz @ 1.8V
- Nonlinearity ∝ slope



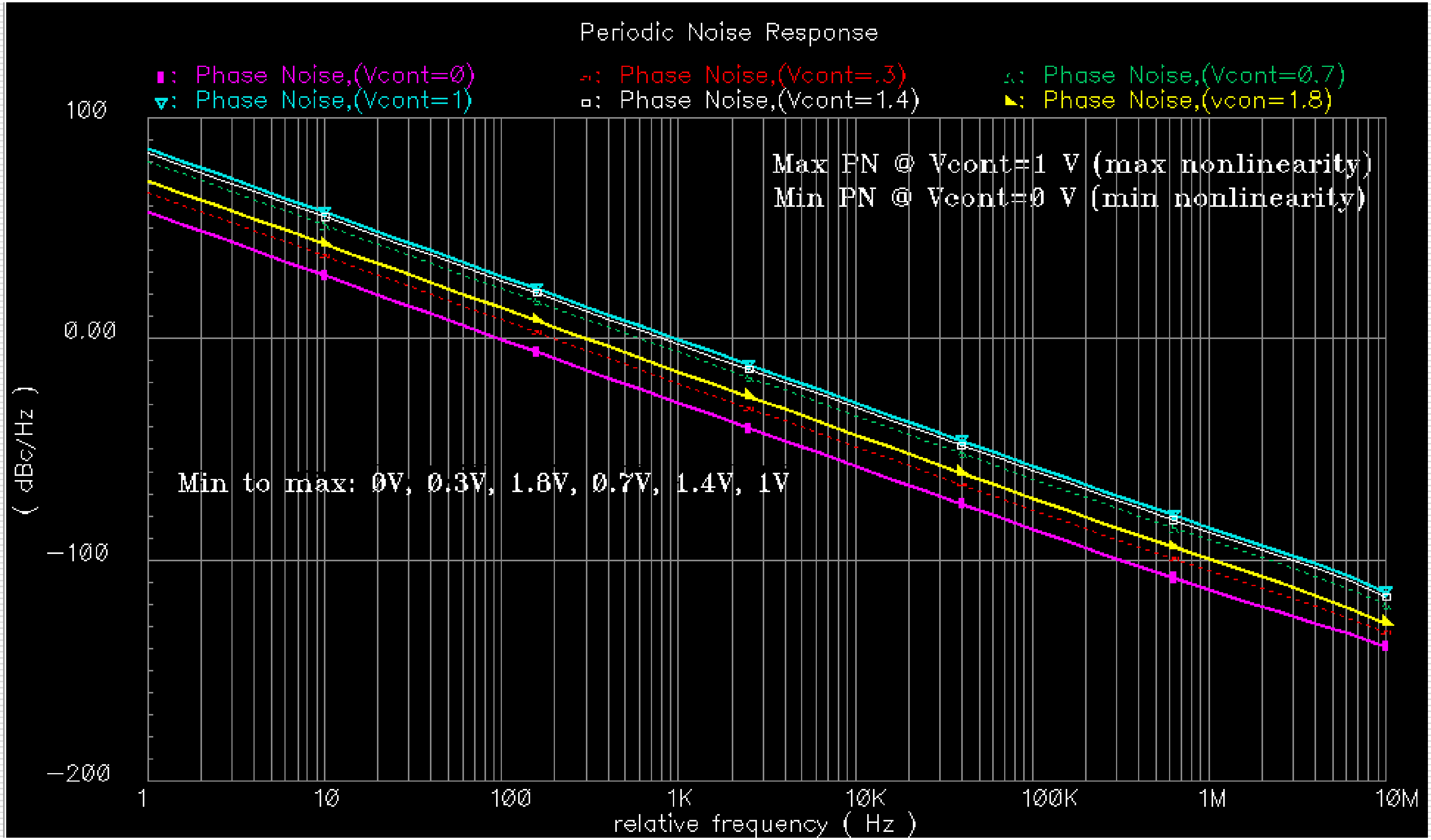


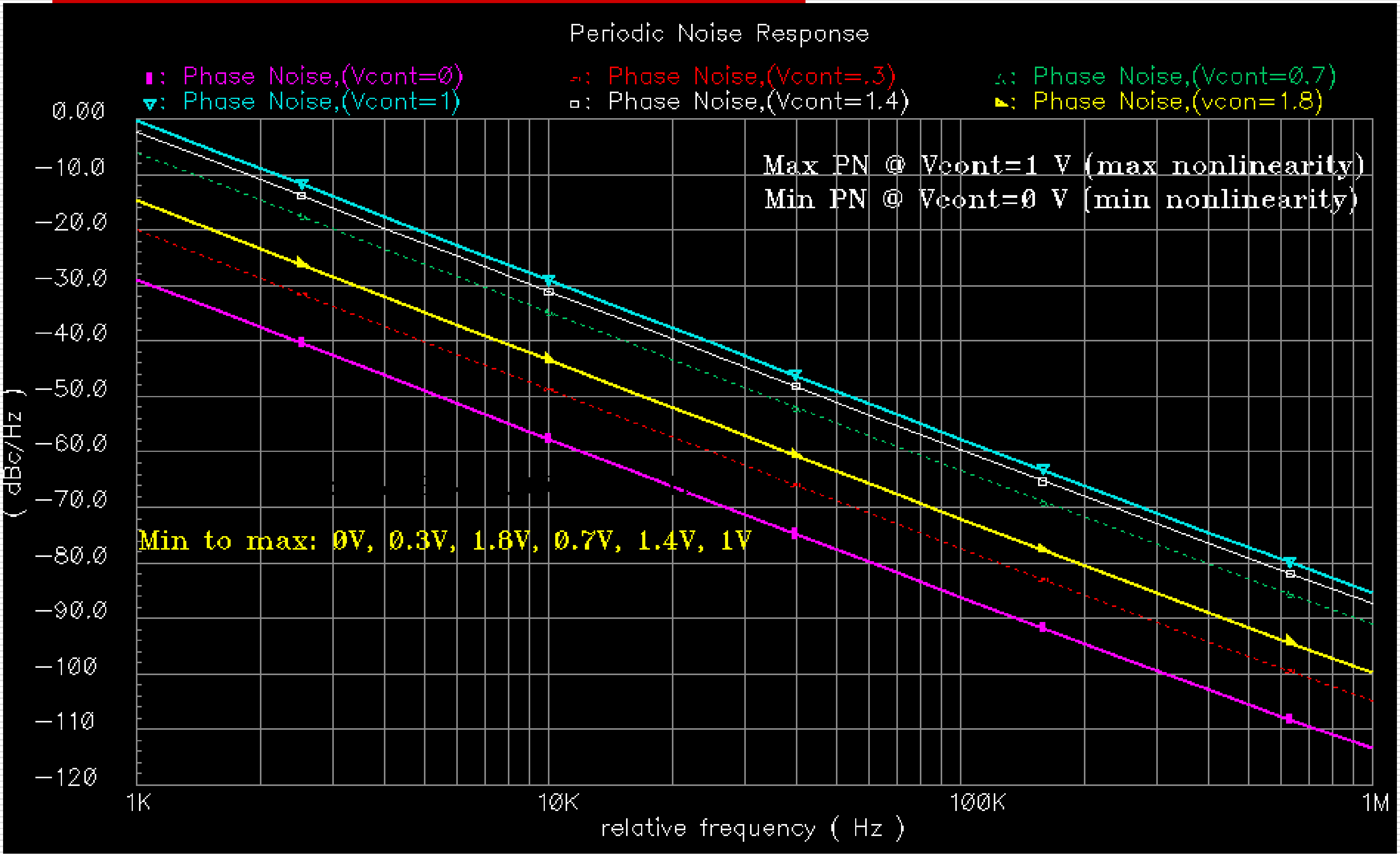
Phase Noise (@ Vcont=0.7V)

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



Effect of Varactor Nonlinearity




Periodic Noise Response
Phase Noise,(Vcont=0)
Phase Noise,(Vcont=.3)
Phase Noise,(Vcont=0.7)
Phase Noise,(Vcont=1)
Phase Noise,(Vcont=1.4)
Phase Noise,(vcon=1.8)
Max PN @ Vcont=1 V (max nonlinearity)
Min PN @ Vcont=0 V (min nonlinearity)
Min to max: 0V, 0.3V, 1.8V, 0.7V, 1.4V, 1V
(dBc/Hz)
0.00
−10.0
−20.0
−30.0
−40.0
−50.0
−60.0
−70.0
−80.0
−90.0
−100
−110
−120
1K
10K
100K
1M
relative frequency (Hz)