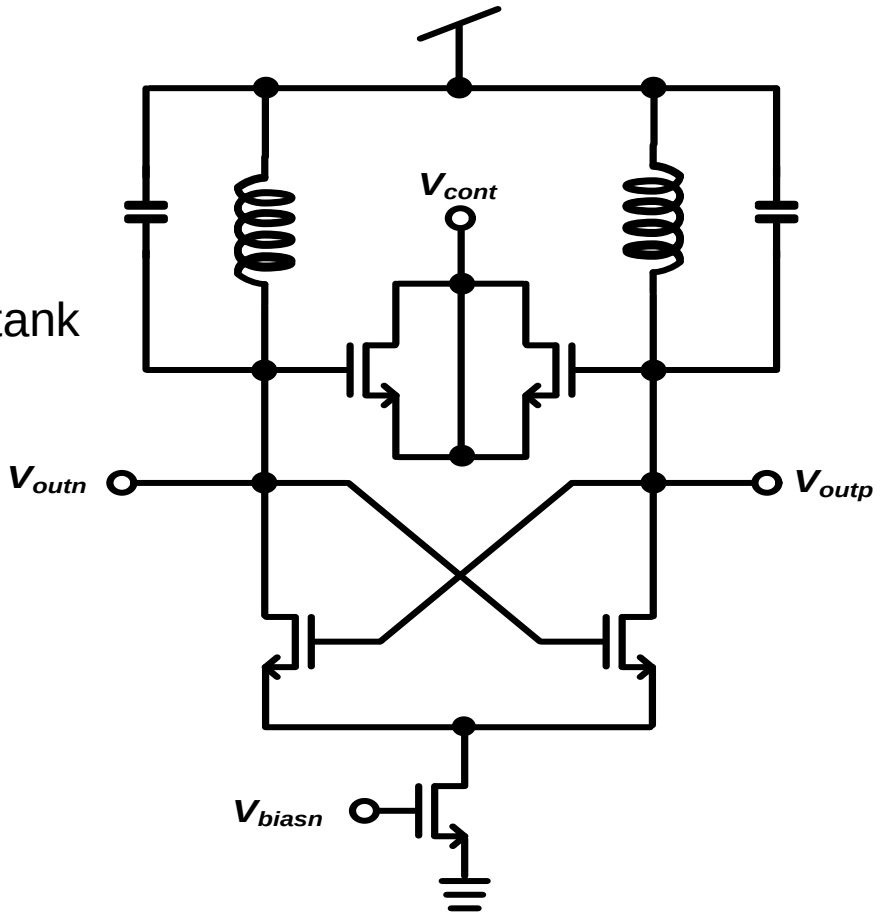
LC VCO Structure

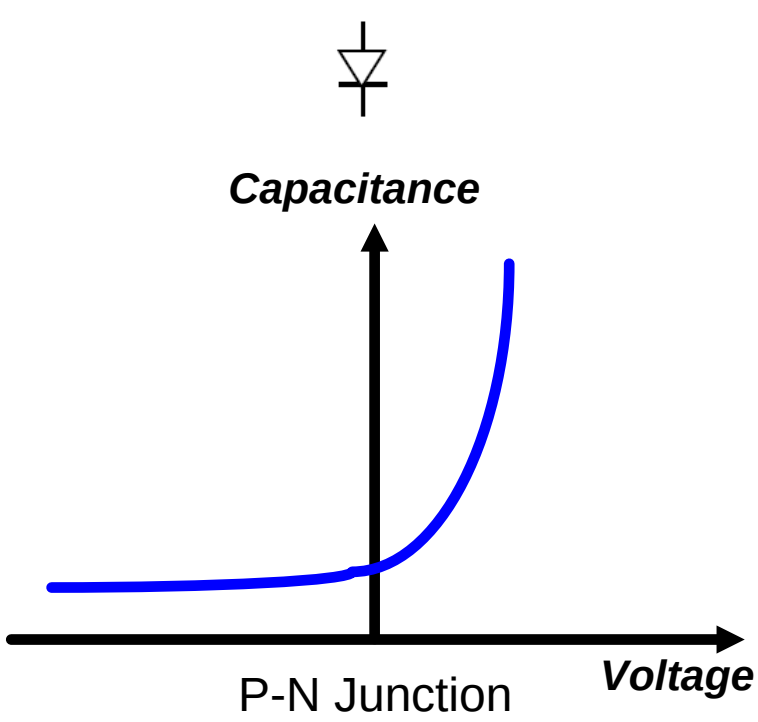
- LV VCO Structure
  - LC Tank
    - Spiral inductor (symmetric type)
    - Ideal cap
  - Cross coupled circuit
    - Negative resistance
    - To compensate for the loss of the tank
  - Source MOSFET
  - Varactor
    - Accumulation varactor
  - OSC frequency

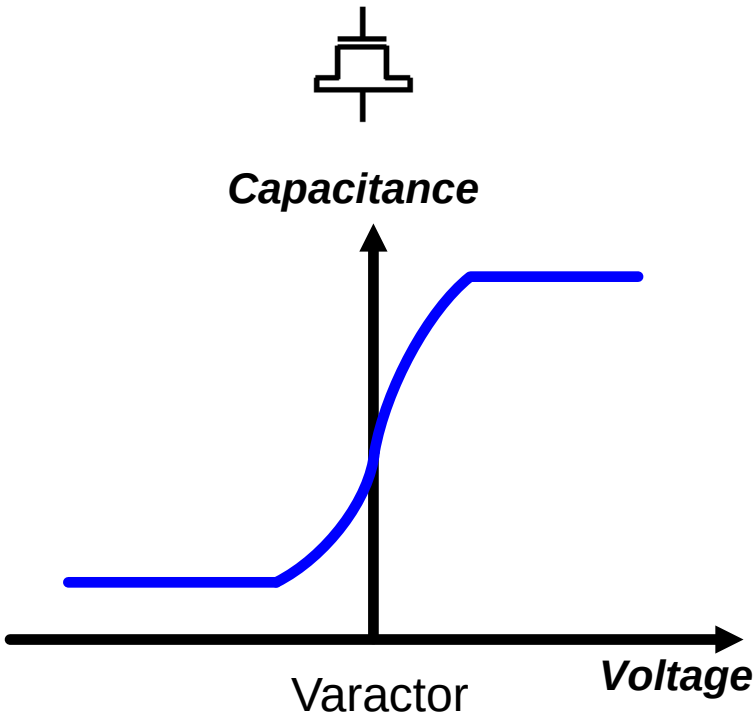
$$f_o = \frac{1}{2\pi\sqrt{LC}}$$



Varactor

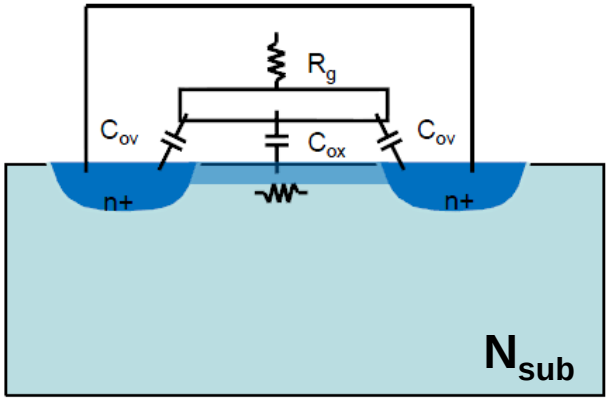
- Varactor type
  - P-N Junction
  - MOS Varactor
    - Inversion mode
    - Accumulation mode



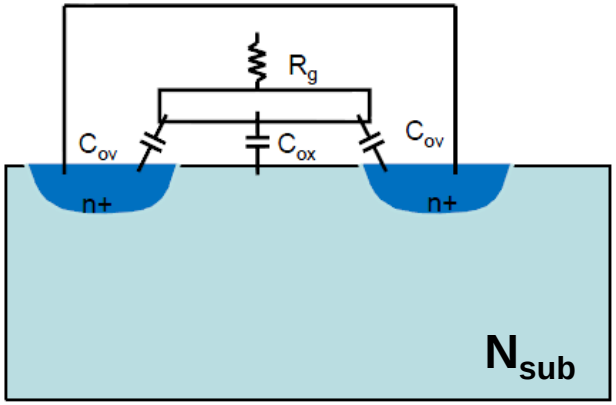


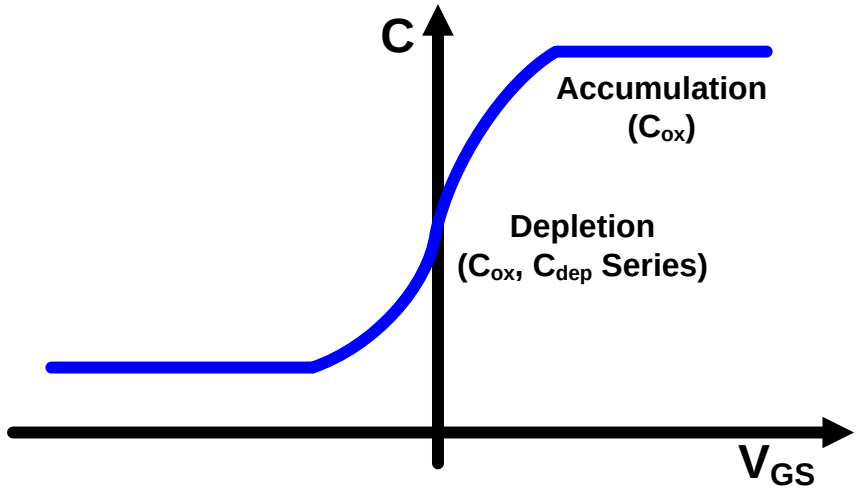
Accumulation Mode Varactor

– On (Accumulated channel)



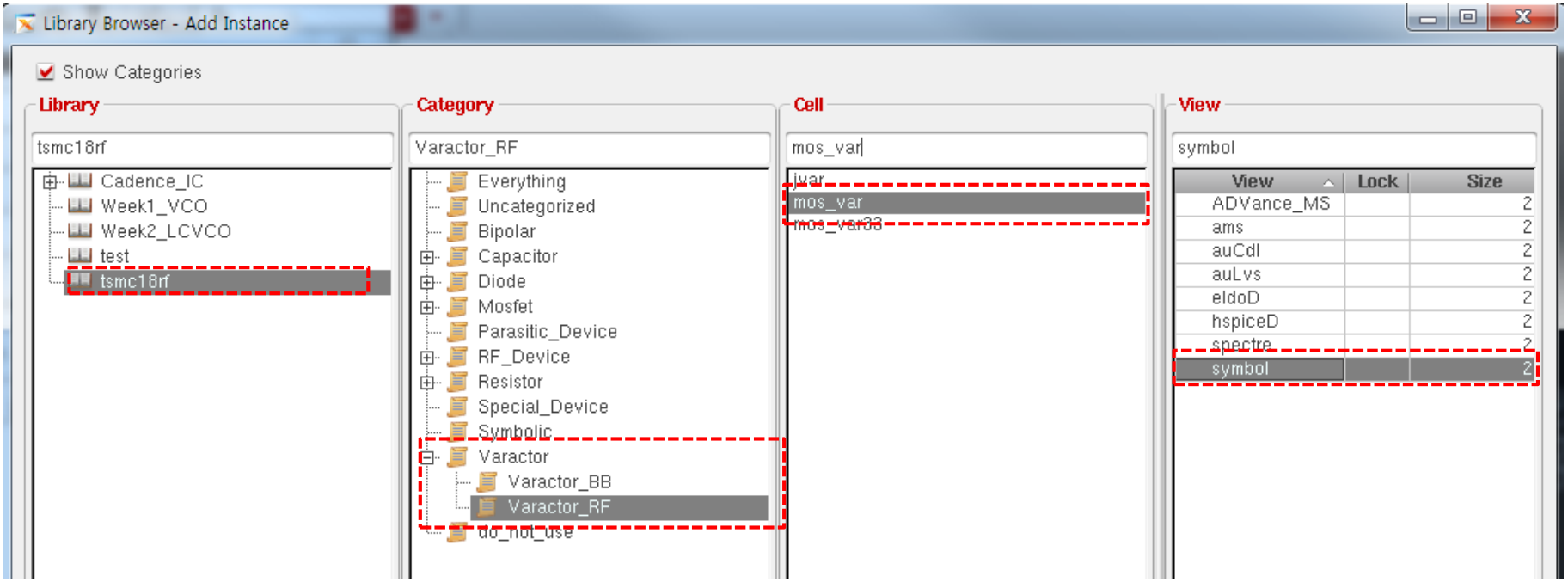
– OFF(Depleted)





TSMC Varactor

- Varactor selection
  - Tsmc18rf → Varactor → Varactor_RF → mos_var → symbol



Varactor Setting

- Setting of Fingers_per_Group, Number_of_Group and multiplier
- Extract min and max capacitance

- Fingers_per_Group(B) : 10
- Number_of_Groups (G) : 2
- Multiplier : 1

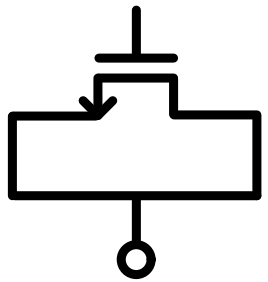
→ Min Capacitance : 92f

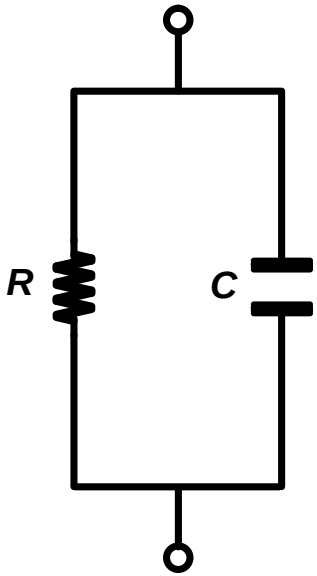
→ Max Capacitance : 243fF

→ Δ Capacitance : 151fF

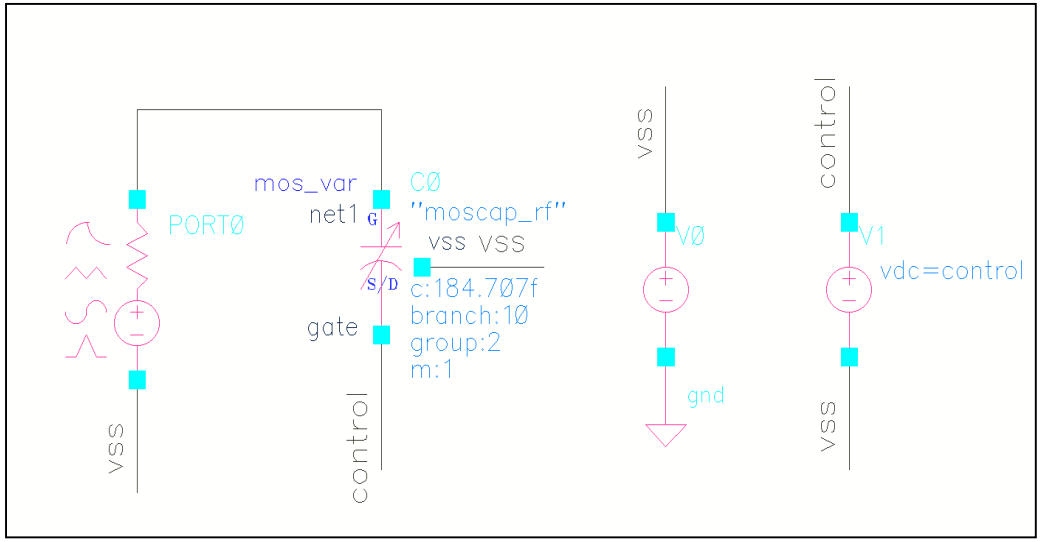
Varactor Modeling

- An equivalent circuit model of varactor
  - Parallel connection of resistance and capacitance
  - Analyze capacitance into using Y-parameter





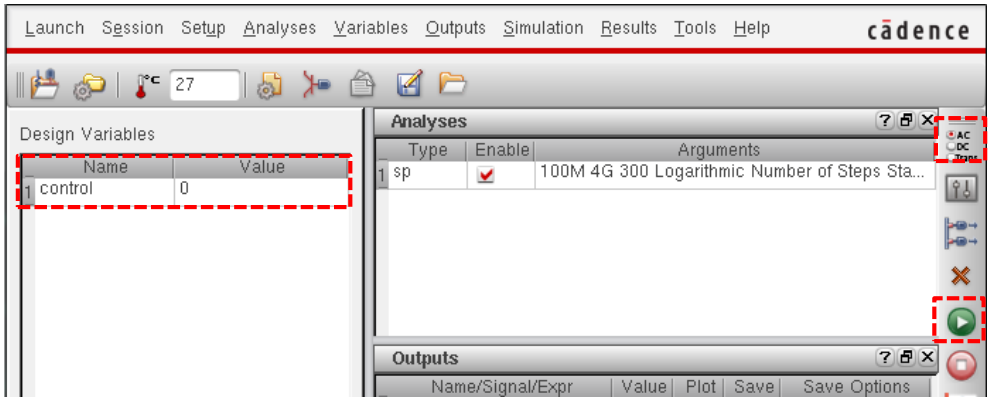
< Equivalent circuit of varactor >

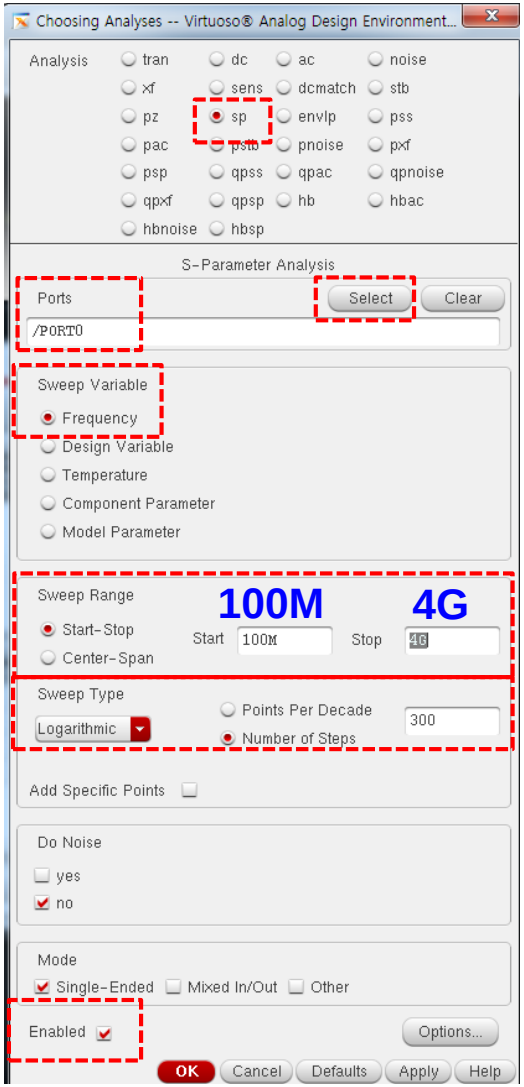


< Test schematic >

S - Parameter

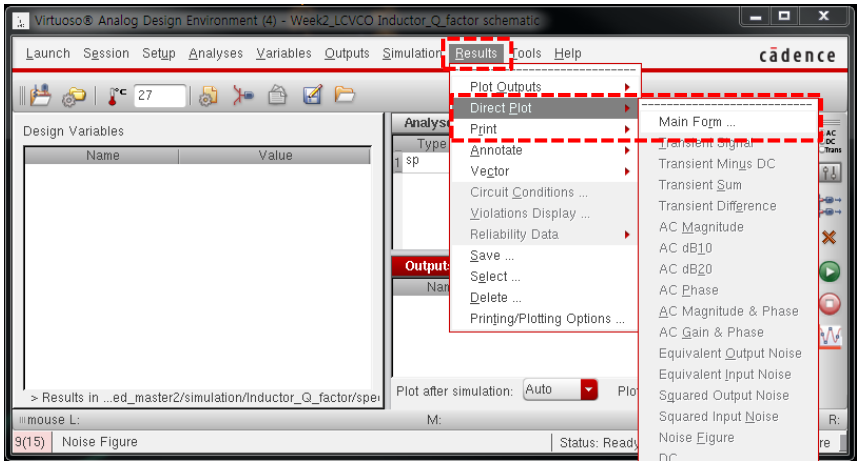
- Simulation condition setting
  - Control voltage : 0V
  - Analysis : sp (S-Parameter Analysis)
  - Ports : Port0 (schematic node choice)
  - Sweep Variable : Frequency
  - Sweep Range : 100M ~ 4G
  - Sweep Type : Logarithmic
  - Number of Steps : 300
  - Enabled check → OK → Netlist and Run

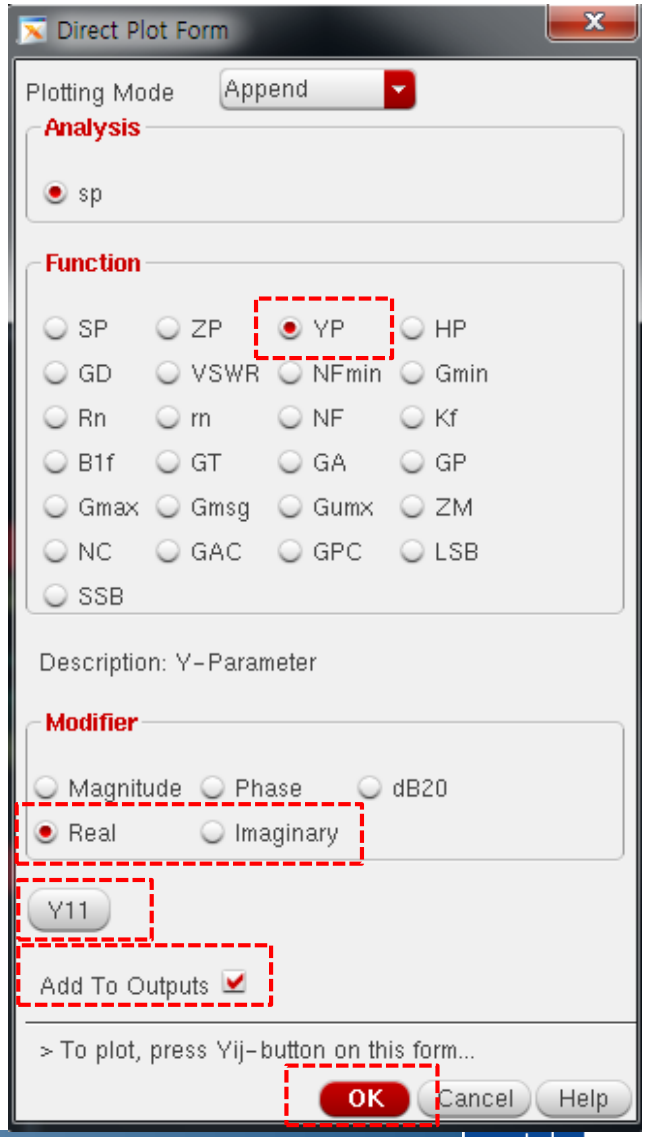




Y- Parameter

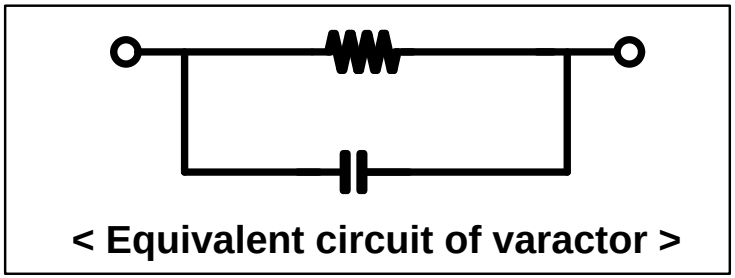
- Simulation condition setting
  - Results → Direct Plot → Main Form
  - Function : YP
  - Add To Outputs choice
  - Modifier : Real → Y11 and Imaginary → Y11
  - OK





Y- Parameter

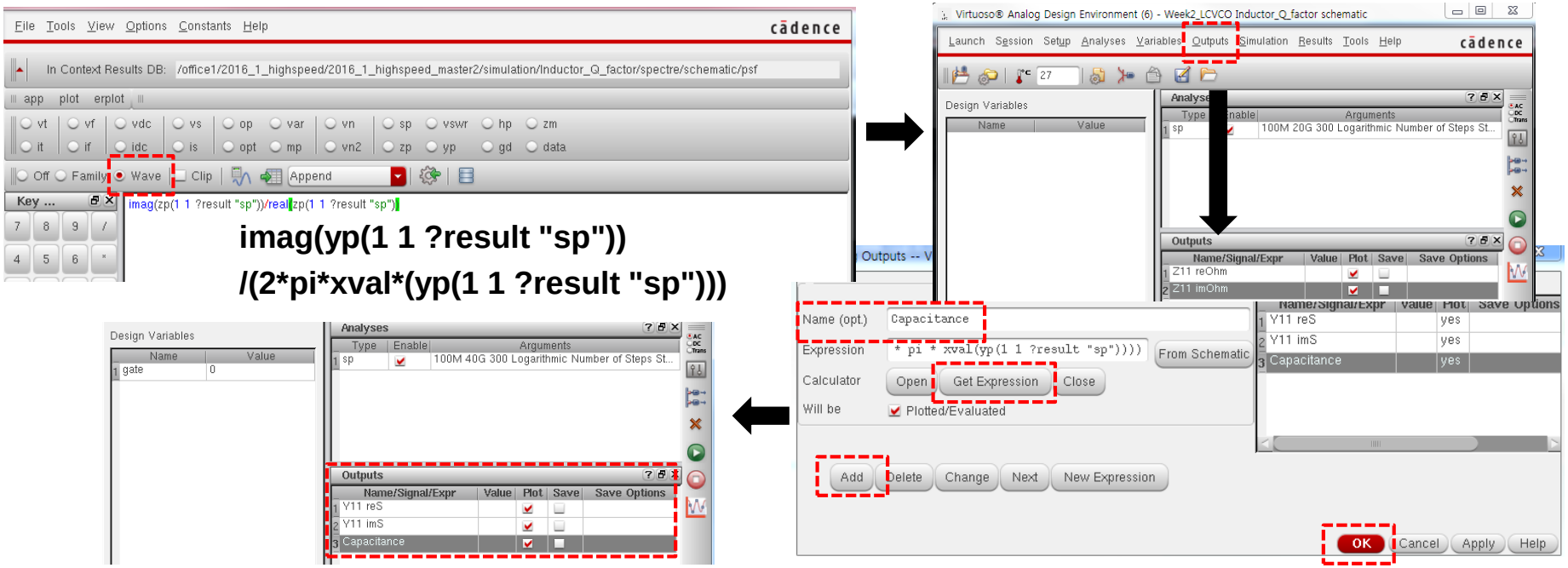
- $Y = \frac{1}{R} + j\omega C$
  - Resistance = $\frac{1}{Real[Y11]}$
  - Capacitance = $\frac{Imaginary\ [Y11]}{\omega}$



< Equivalent circuit of varactor >

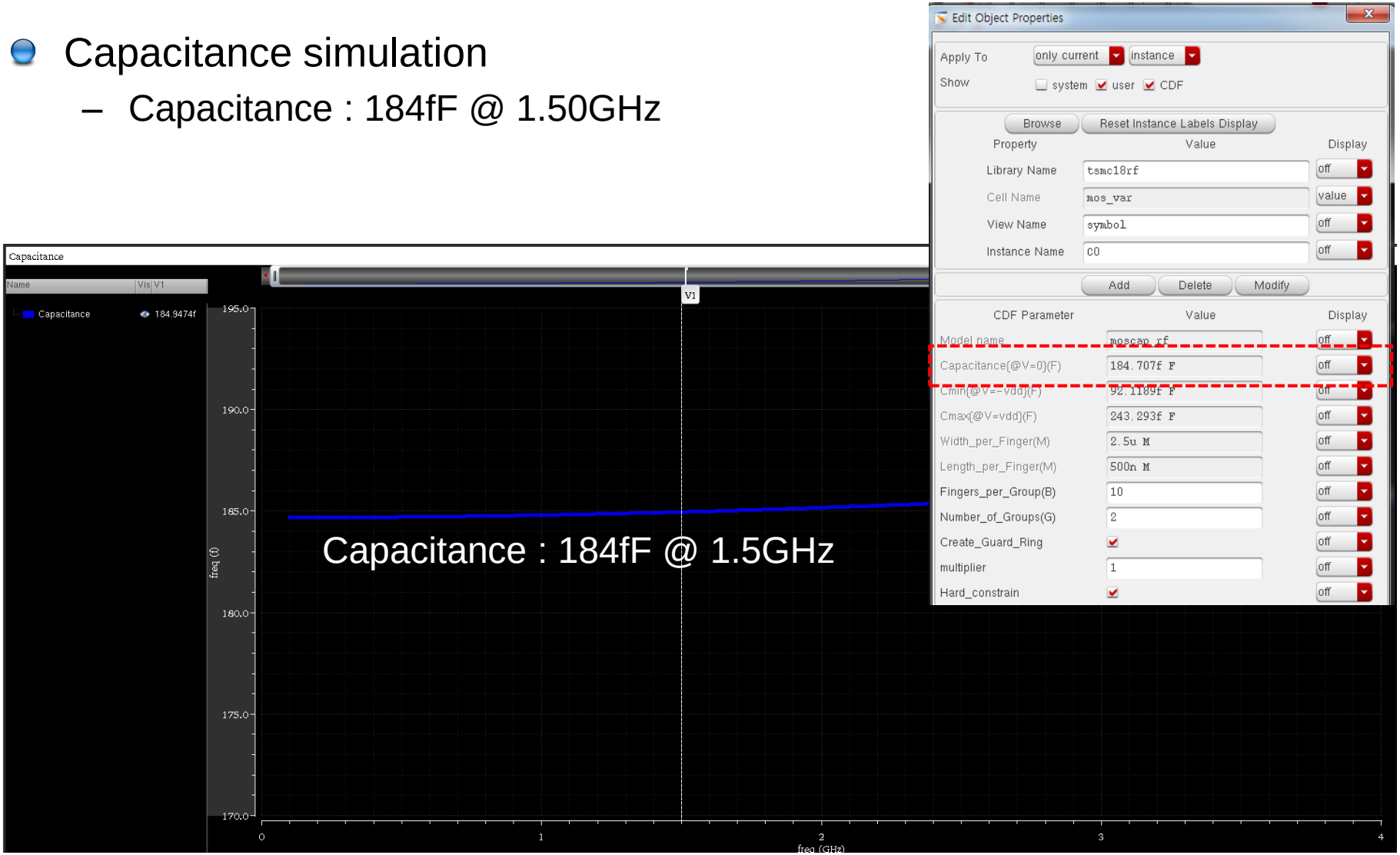
Capacitance

- Simulation condition setting
  - $C = \frac{\omega C}{\omega} = \frac{Imag[Y11]}{\omega}$
  - Calculator (Visualization & Analysis XL)
  - Wave choice → imag(yp(1 1 ?result "sp")) /(2*pi*xval(yp(1 1 ?result "sp")))
  - Outputs → Setup → Name (Capacitance) → Get Expression → Add → OK



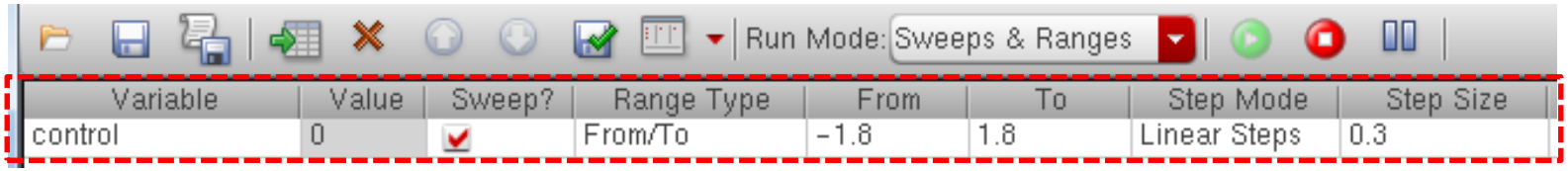
Capacitance (Control = 0V)

- Capacitance simulation
  - Capacitance : 184fF @ 1.50GHz

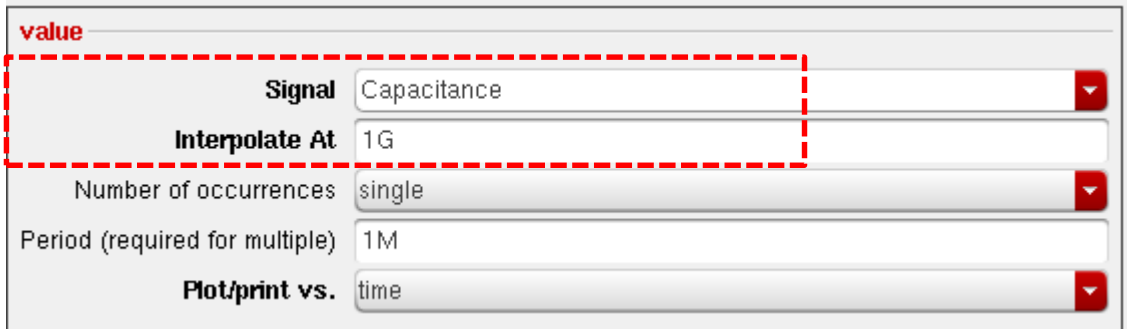


Capacitance Variation

- Control voltage sweep
  - Tools → Parametric Analysis
    - Control voltage : -1.8V ~ 1.8V (Linear steps :0.3V)

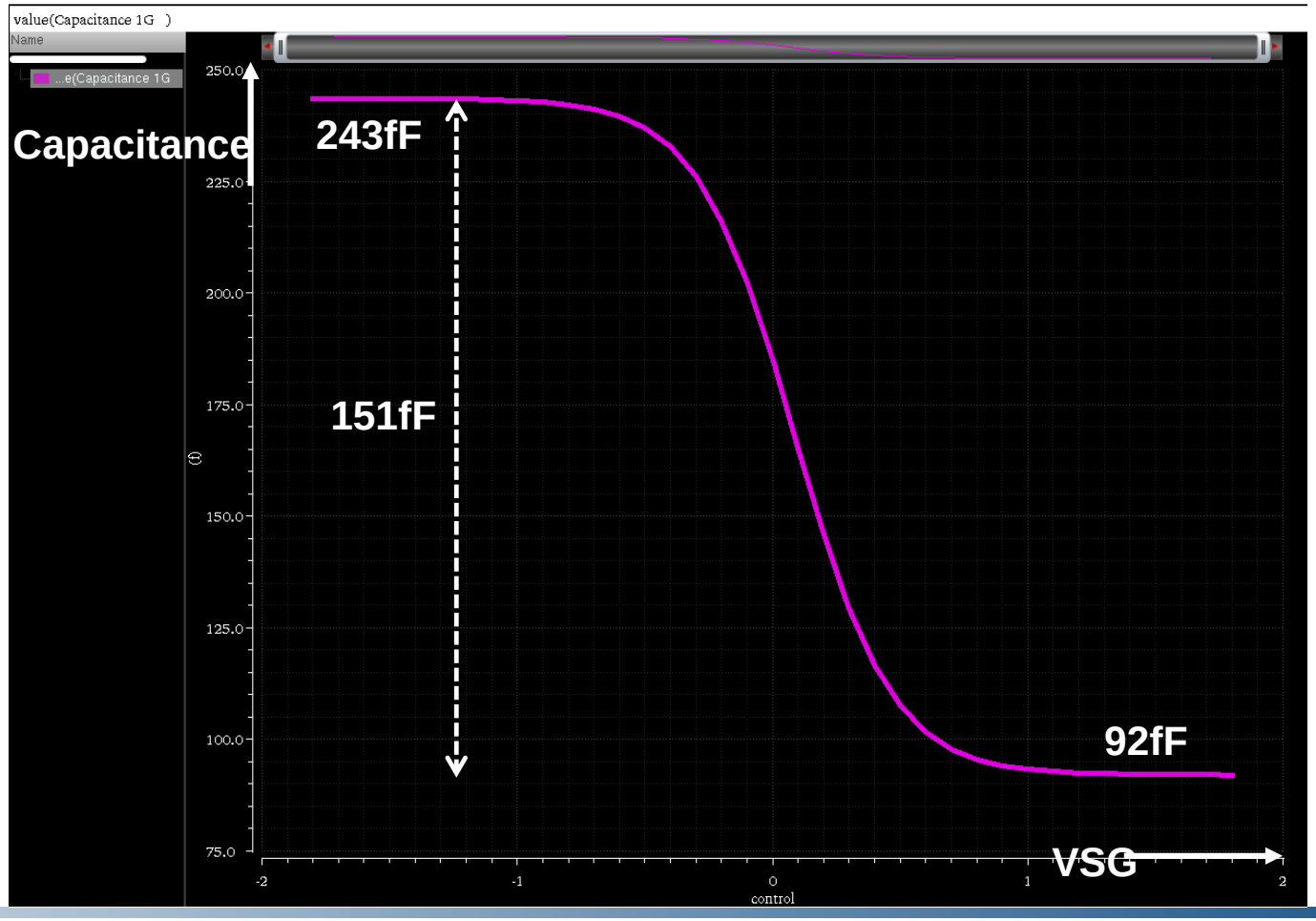


  - Calculator → Family → value → 파형 선택 (Capacitance) → Plot
    - Interpolate At : 1G



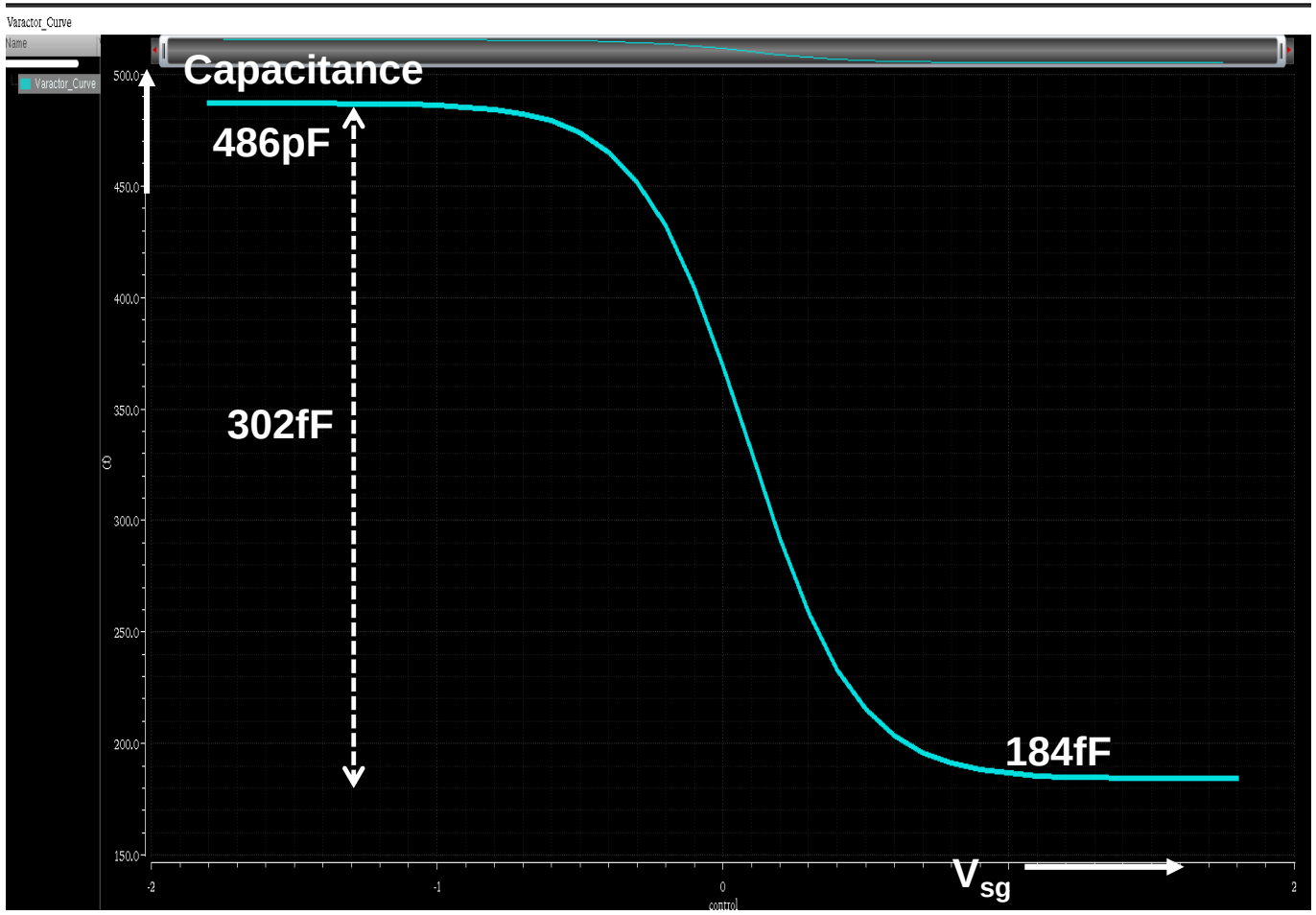
Capacitance Variation

- V_{SG} vs Capacitance
  - Multiplier : 1



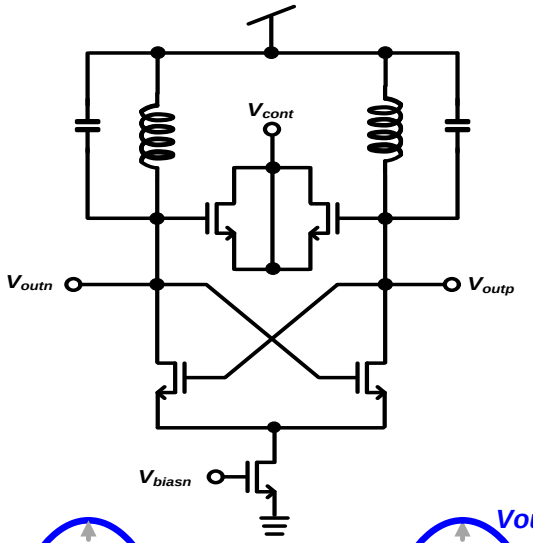
Capacitance Variation

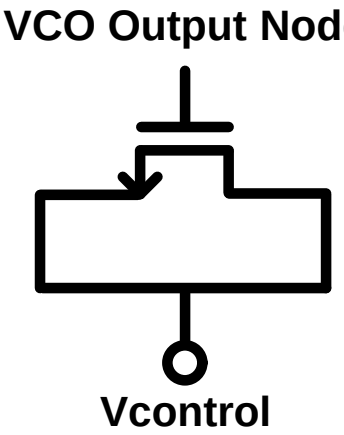
- V_{GS} vs Capacitance
  - Multiplier : 2

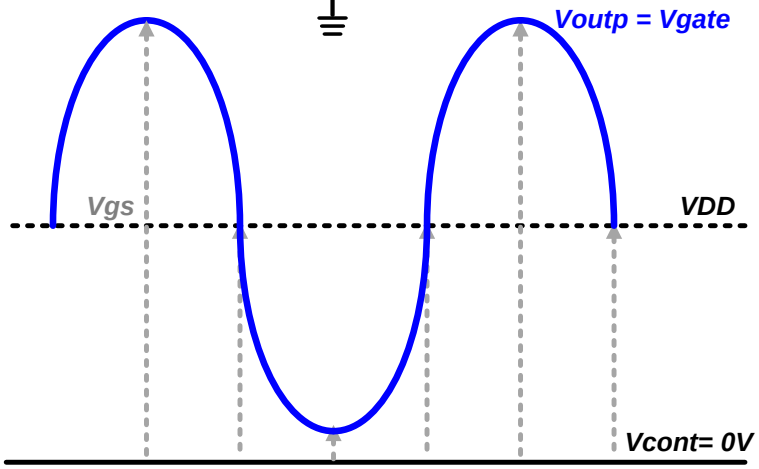


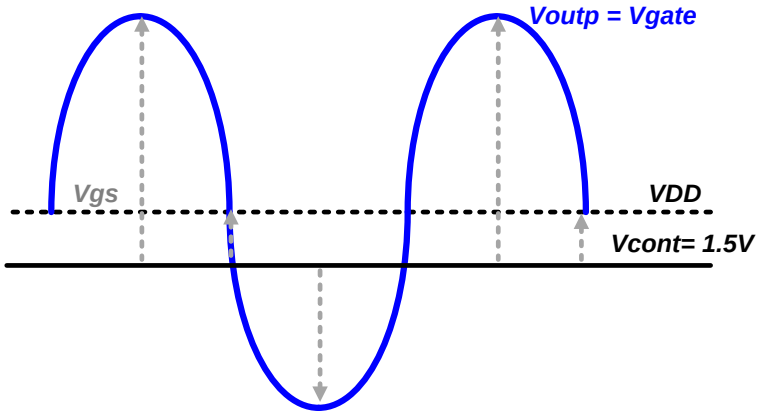
Varactor Operation

– Change average capacitance from control voltage.



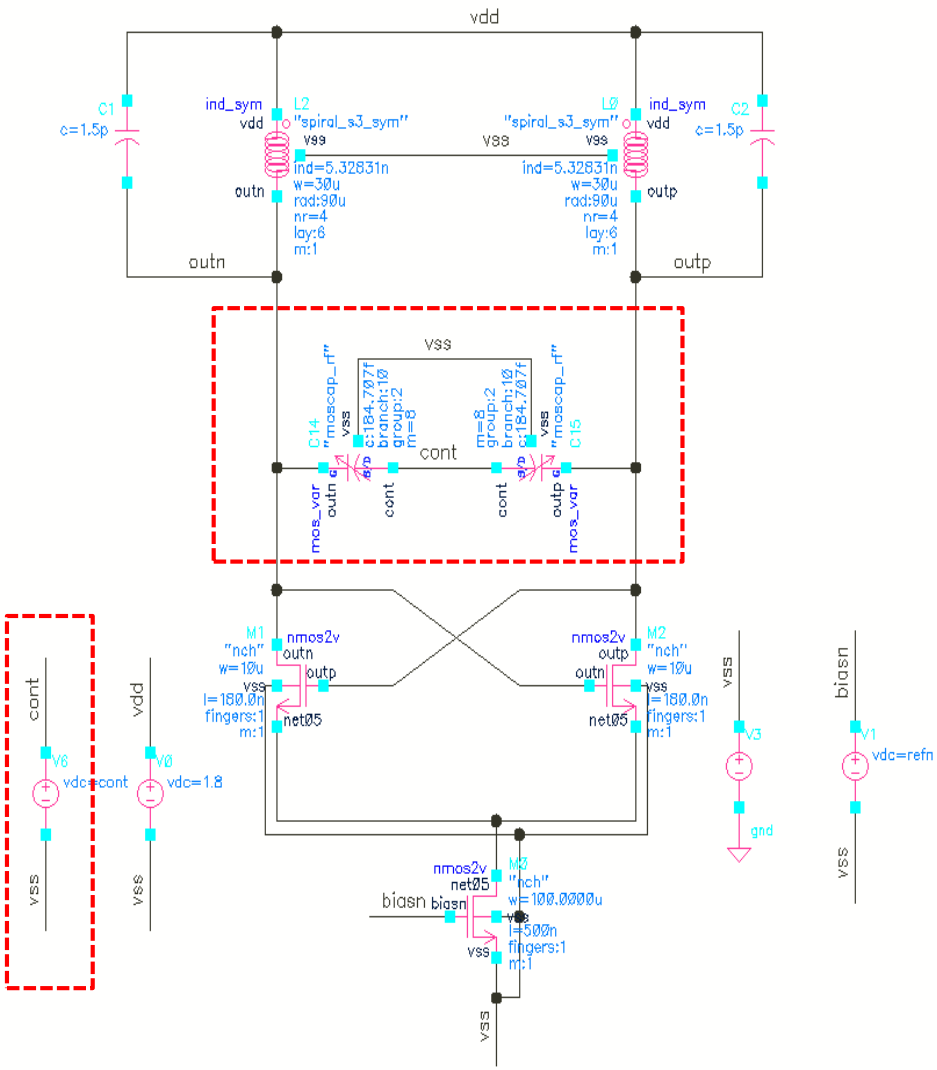






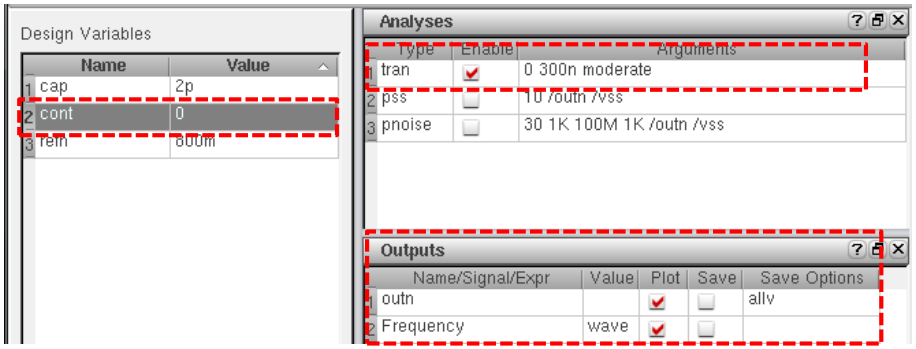
LC VCO Schematic

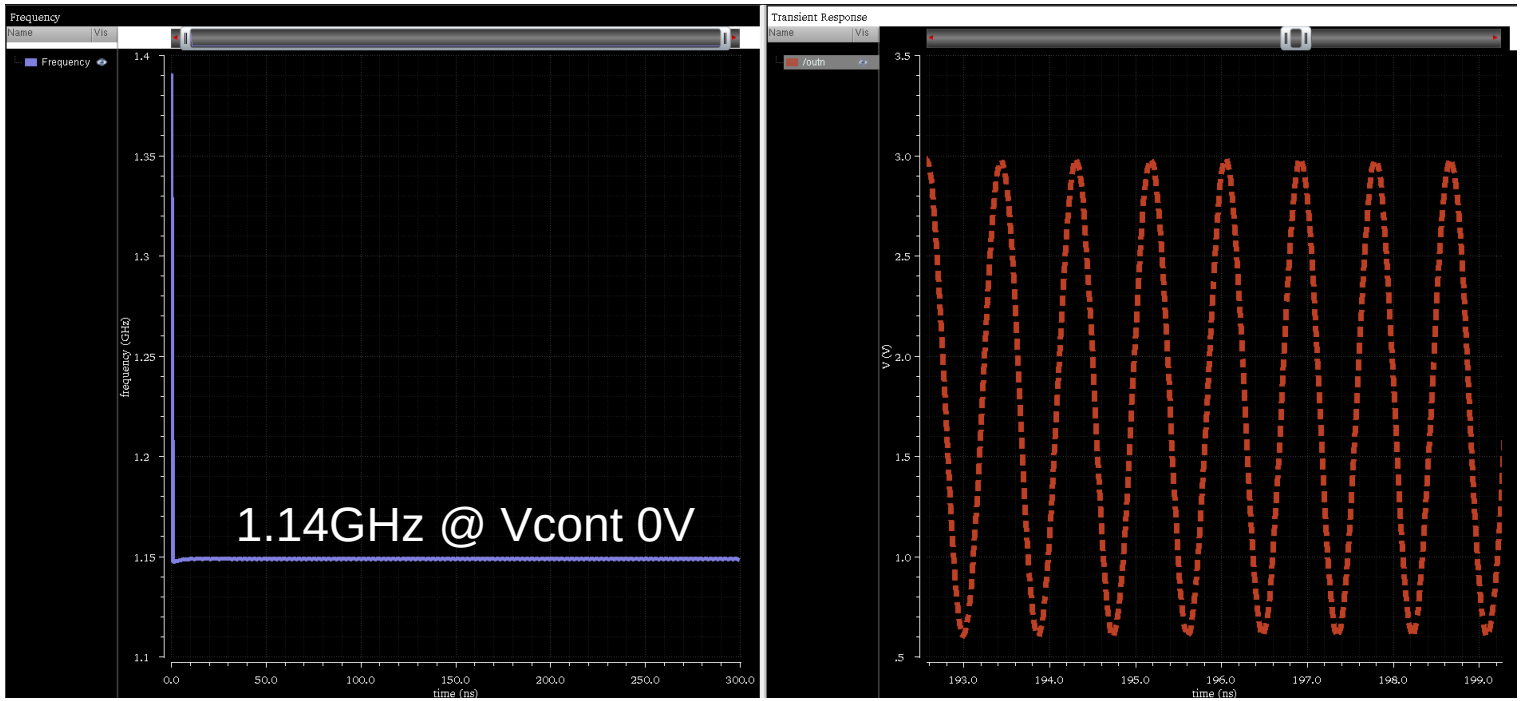
- Simulation LC VCO schematic
  - Inductor : 5.42nH
  - Capacitor : 1.5pF
  - Input NMOS
    - Length : 180n
    - Total Width : 10u (finger :1)
  - Source NMOS
    - Length : 500n
    - Total Width : 100u (finger :1)
  - Varactor
    - Fingers_per_Group(B) : 10
    - Number_of_Group(G) : 2
    - Multiplier : 8
  - vdd : 1.8V
  - biasn : 0.8V
  - cont : 변수 지정 (cont)



OSC Frequency (Vcont = 0V)

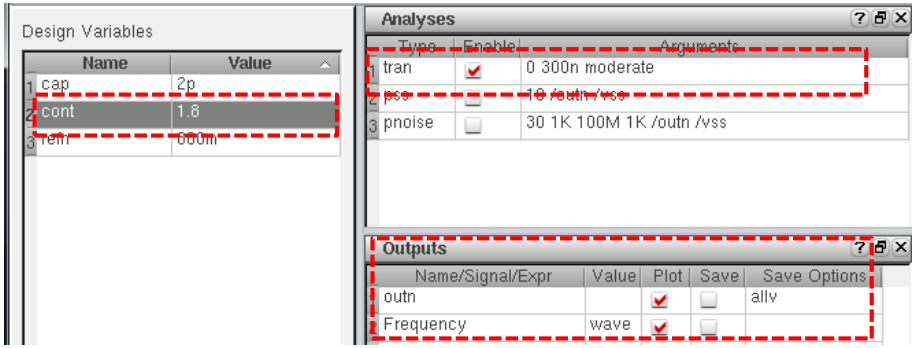
- Control Voltage 0V
  - OSC frequency : 1.14GHz
  - Transient simulation (300ns)
  - Output 파형 및 Frequency 측정

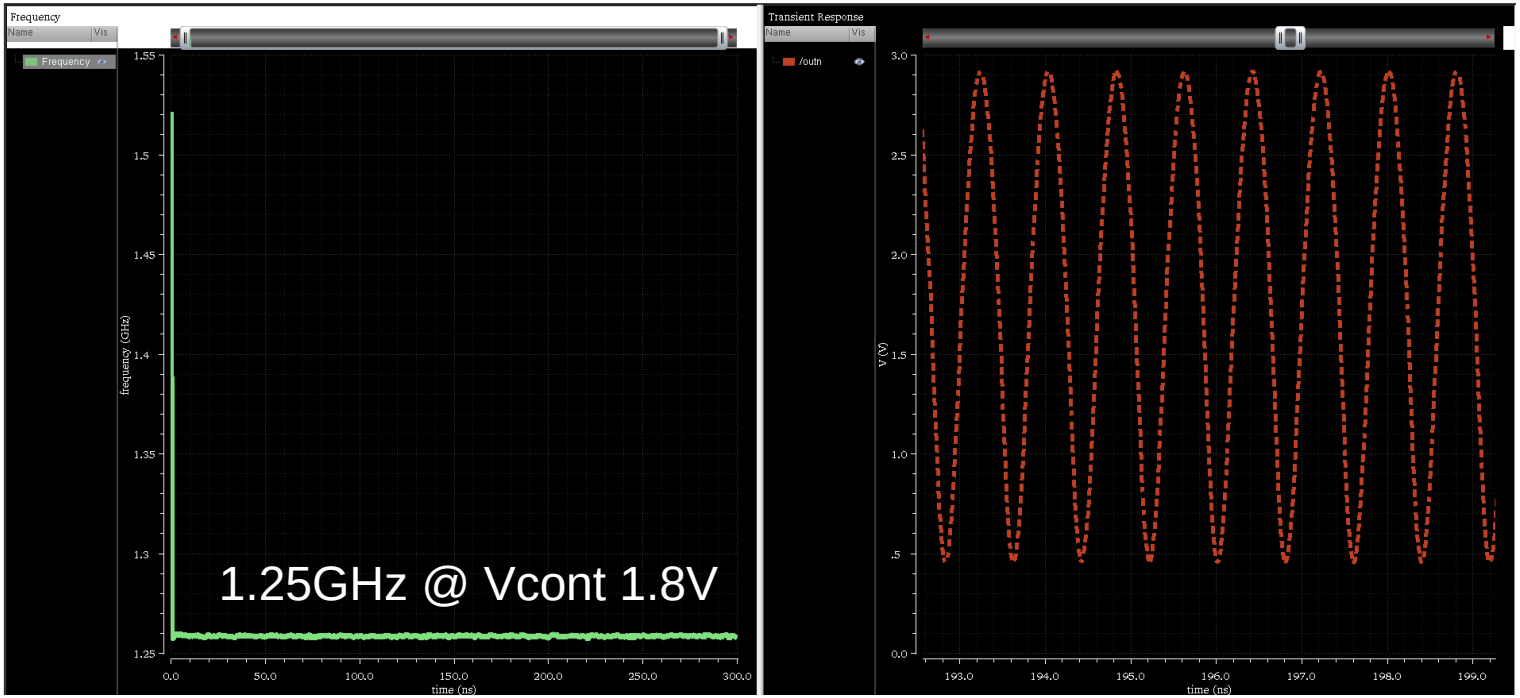




OSC Frequency (Vcont = 1.8V)

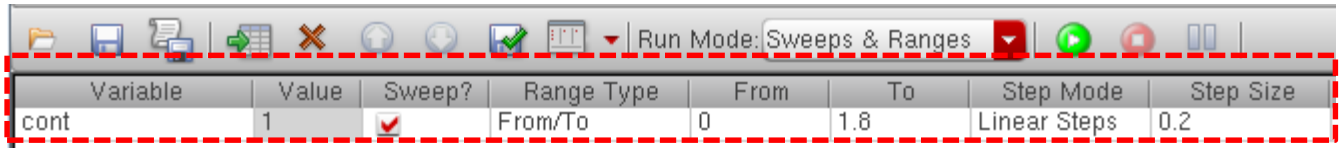
- Control Voltage 1.8V
  - OSC frequency : 1.25GHz
  - Transient simulation (300ns)
  - Output 파형 및 Frequency 측정



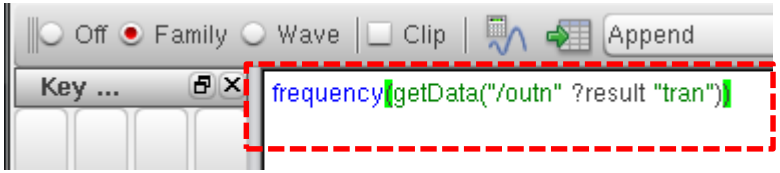


Frequency Tuning Range

- Control voltage sweep
  - Tools → Parametric Analysis
    - Control voltage : 0 ~ 1.8V (Linear steps :0.2V)

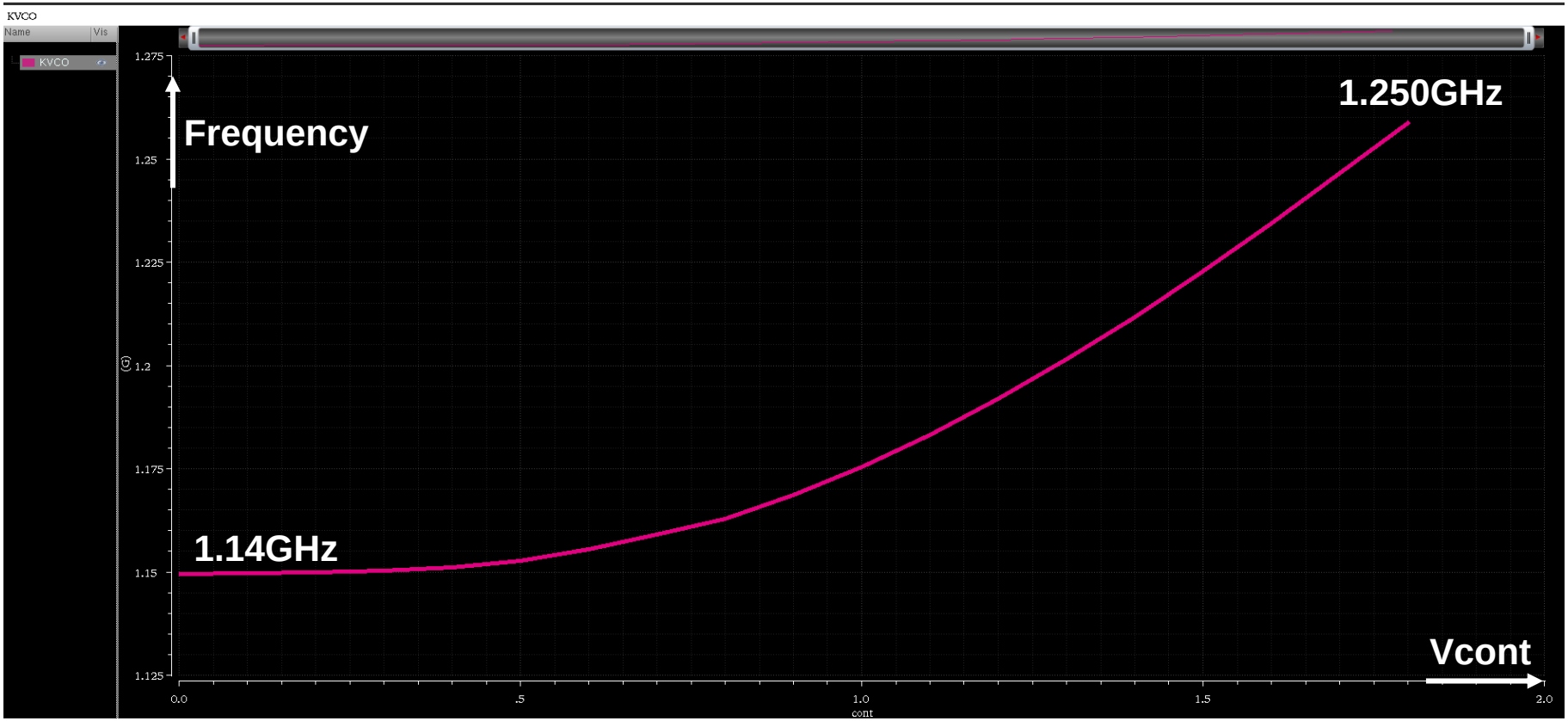


  - Calculator → Family → 파형 선택 (Output) → Function (frequency) → Plot



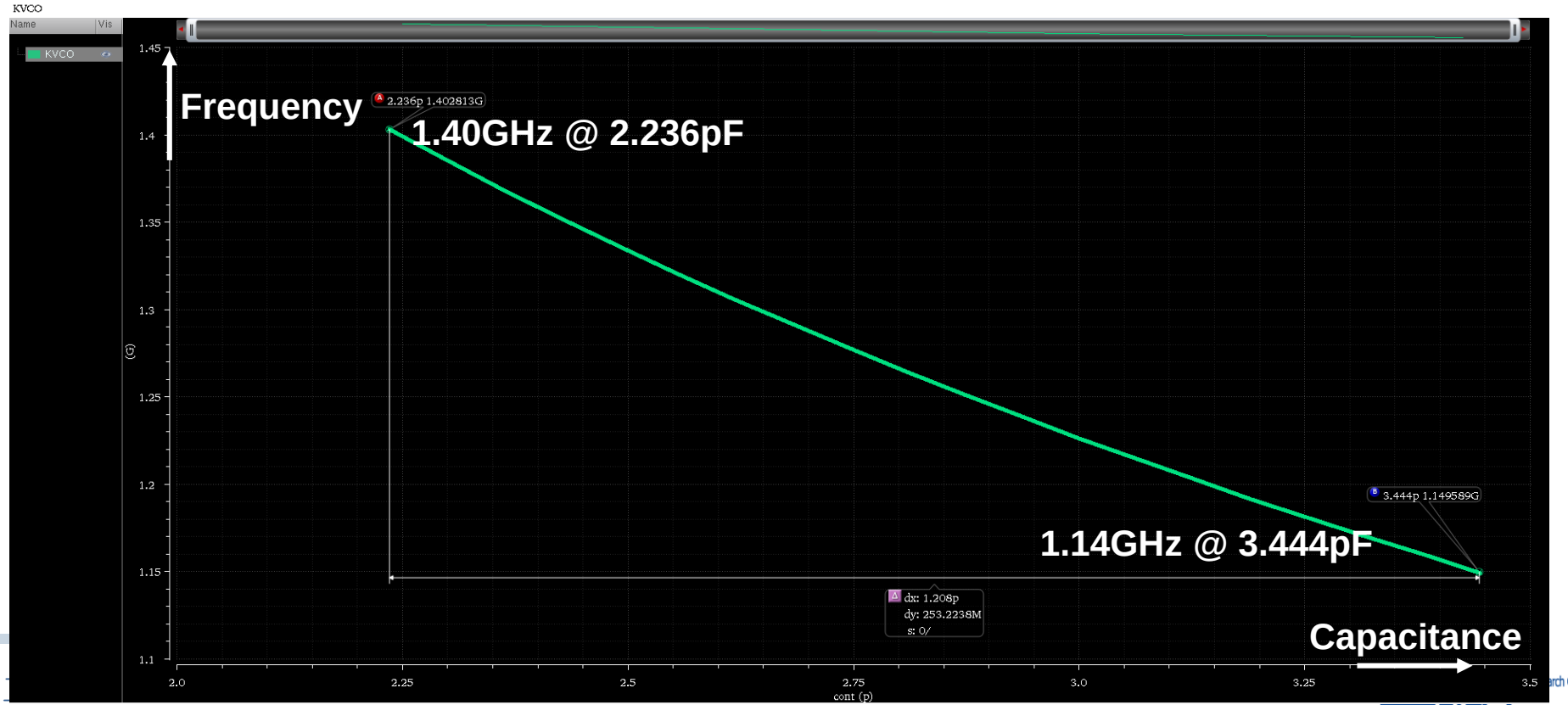
Frequency Tuning Range

- Varactor control sweep
- Varactor control voltage range : 0V ~ 1.8V
- Frequency tuning range : 110MHz

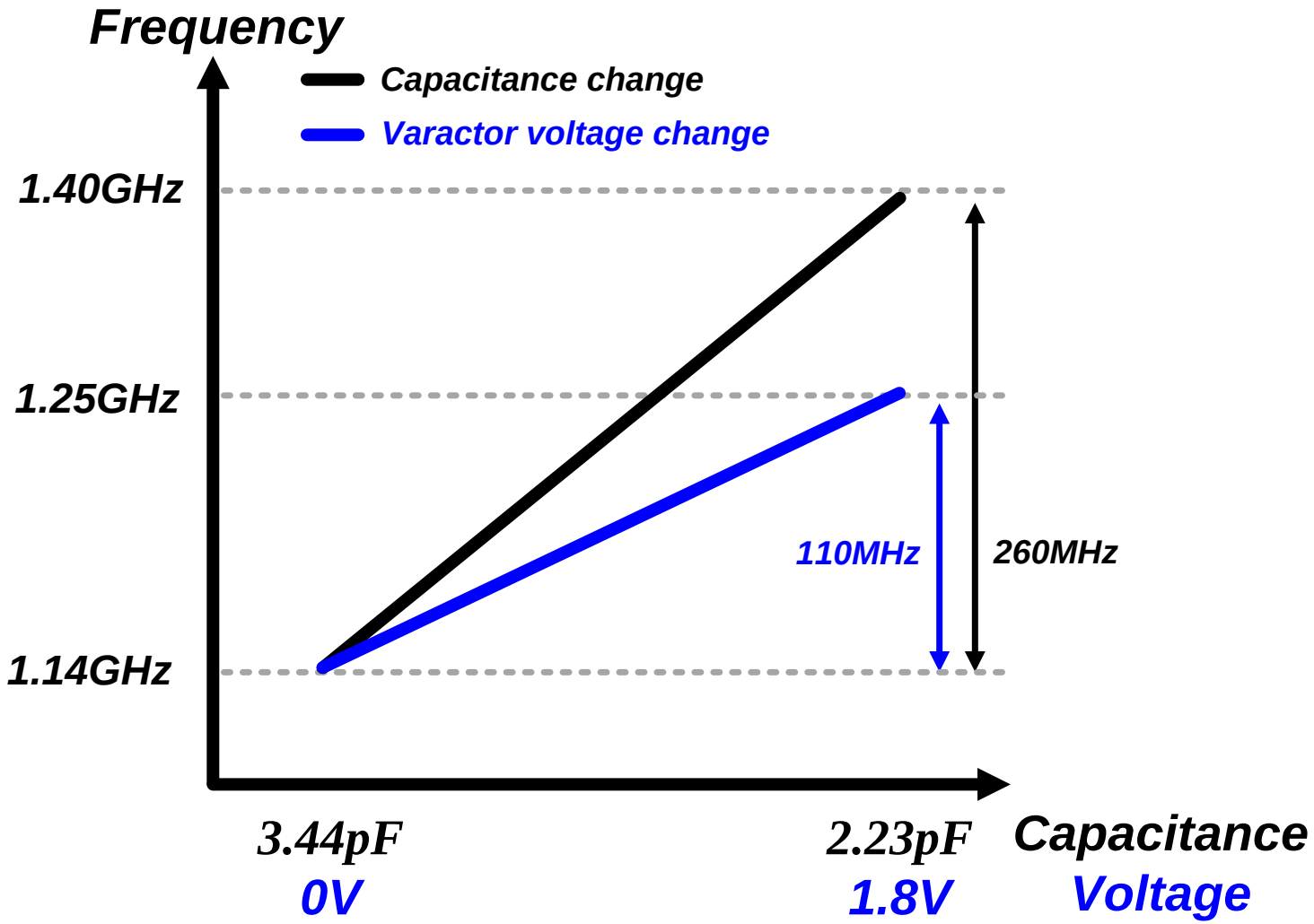


Frequency Tuning Range

- Capacitance value sweep
- Varactor capacitance
  - Control voltage 0V : 1944fF (Total capacitance 3444fF)
  - Control voltage 1.8V : 736fF (Total capacitance 2236fF)
- frequency tuning range : 260MHz



Frequency Tuning Range

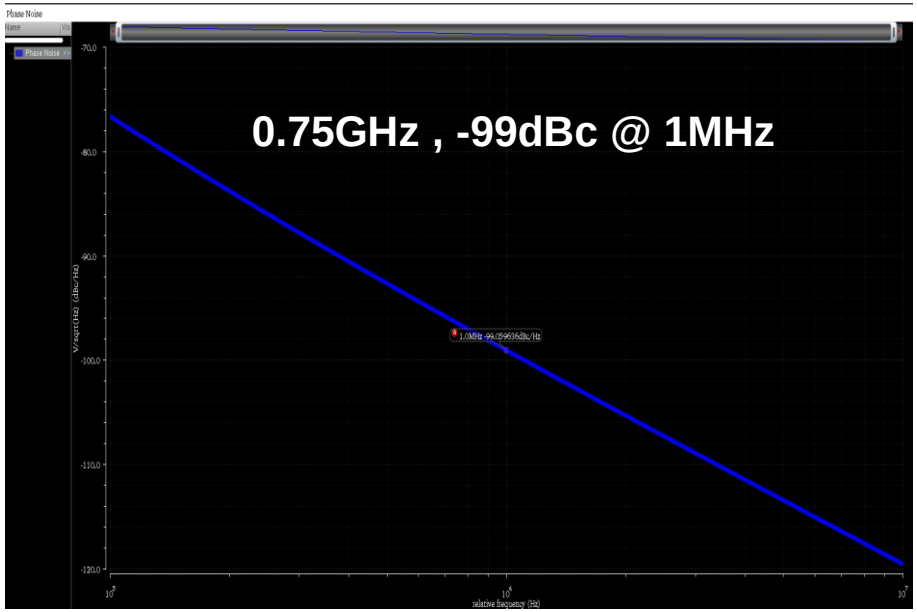


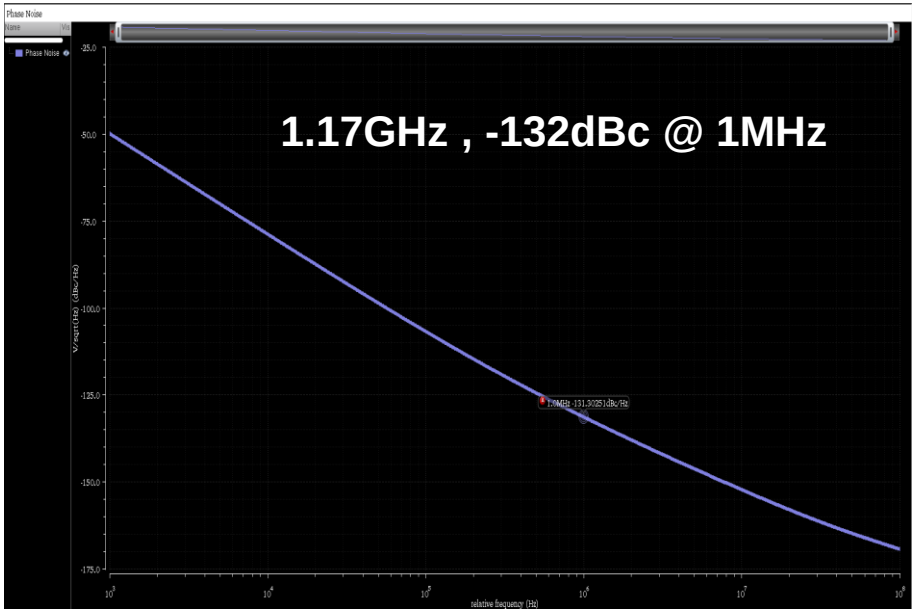
Phase Noise (cont : 1V)

- Phase Noise
  - 1.17GHz, -131dBc @ 1MHz

VCO Comparison #1

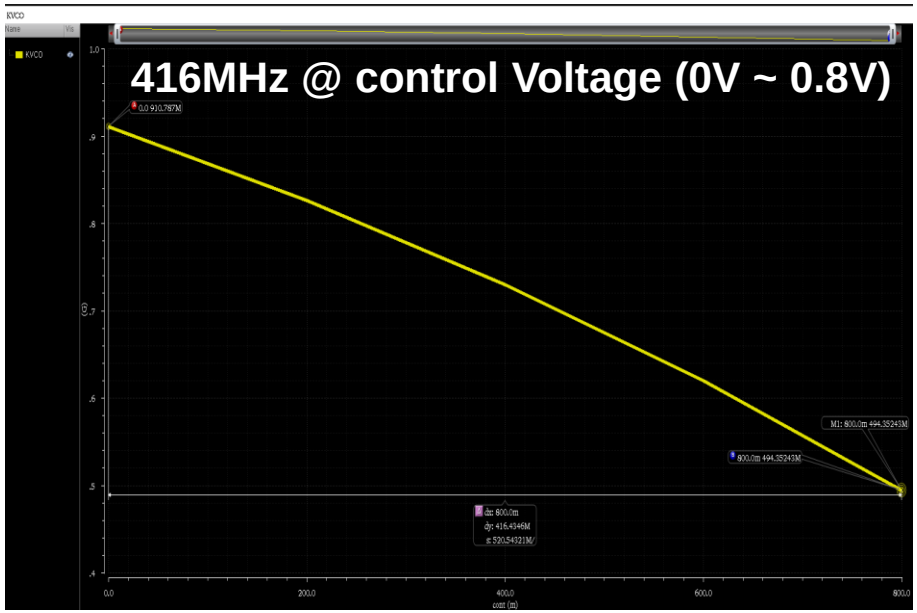
- Phase noise
  - Ring VCO : -99dBc @ 0.75GHz 1MHz offset
  - LC VCO : -132dBc @ 1.35GHz 1MHz offset
  - **LC VCO is better for phase noise.**

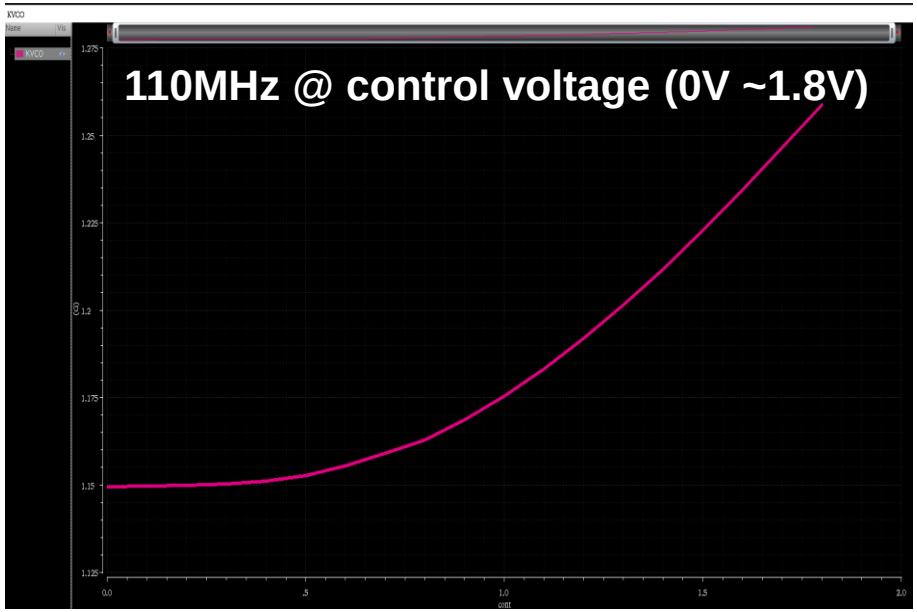




VCO Comparison #2

- Frequency tuning range
  - Ring VCO : 416MHz @ control voltage (0V ~ 0.8V)
  - LC VCO : 110MHz @ control voltage (0V ~ 1.8V)
  - **Ring VCO is better for frequency tuning range.**





Assignments

- Design 2GHz (±100MHz) LC VCO with frequency tuning range 100MHz.
- Verify and plot output waveforms and frequency tuning range.
- Verify and plot phase noise with control voltage 0V , 0.9V and 1.8V.
- Indicate LC VCO schematic, inductor and capacitor value, and using varactor design value.

- LC VCO specification
  - VDD supply voltage : 1.8V
  - Bias voltage : 0.8V
  - Phase noise : Min -115dBc/Hz
  - Frequency tuning range : Min 100MHz

- Due: 29 Mar. 9:30(Hardcopy)

Q & A

superpyunki@gmail.com