C-comp extraction methods for High-Speed I/O buffers

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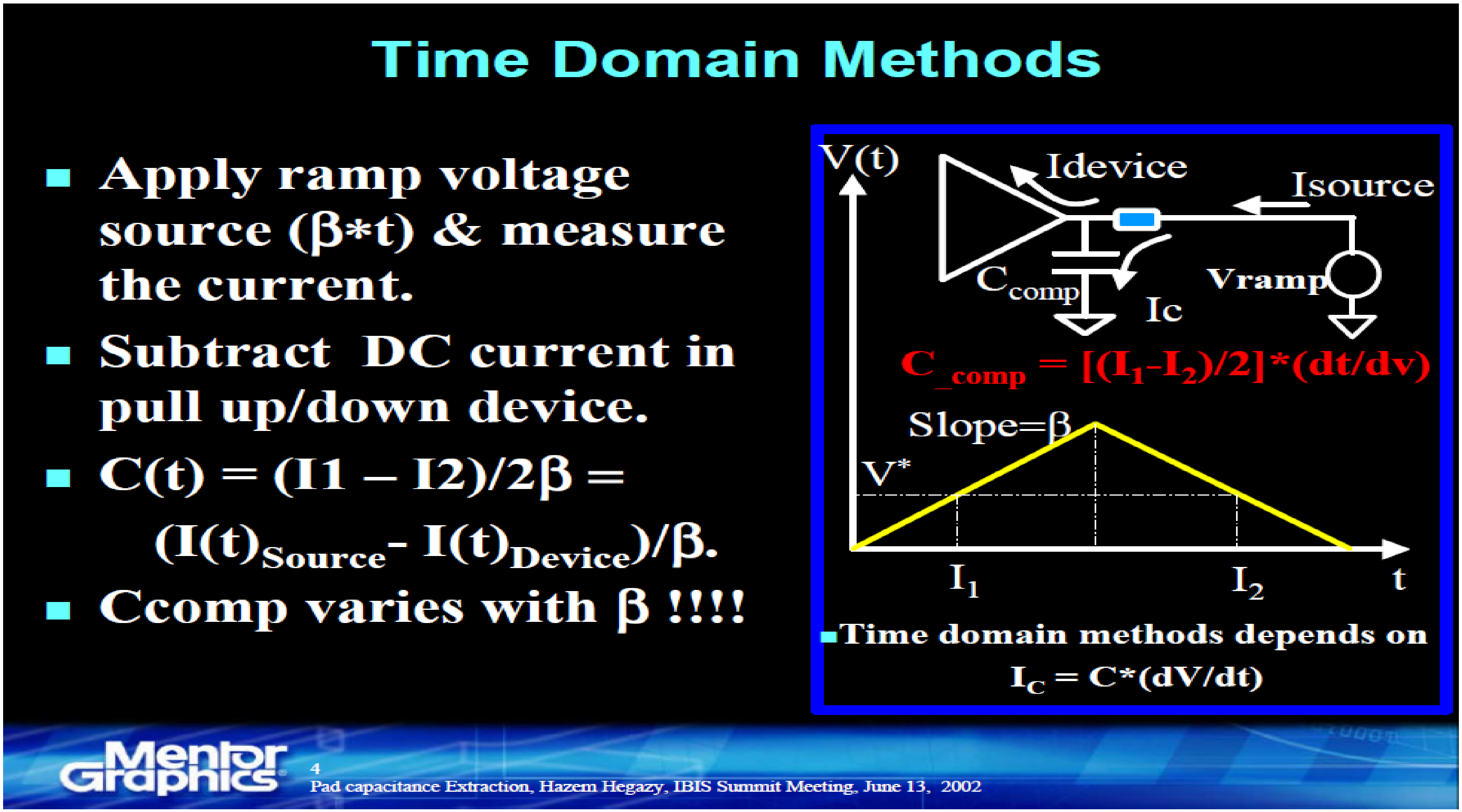
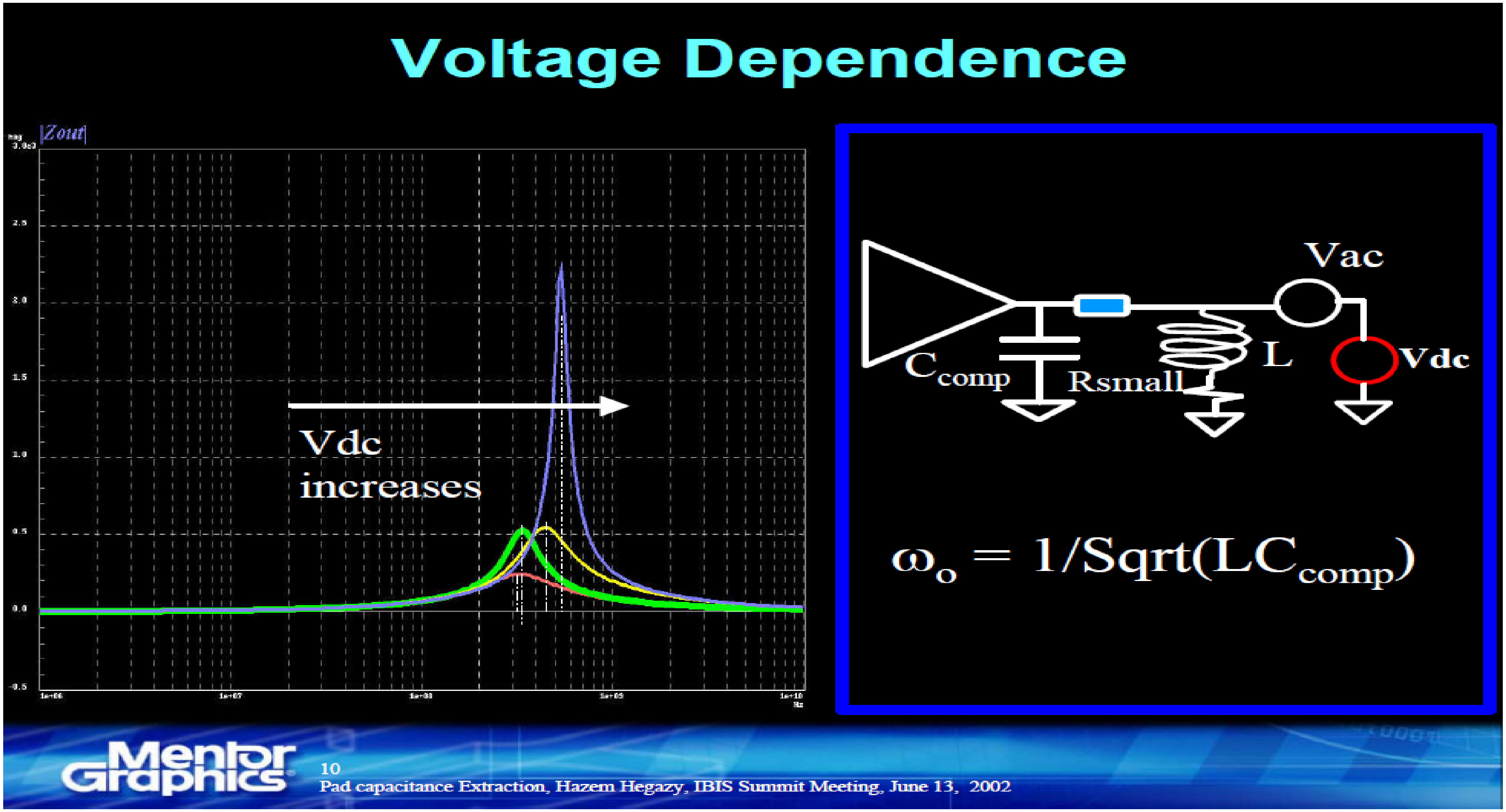
Outlines

- Review C-comp extraction methods
  - Time domain
  - Frequency domain
- Look into C-comp for pullup, pulldown, powerclamp and groundclamp
  - Frequency domain with voltage variables
- Define frequency and voltages
- Conclusions

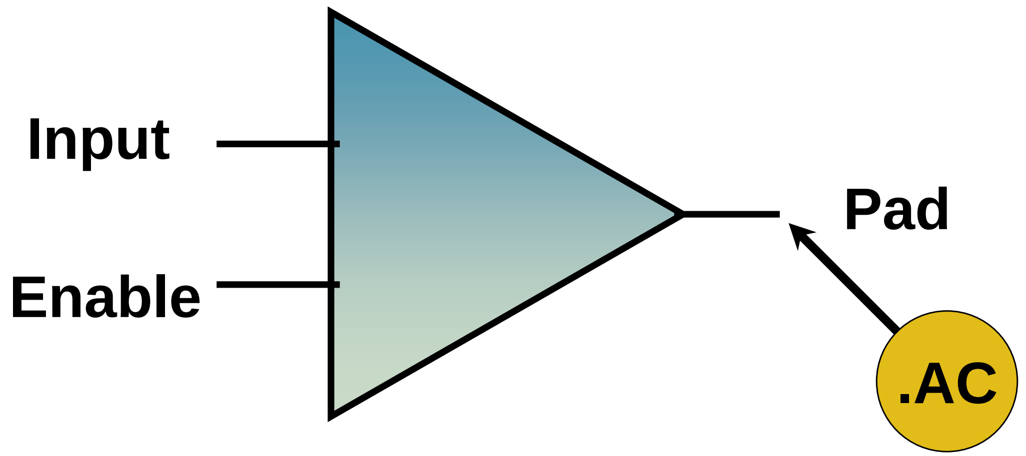
Time domain


Time Domain Methods
Apply ramp voltage source (β*t) & measure the current.
Subtract DC current in pull up/down device.
C(t) = (I1 – I2)/2β =
(I(t)Source- I(t)Device)/β.
Ccomp varies with β !!!!
V(t)
Idevice
Isource
Ccomp
Ic
Vramp
C_comp = [(I1-I2)/2]*(dt/dv)
Slope=β
V*
I1
I2
t
Time domain methods depends on
IC = C*(dV/dt)
Mentor Graphics
4
Pad capacitance Extraction, Hazem Hegazy, IBIS Summit Meeting, June 13, 2002

Frequency domain



C-comps for pullup, pulldown, powerclamp and groundclamp



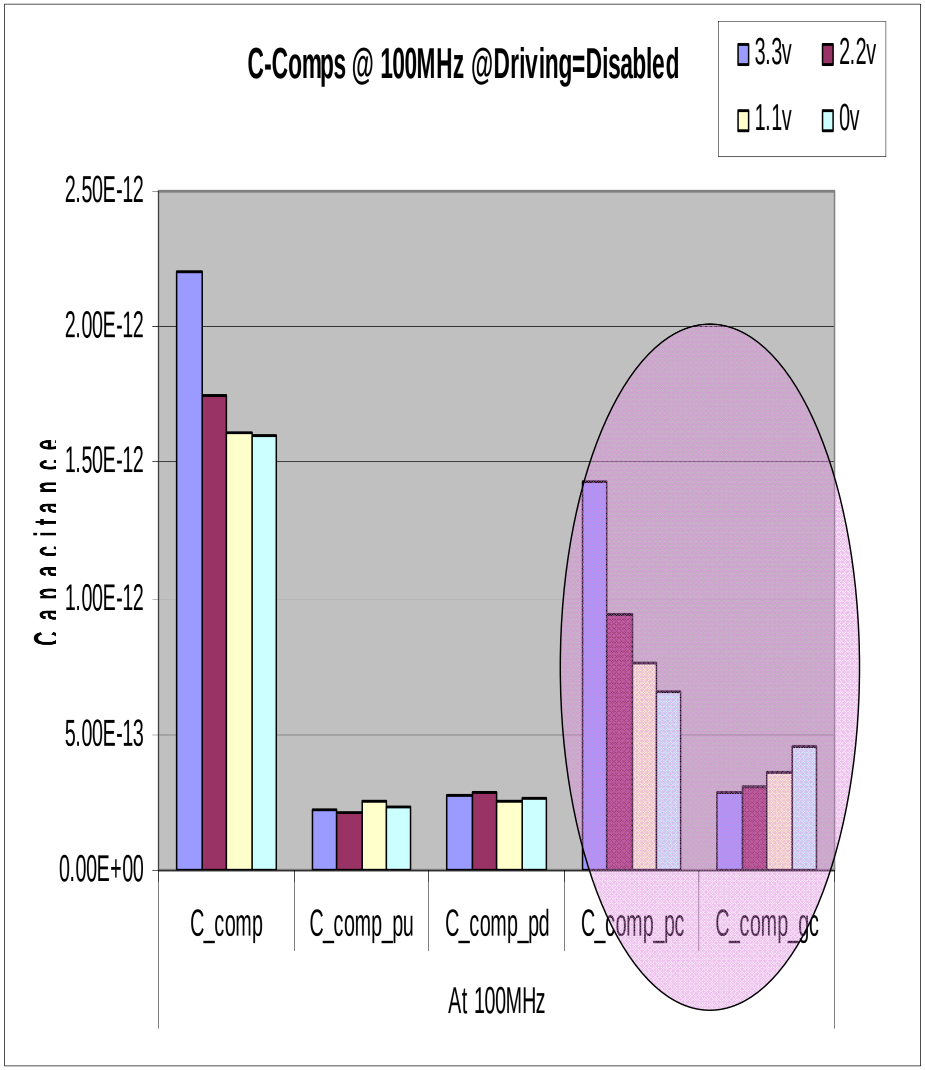
- Pad DC levels
  - 3.3v, 2.2v, 1.1v, 0v
- Input DC levels
  - High, Low
- Enable DC levels
  - Enabled, Disabled

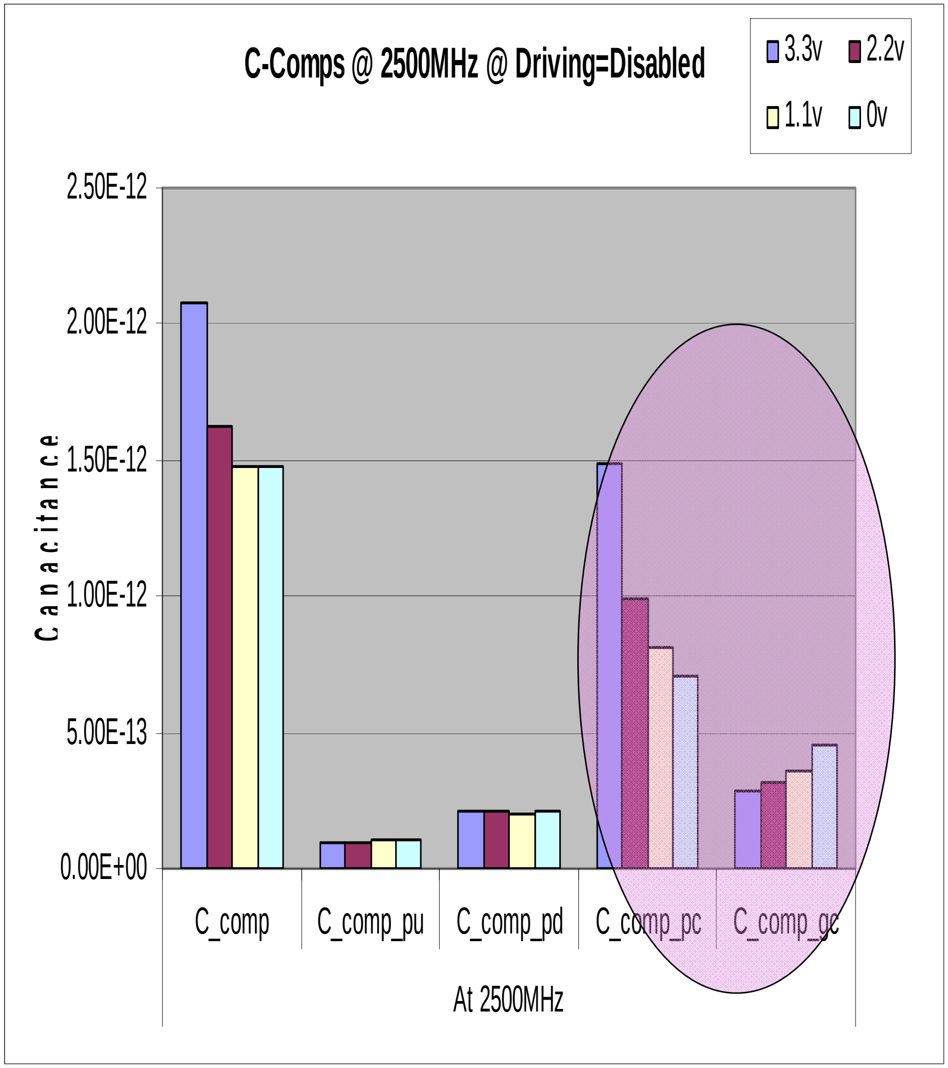
3 DC variables for C-comp frequency-domain extractions

Non-driving mode summary

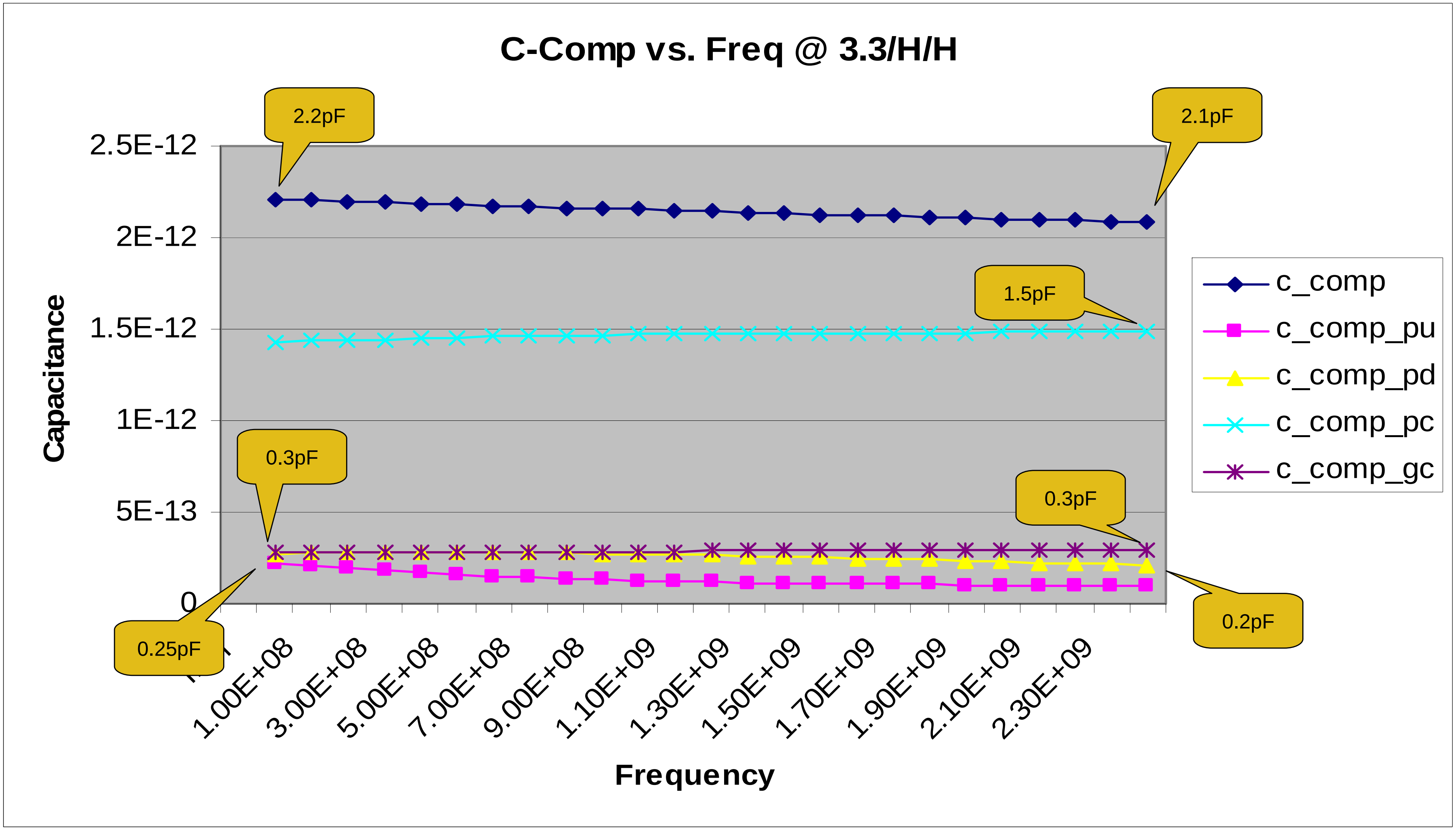
- Almost identical C-comp values for clamps when frequency changes
- Pad DC levels impact C-comp values for clamps
- For I/O buffers, C-comps values for Pullup and Pulldown may not be zero. They could change with frequency changes
- For I/O buffers, non-driving mode C-comp values are different than driving mode’s. They could be big enough to affect your simulation analysis result

Non-driving mode @ 100MHz and 2500 MHz

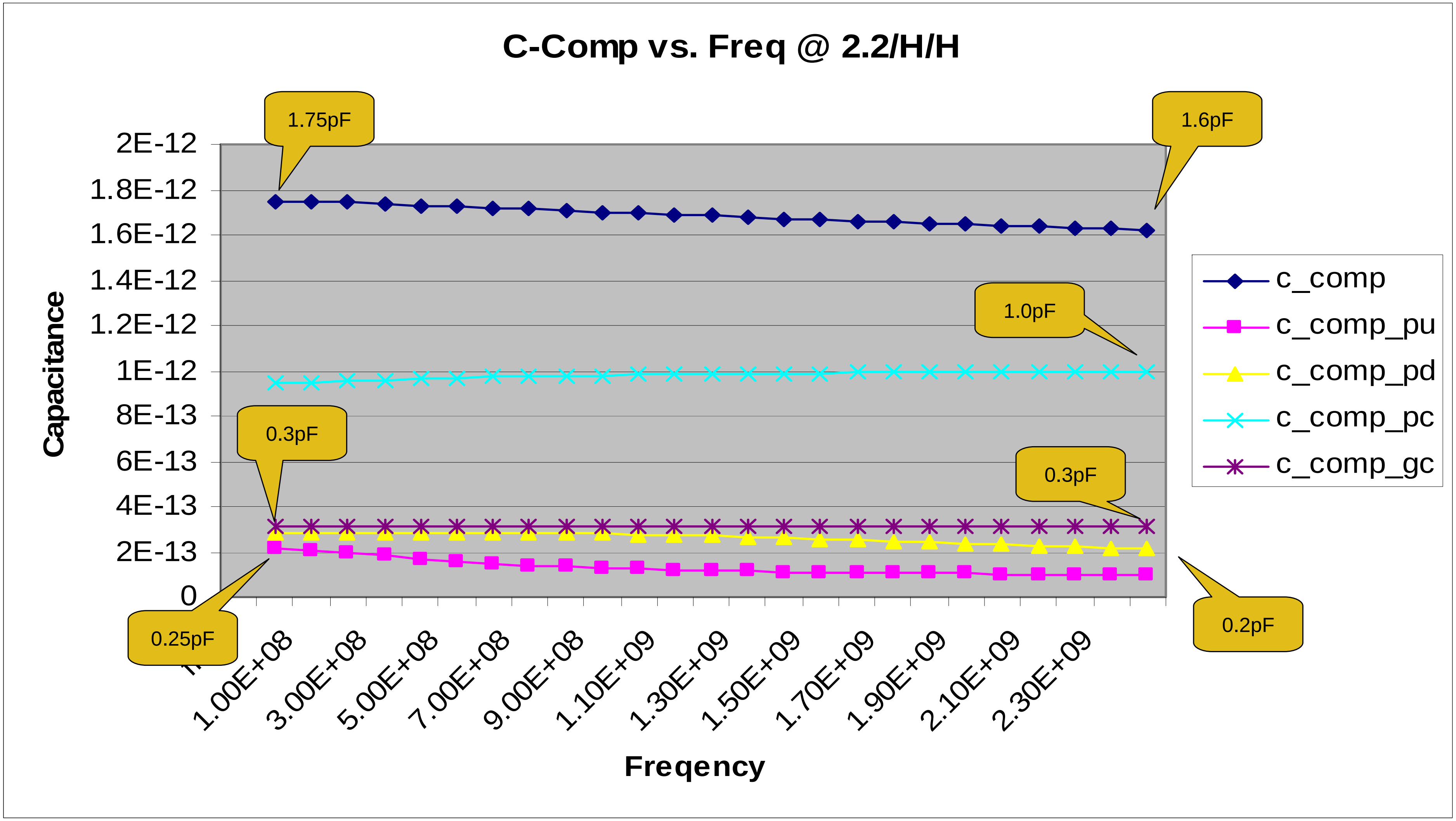




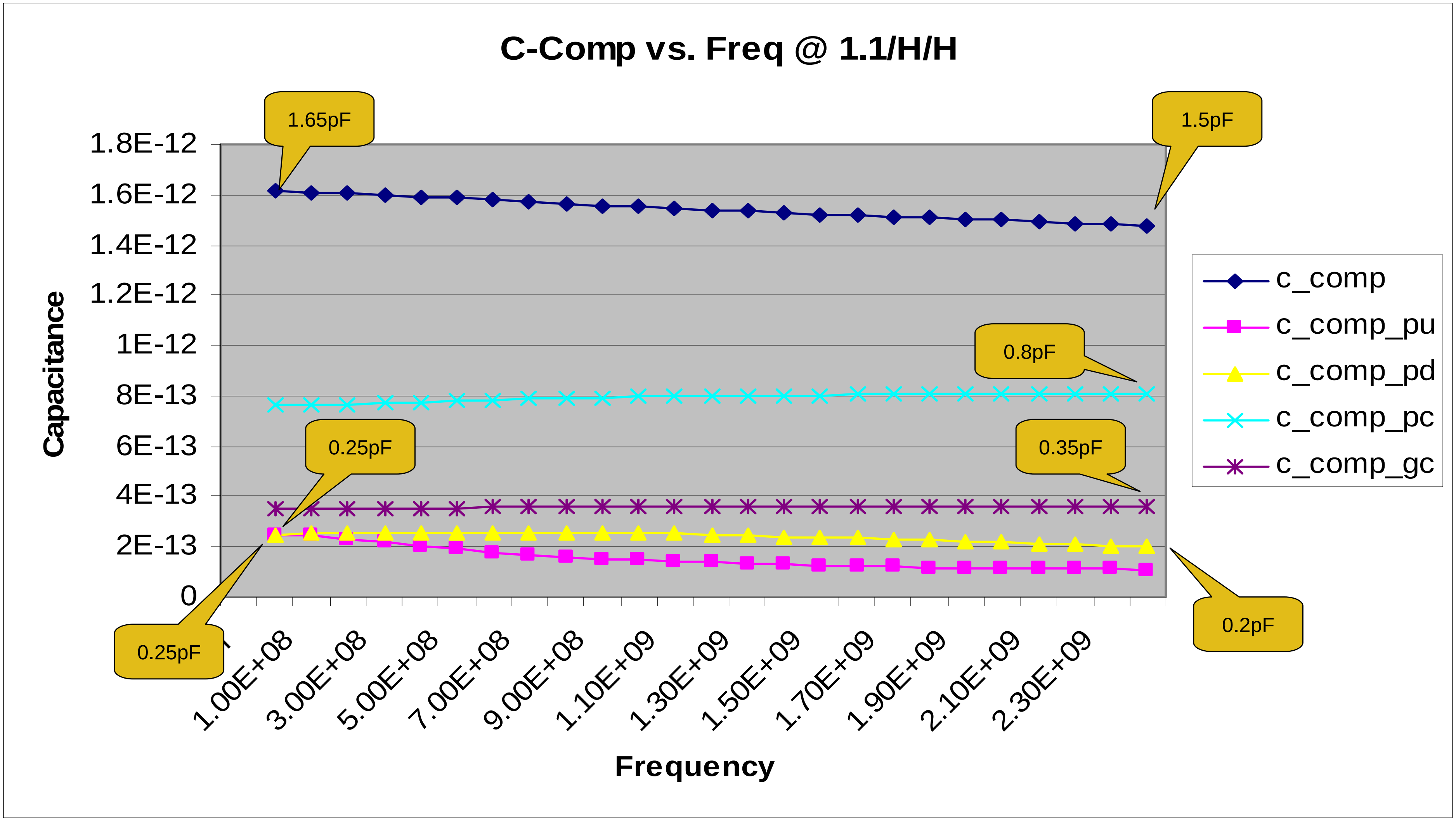
Pad DC = 3.3v
Driving mode = Disabled



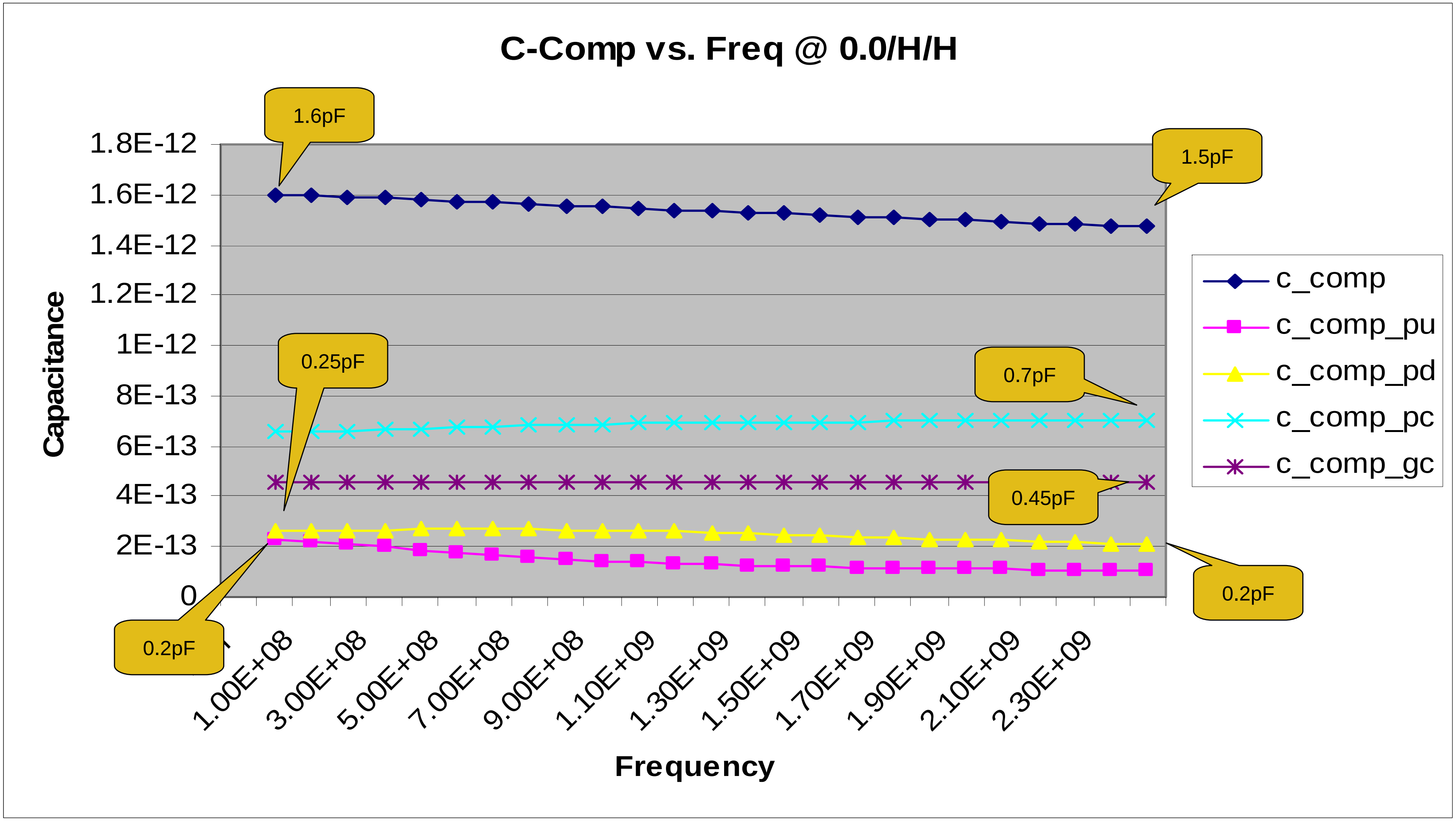
Pad DC = 2.2v
Driving mode = Disabled



Pad DC = 1.1v
Driving mode = Disabled



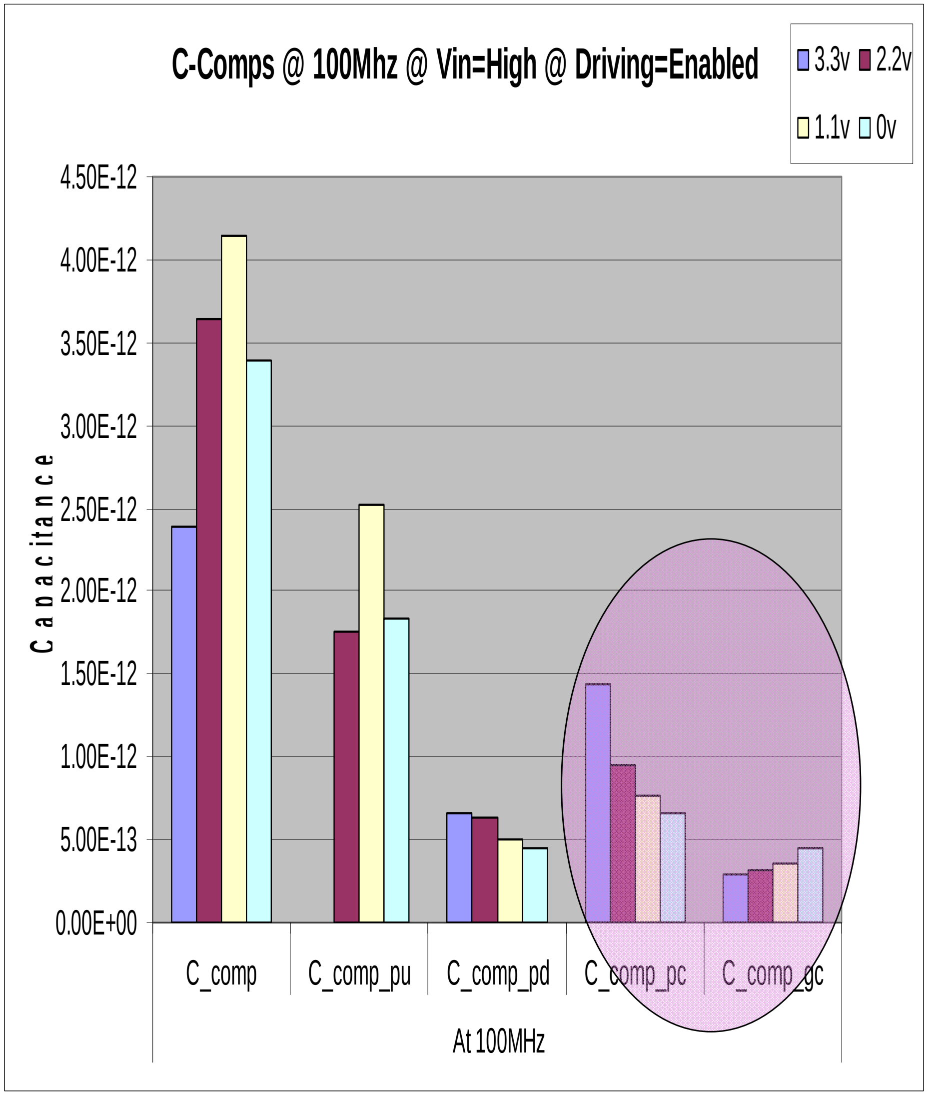
Pad DC = 0.0v
Driving mode = Disabled

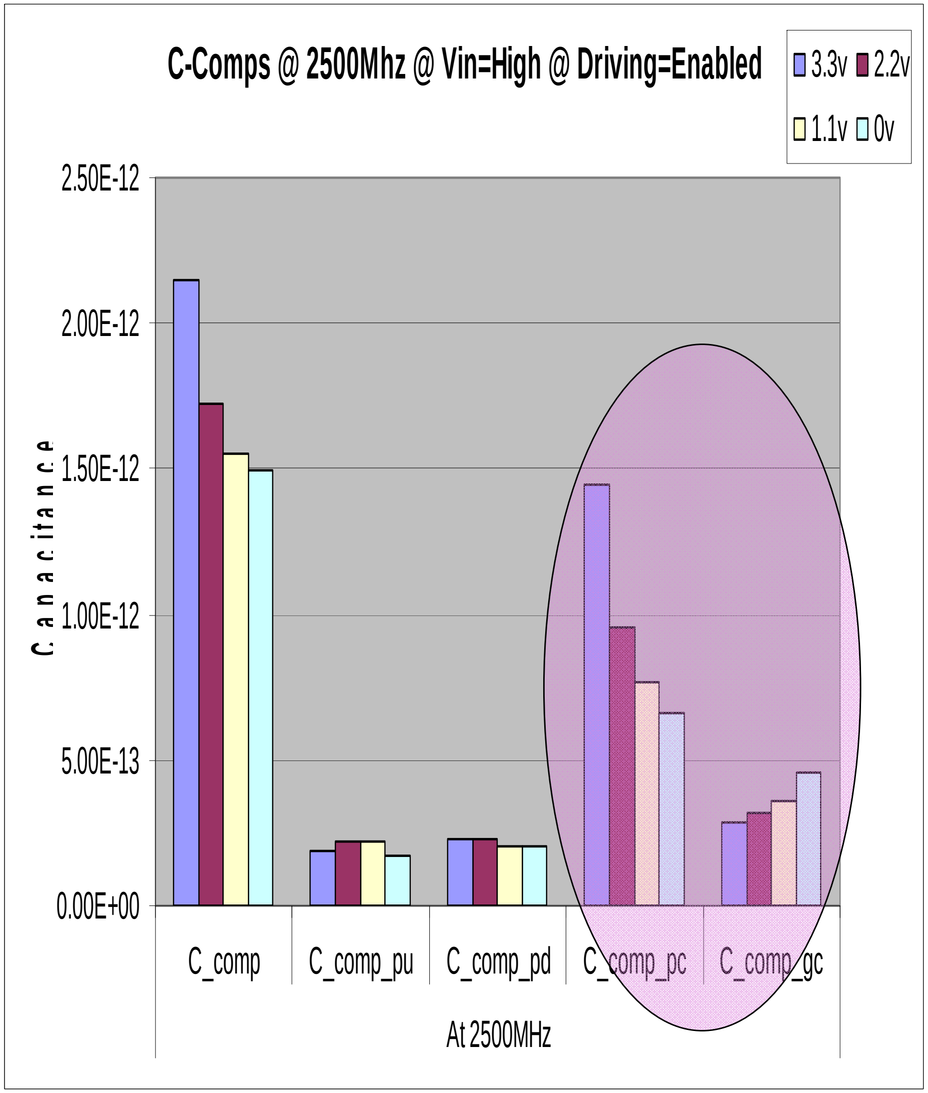


Driving mode summary

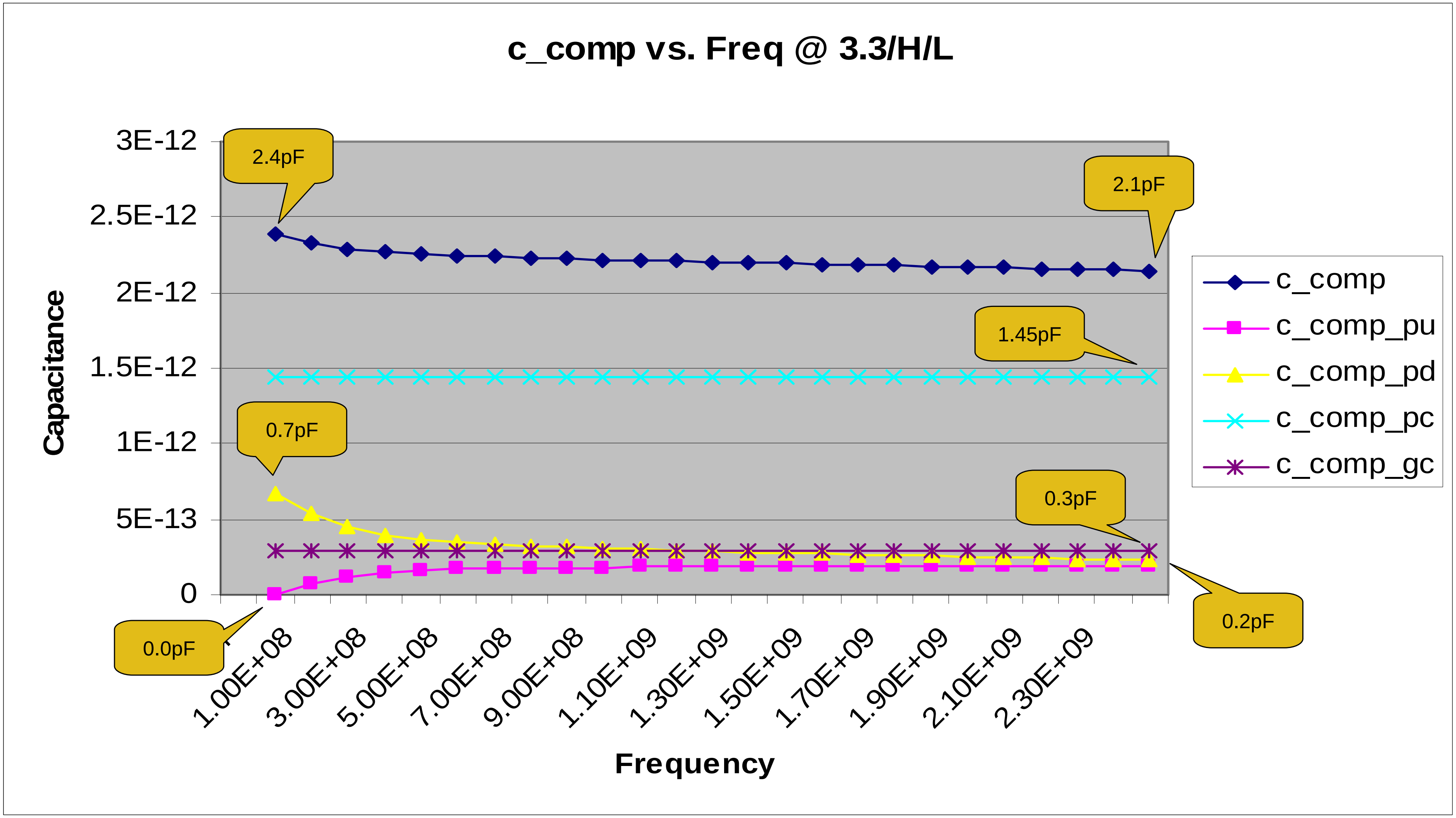
- Identical C-comp values for clamps with frequency changes
- Pad DC levels impact C-comp values for clamps
- Pullup and Pulldown C-comp values vary with frequency changes. But it settles at a frequency point and up (being flat)
  - Input DC (level = High) impacts more on Pullup
  - Input DC (level = Low) impacts more on Pulldown

Driving mode with Vin=High @ 100MHz and 2500MHz

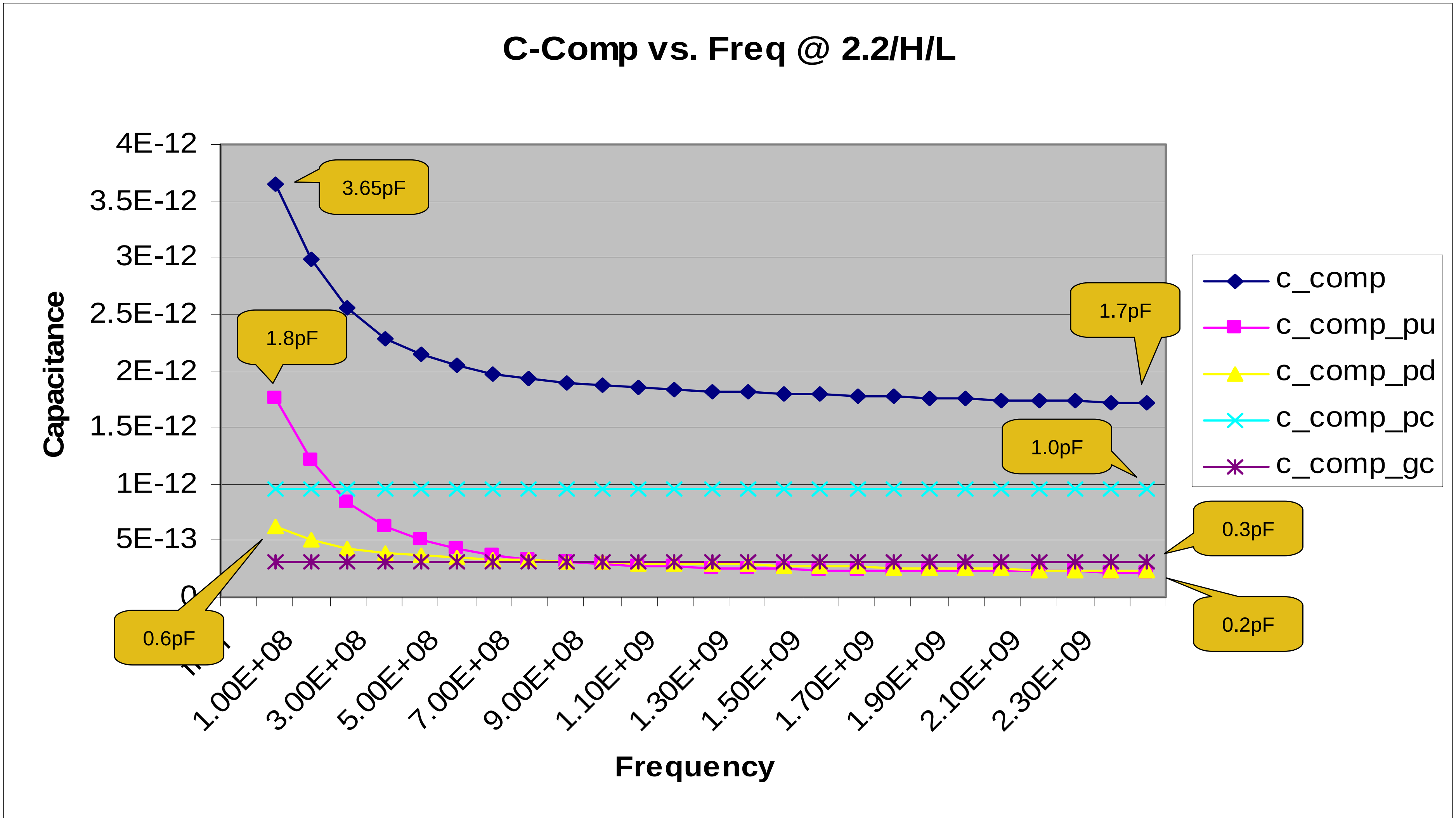




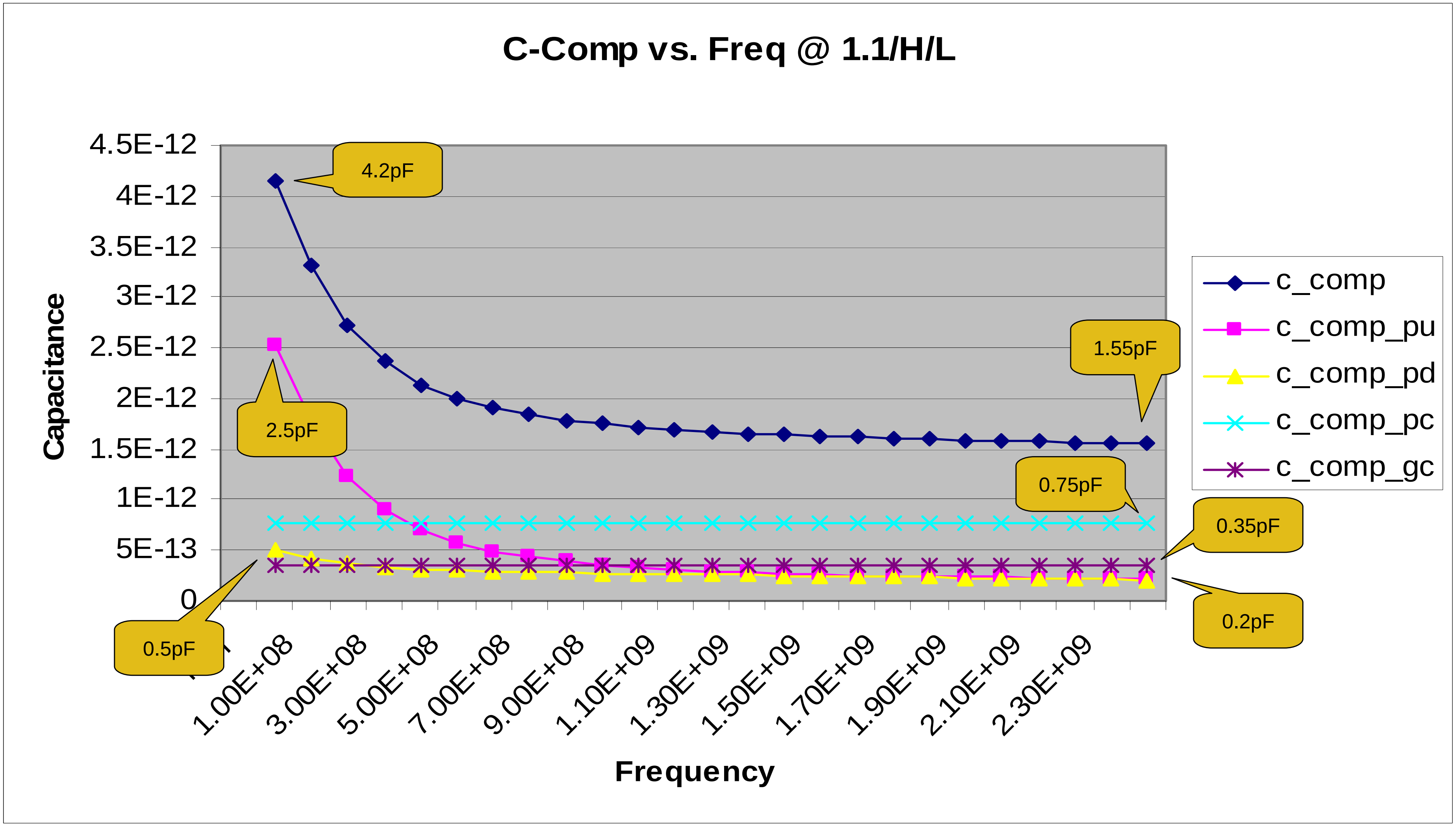
Pad DC = 3.3v, Input DC = High, Driving mode = Enabled



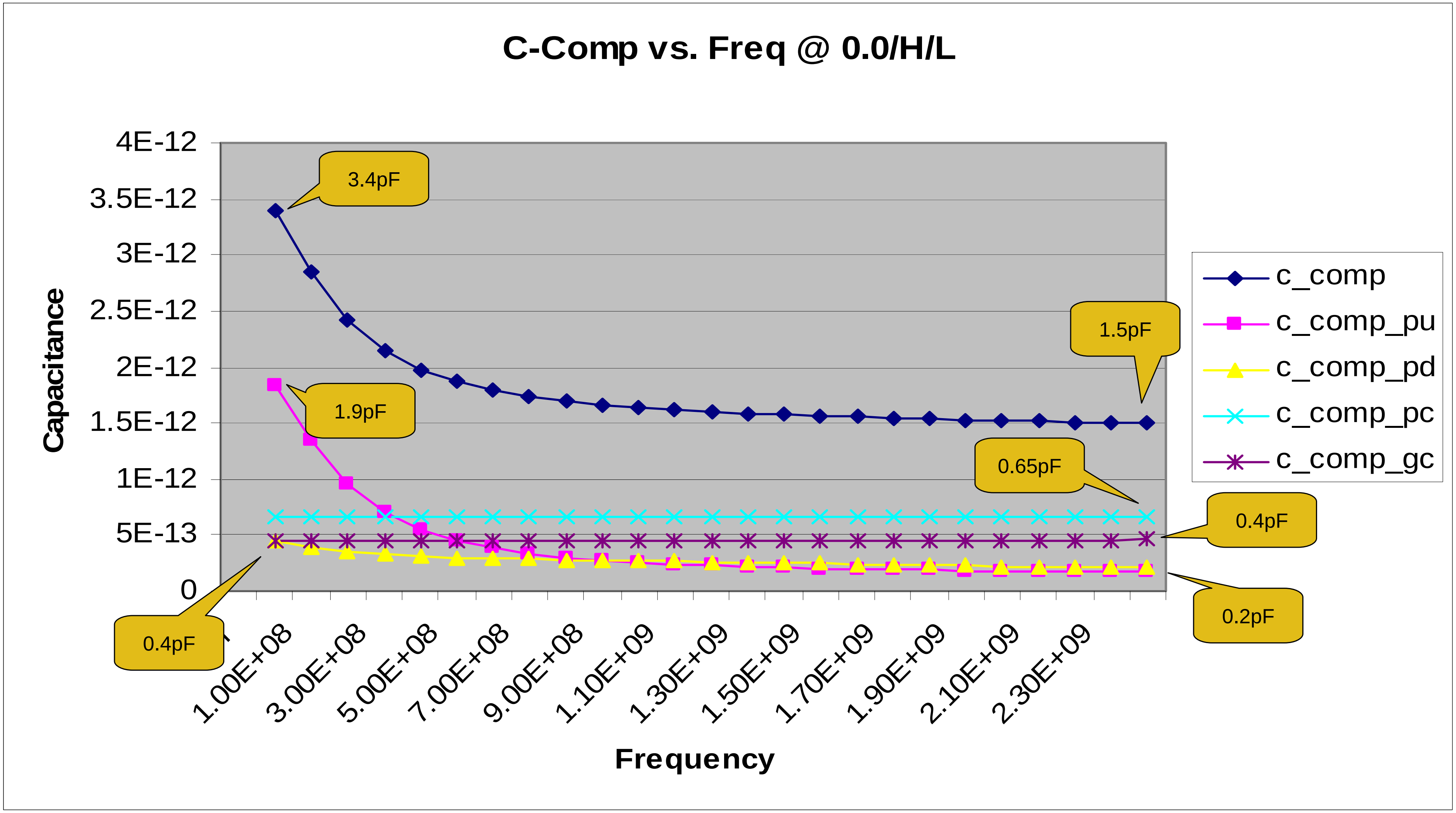
Pad DC = 2.2v, Input DC = High, Driving mode = Enabled



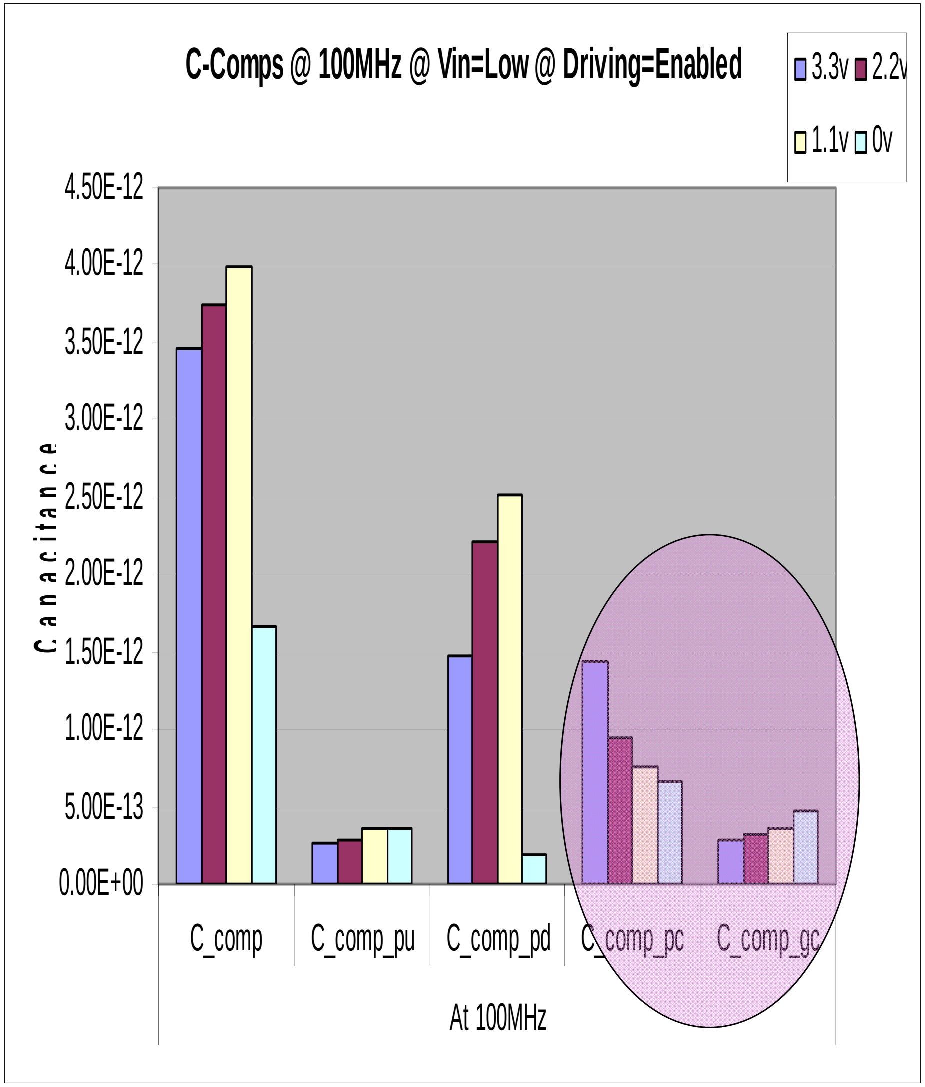
Pad DC = 1.1v, Input DC = High, Driving mode = Enabled

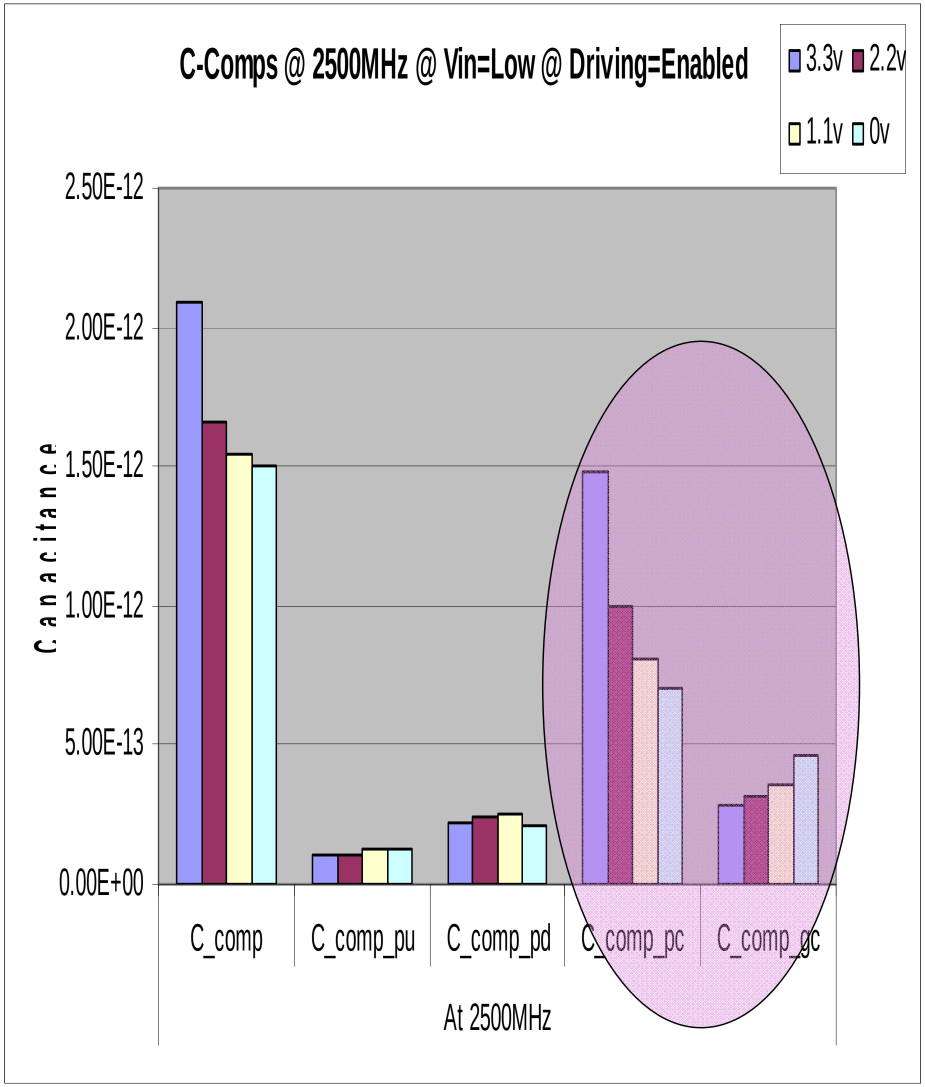


Pad DC = 0.0v, Input DC = High, Driving mode = Enabled

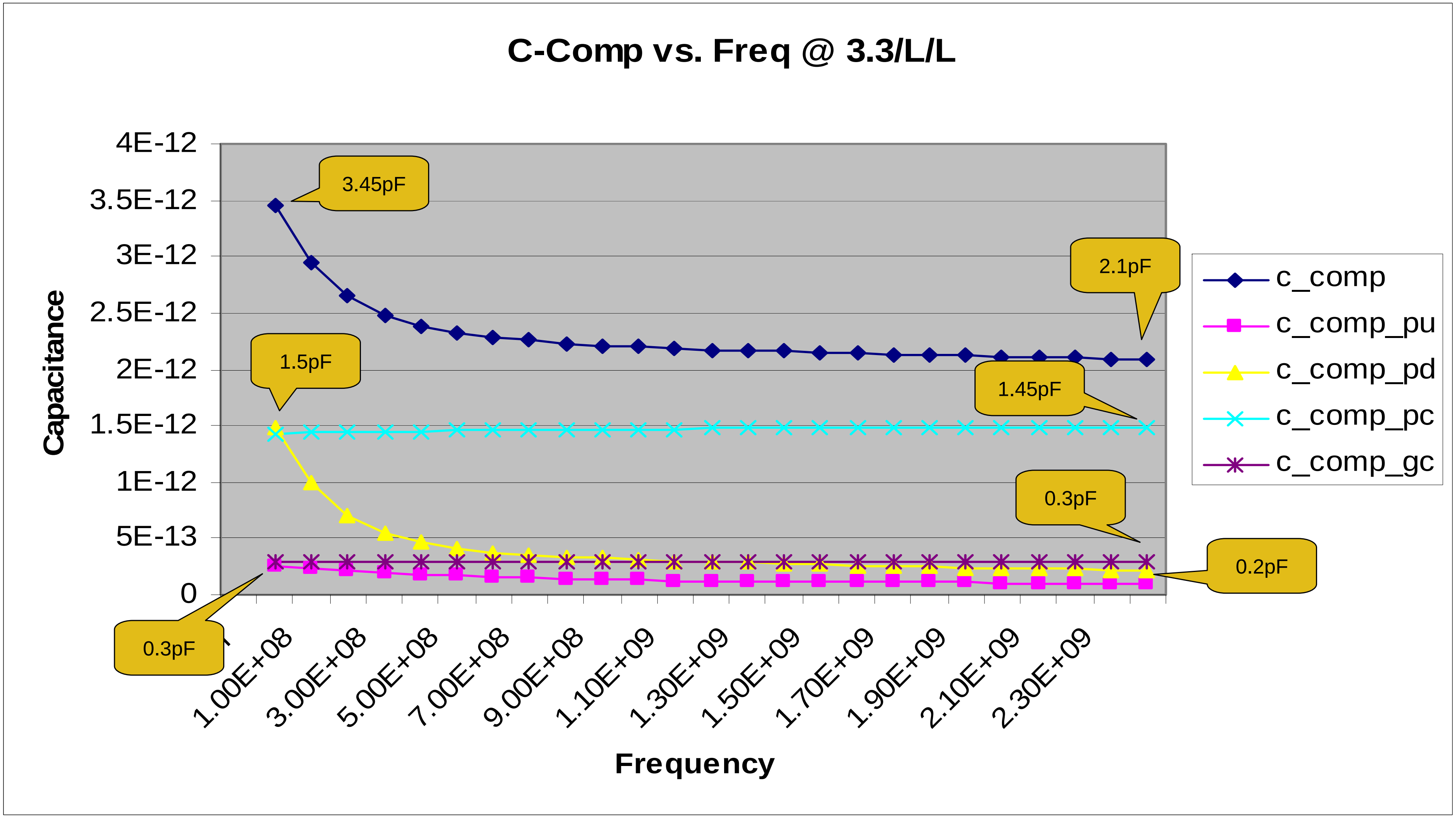


Driving mode with Vin=Low @ 100MHz and 2500 MHz

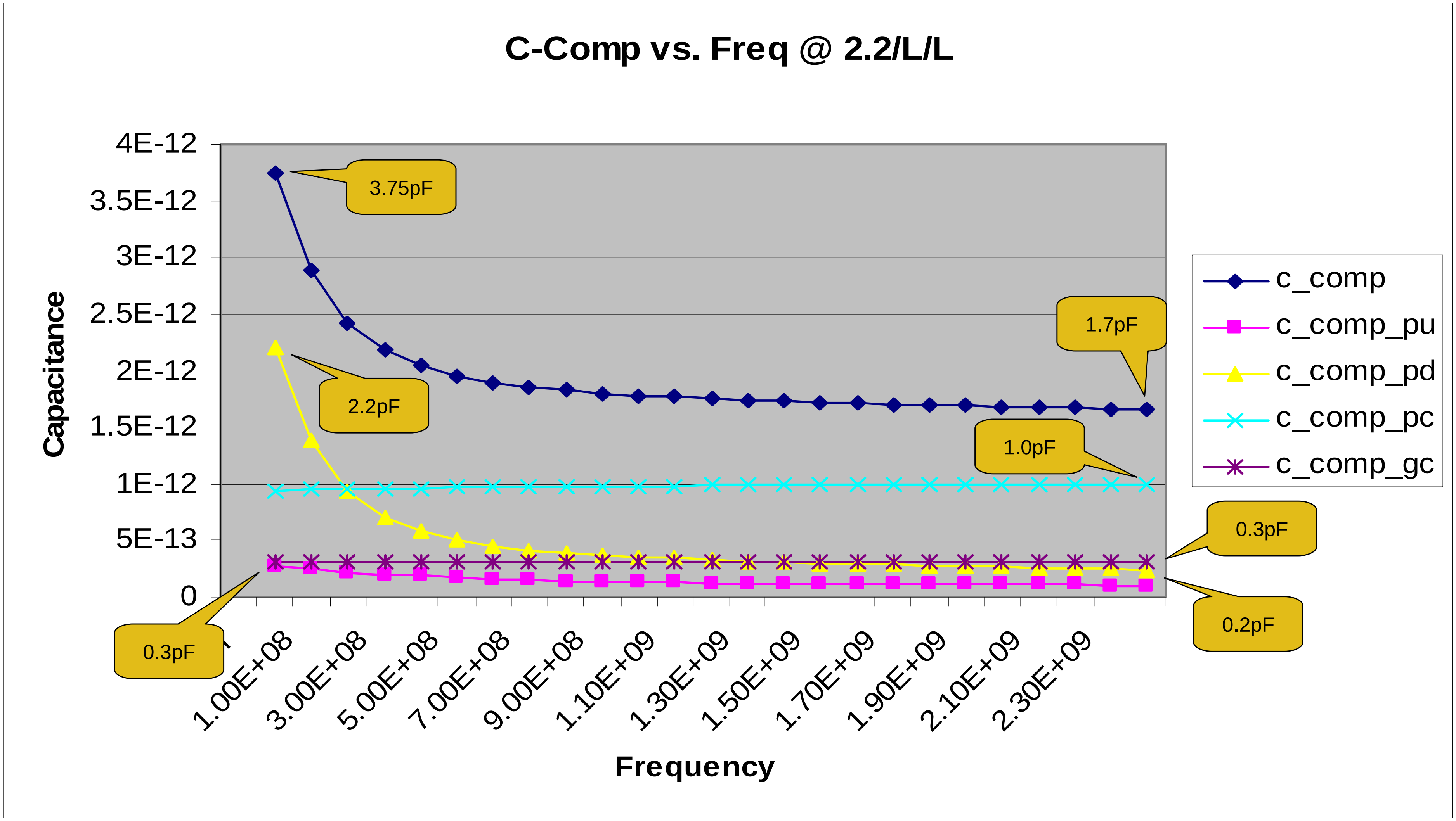




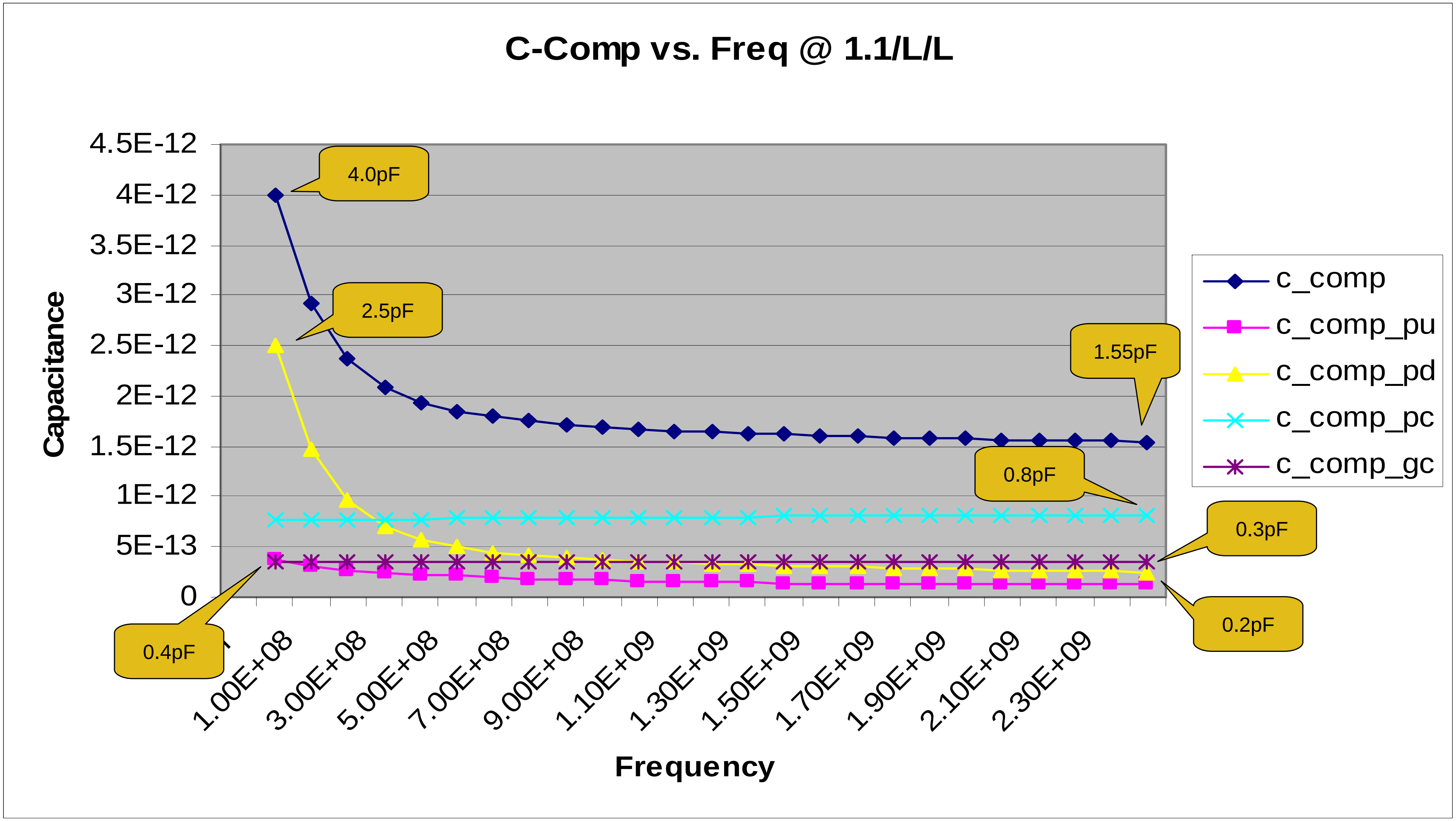
Pad DC = 3.3v, Input DC = Low, Driving mode = Enabled



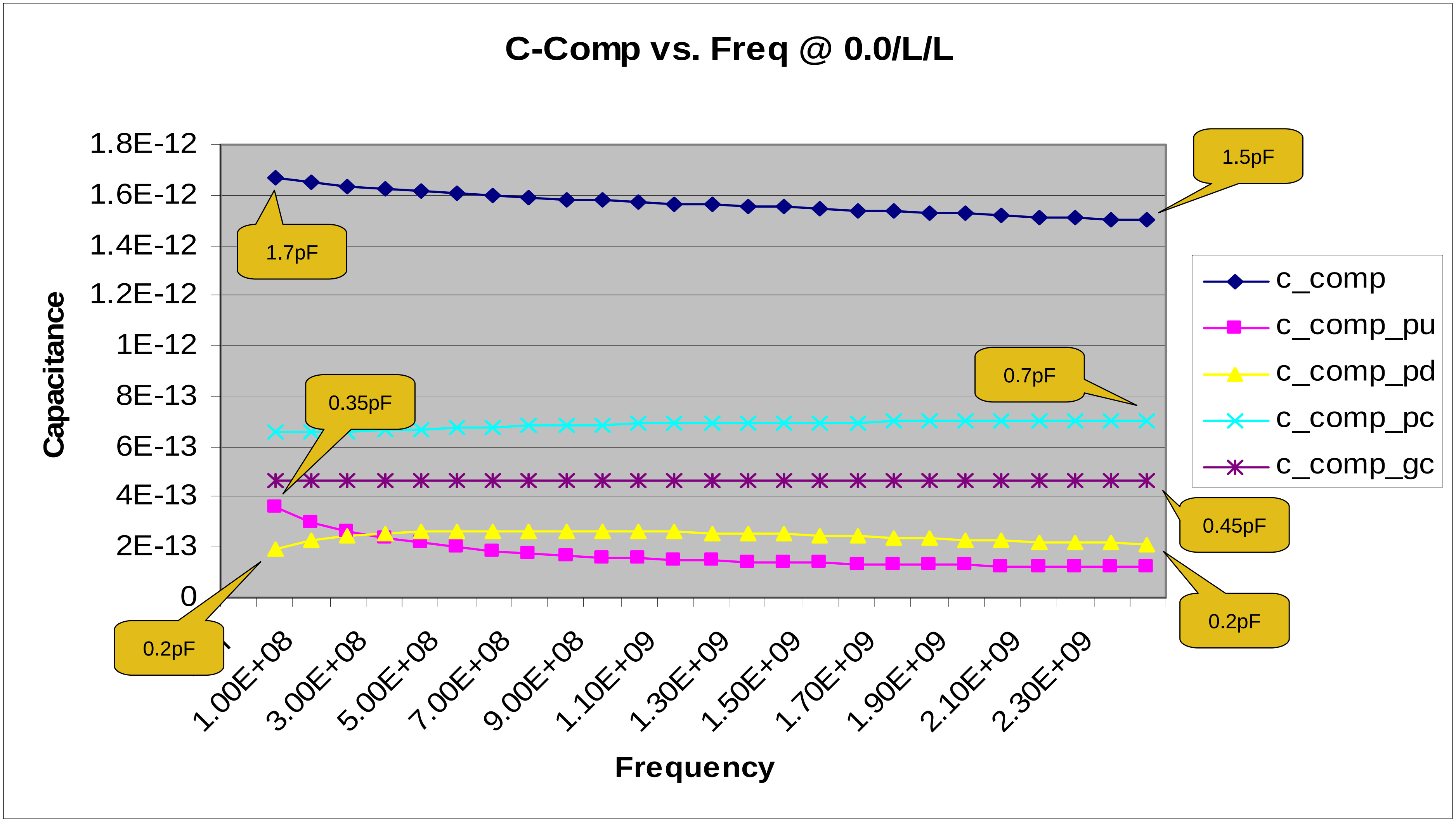
Pad DC = 2.2v, Input DC = Low, Driving mode = Enabled



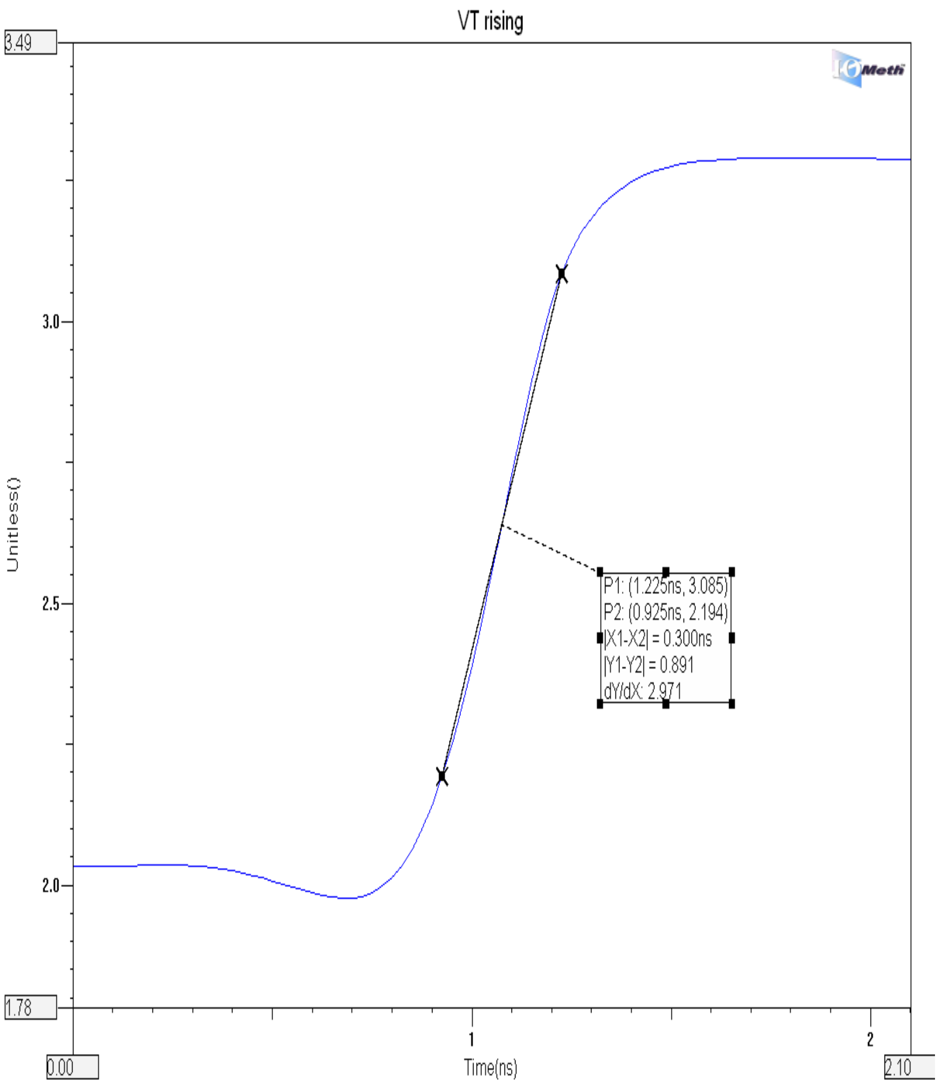
Pad DC = 1.1v, Input DC = Low, Driving mode = Enabled



Pad DC = 0.0v, Input DC = Low, Driving mode = Enabled



Define frequency and voltages



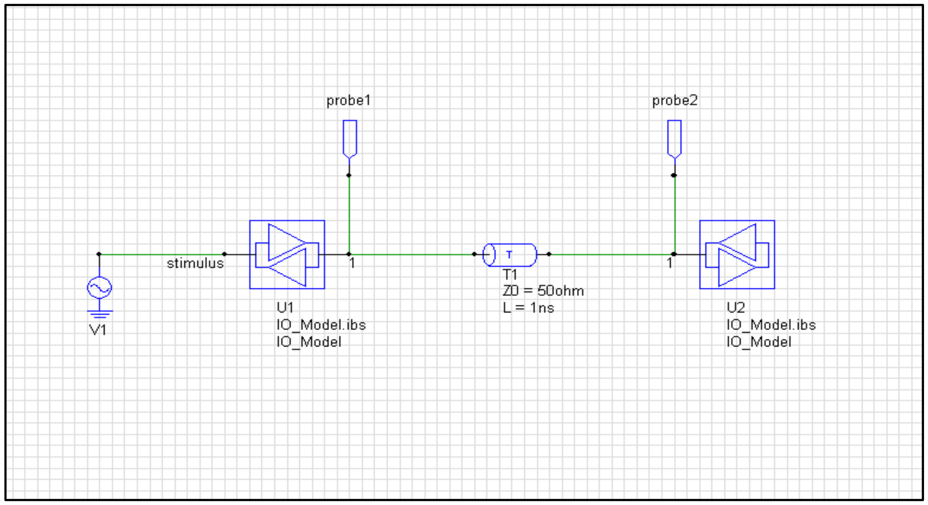
- Frequency
  - Use [Ramp] data as the reference
  - Buffer output frequency (Foutput)

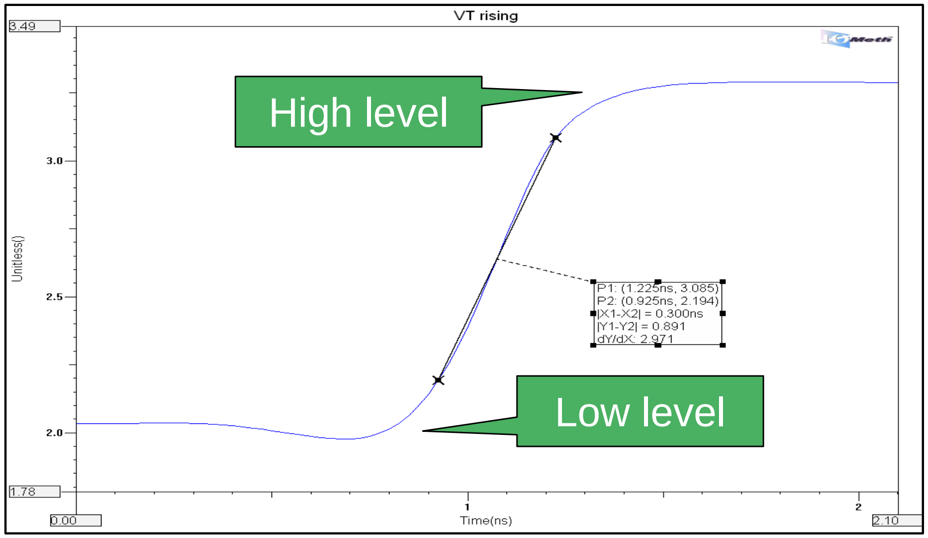
  Foutput = 1/(Rising_dt + Falling_dt)

  (for the most of high-speed buffer, the calculated output frequency point is in the settled region)
- Input buffer c-comp is not impacted much by output frequency changes. But suggest to use slightly higher frequency

Define frequency and voltages

- Voltages
  - Typical application settings
  - Operation voltage ranges
  - Using High and Low level DC settings
  - Averaging extracted C-comp values is a practical way for IBIS model
- Important to correctly define DC voltages





Conclusions

- C-comp (die capacitance) is important in high-speed buffers
- Understand your high-speed buffer die-capacitance arrangement is the first step for extractions
- Frequency domain with defined frequency and DC voltage settings is practical for accurate C-comp extractions
- IBIS specification improvements are required:
  - Separate driving and non-driving mode C-comp values for accurate high-speed simulations
  - Separate different DC level C-comp values for different applications

Thank You

谢谢

ありがとうございました

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