



Keeping Things Quiet: A New Methodology for Dynamic Comparator Noise Analysis

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EE Journal Chalk Talk Series
December 2016

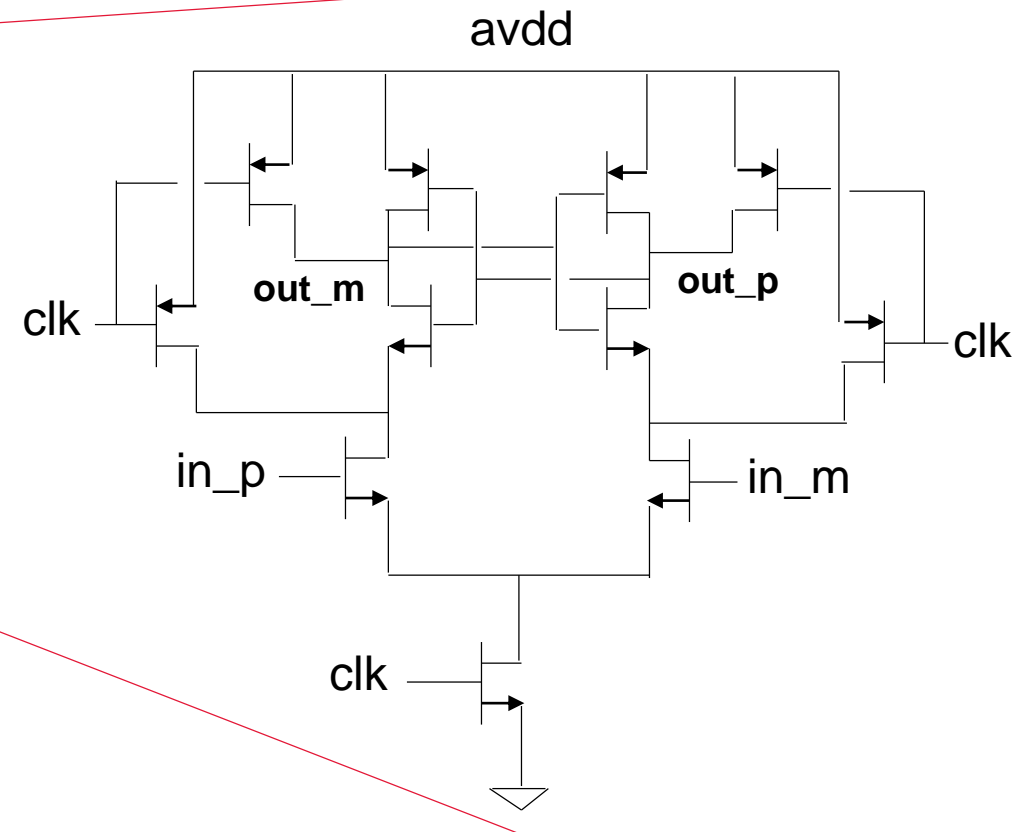
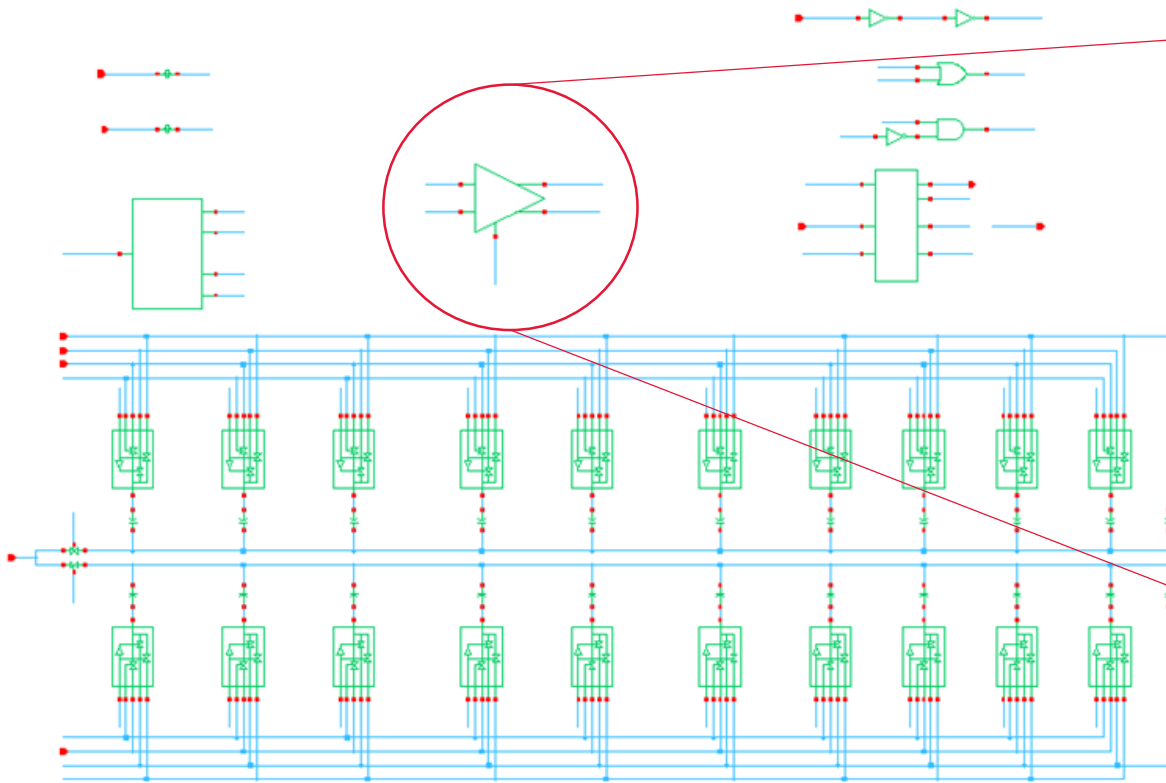
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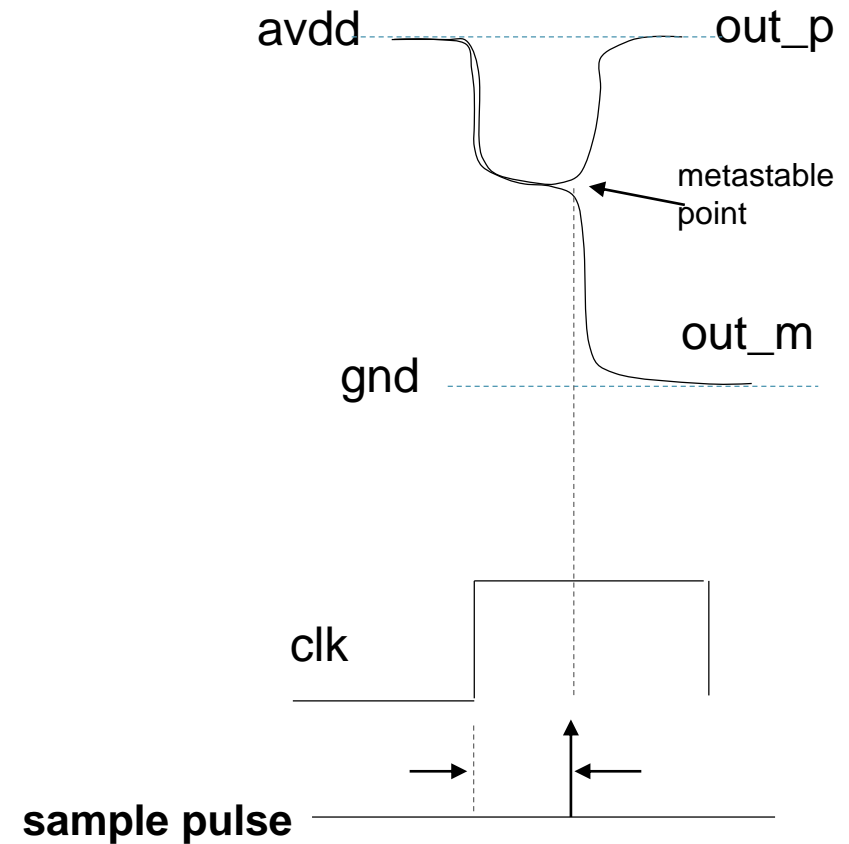
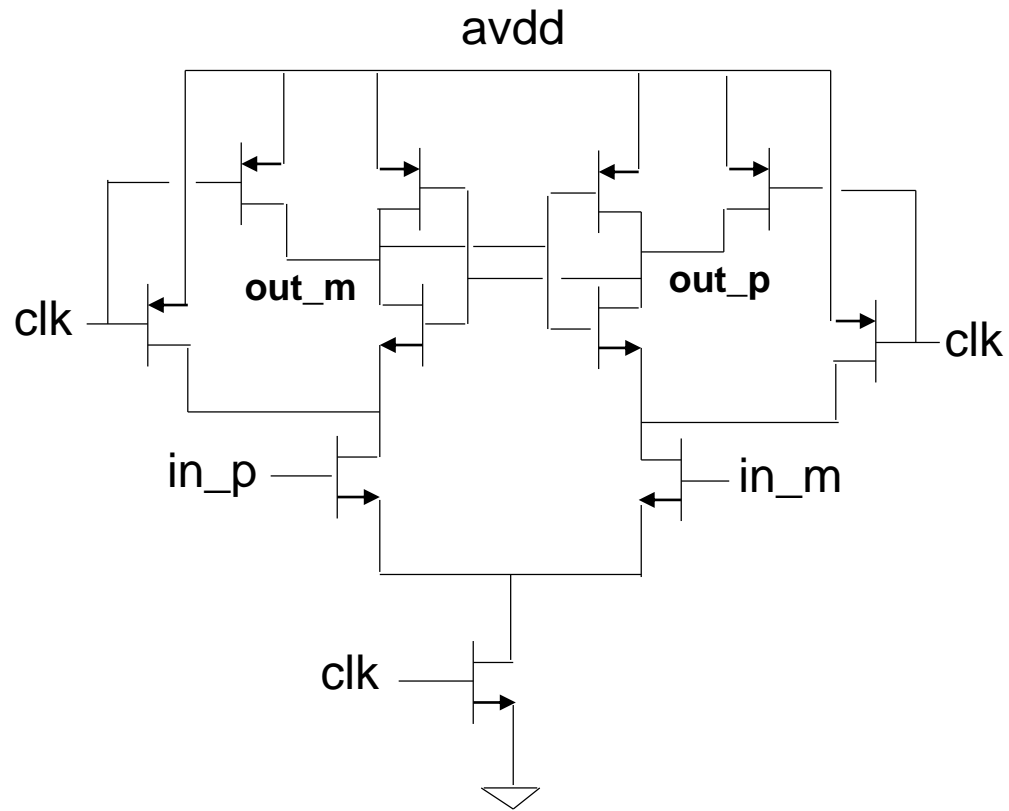
Design Challenge

Dynamic comparator is enabling technology



Dynamic Comparator

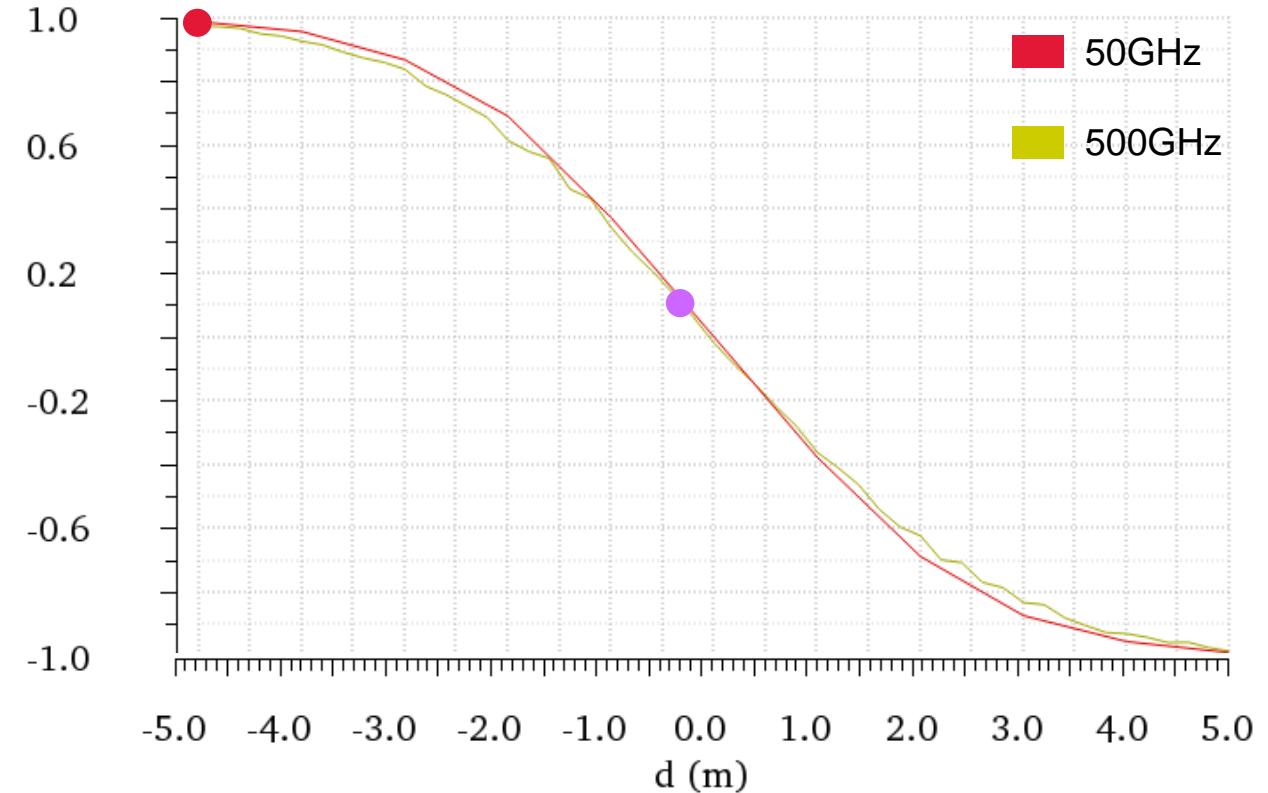
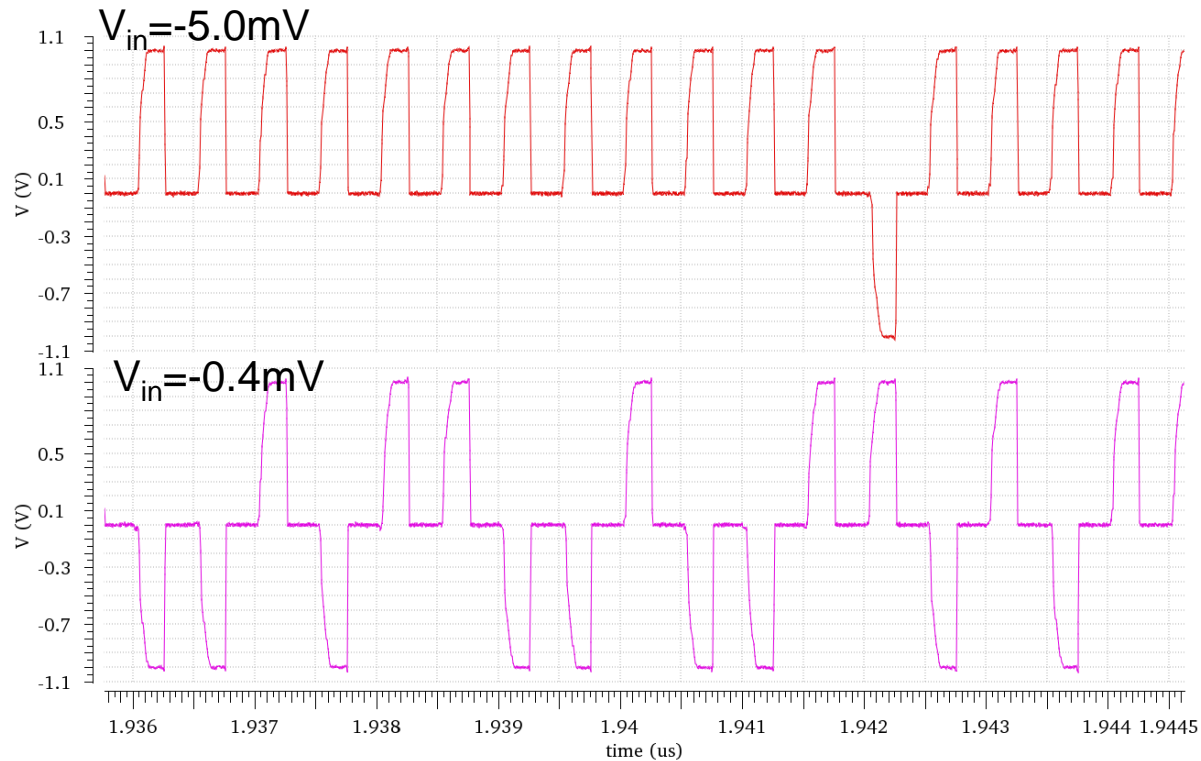
Using a Strong Arm latch as dynamic comparator



How do you calculate the noise of a circuit that doesn't have a DC operating point?

Calculating Dynamic Comparator Noise with Transient Noise

Using transient noise analysis



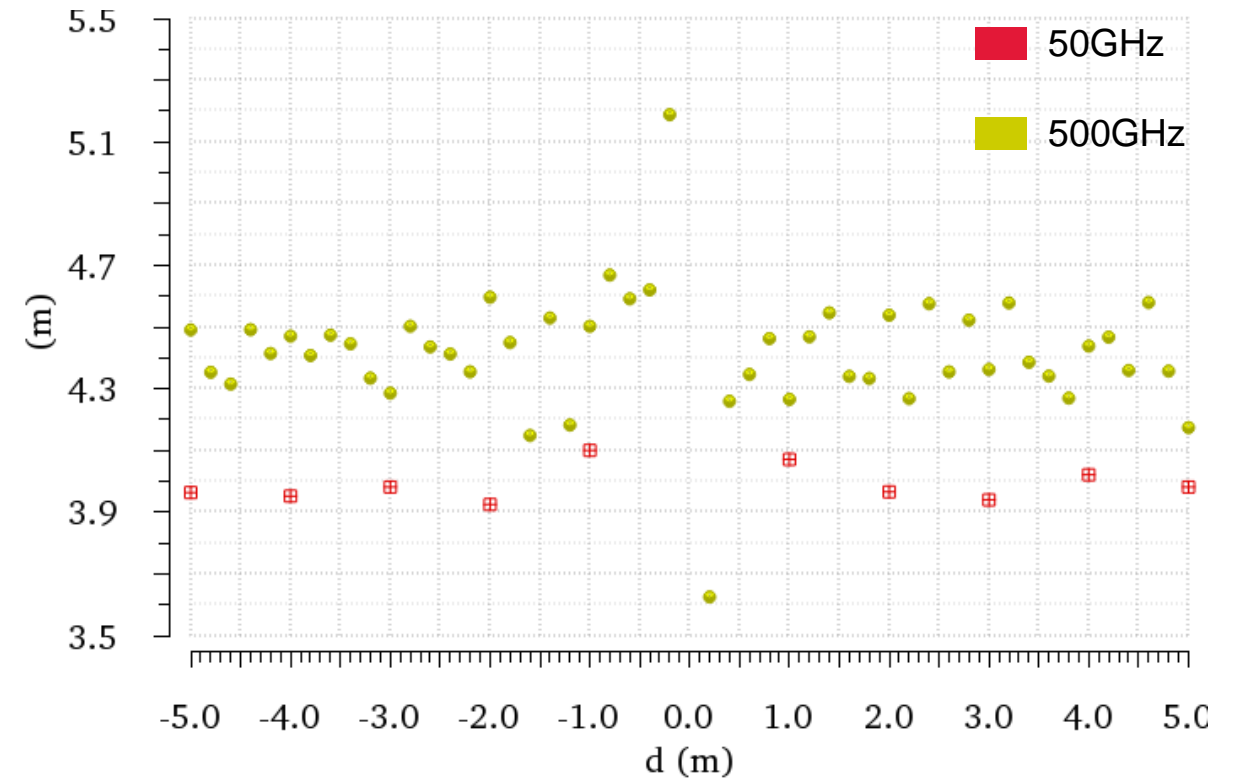
Total inferred noise is $\sim 4.4\text{mV}_{\text{rms}}$ for noise_{fmax} of 500GHz

Method from "A Low-Noise Self-Calibrating Dynamic Comparator for High-Speed ADCs", Masaya Miyahara, Yusuke Asada, Daehwa Paik and Akira Matsuzawa, A-SSCC 2008. IEEE Asian Solid-State Circuits Conference, 2008, pg. 269-272

Calculating Dynamic Comparator Noise with Transient Noise

Alternative transient noise method

- We have developed an alternative method of calculating the noise from the transient noise simulation results
 - Calculate the noise at each input voltage and average the results
 - Allows users to assess the accuracy of the simulation results
- The total inferred noise is $\sim 4.42\text{mV}_{\text{rms}}$ for noise_{max} of 500GHz



Calculating Dynamic Comparator Noise with Transient Noise

Transient noise analysis setup

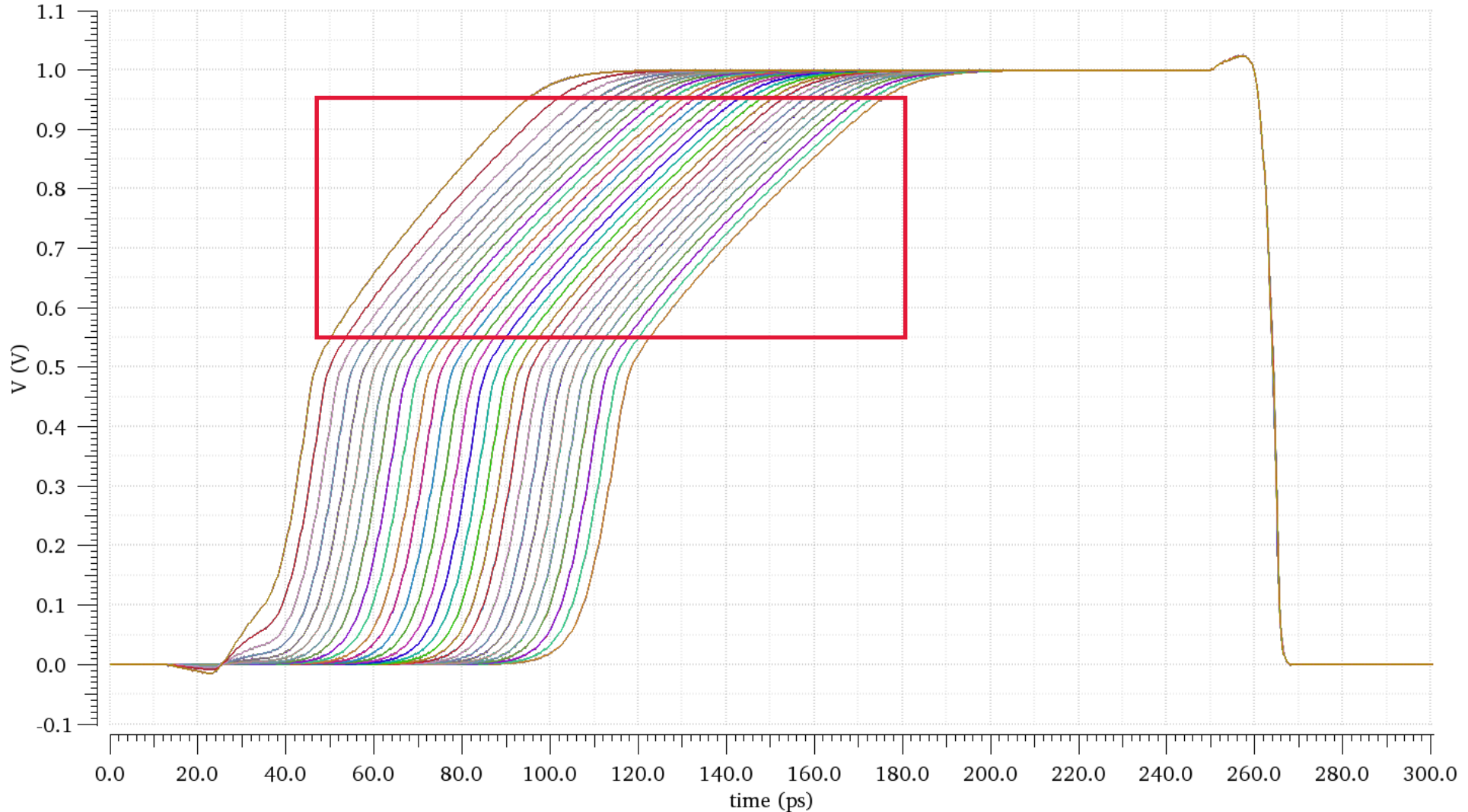
- Transient noise analysis setup

```
parameters d=0.0
sweep sweep param=d start=-5m step=0.2m stop=5m {
    tran tran start=0 stop=2u noisefmax=500G noisefmin=1 noiseseed=1+(d+5m)*10000
}
```

- Sweep offset voltage from -5mV to +5mV in 0.2mV steps
- Choose transient stop sufficiently long
 - Need multiple errors to accurately predict the probability
- Set the noisefmax to a high value
 - Consider the effective noise bandwidth of the system

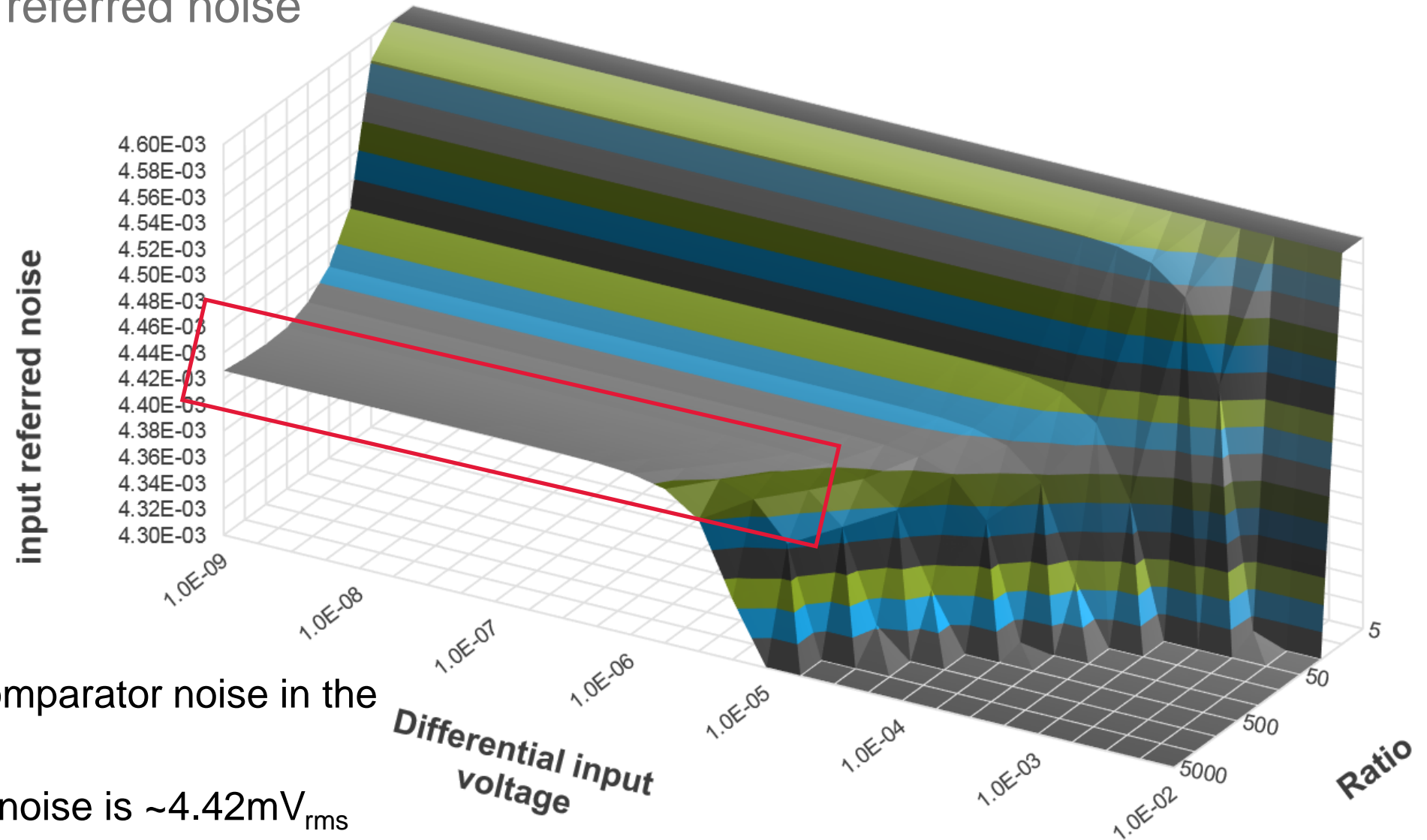
Calculating Dynamic Comparator Noise with PNOISE

Finding the linear operating region of a non-linear circuit



Calculating Dynamic Comparator Noise with PNOISE

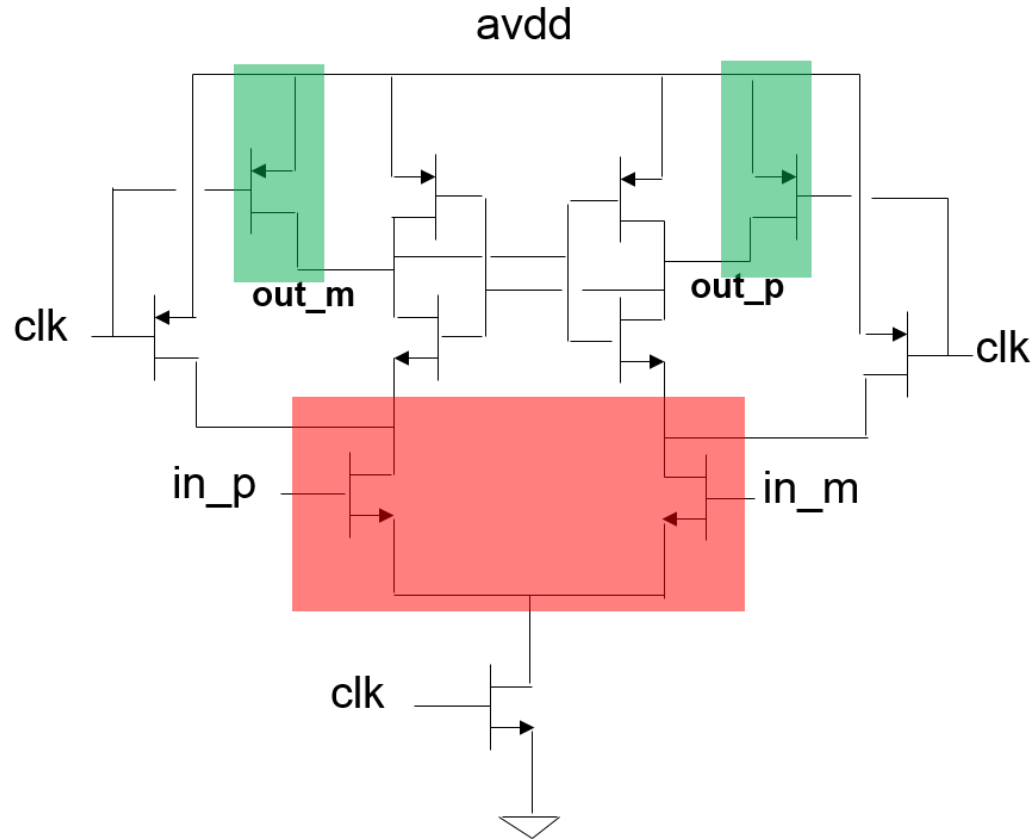
Calculated input referred noise



- Calculating the comparator noise in the “linear” region
- The total inferred noise is $\sim 4.42\text{mV}_{\text{rms}}$

Calculating Dynamic Comparator Noise with PNOISE

Noise summary from periodic noise analysis



IRN	sum	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
mV	mV ²											
4.423	19.56	0.00	7.63	7.63	0.19	0.19	0.58	0.58	1.21	1.21	0.18	0.18

- A noise summary can be generated from the periodic noise analysis results
 - Allows designers to identify noise sources and trade off noise and performance
- The transfer function from noise analysis can be used to calculate sampling bandwidth and sampling aperture

Method from ADC Verification Workshop,
http://support.cadence.com/wps/PA_DocumentViewer/wp/ProductInformation/Custom_IC_Design/ApplicationPackages/download/licenseRAK.htm?download=ADC_verification_WS_v2.0_20140827_pdf.html

Calculating Dynamic Comparator Noise with PNOISE

PSS/PNOISE analysis setup

- PSS/pnoise analysis setup

```
parameters d=0.1u gain=10000
sweep sweep param=ratio values=[5 10 20 50 100 200 500 1k 2k 5k] {
  sweep1 sweep param=d start=0.001u stop=10m dec=4 {
    pss pss period=0.5n harms=100
    pnoise (om op) pnoise start=1 stop=1G noisetype=pmjitter \
      crossingdirection=rise thresholdvalue=(d*ratio) \
      pnoisemethod=fullspectrum
  }
}
```

- Parameters:

- Input differential input voltage, d, and ratio

- Use the full spectrum noise analysis option

- Set the maximum frequency of the noise sweep to the Nyquist rate

- The stop frequency is $\frac{1}{2}$ the sampling clock frequency

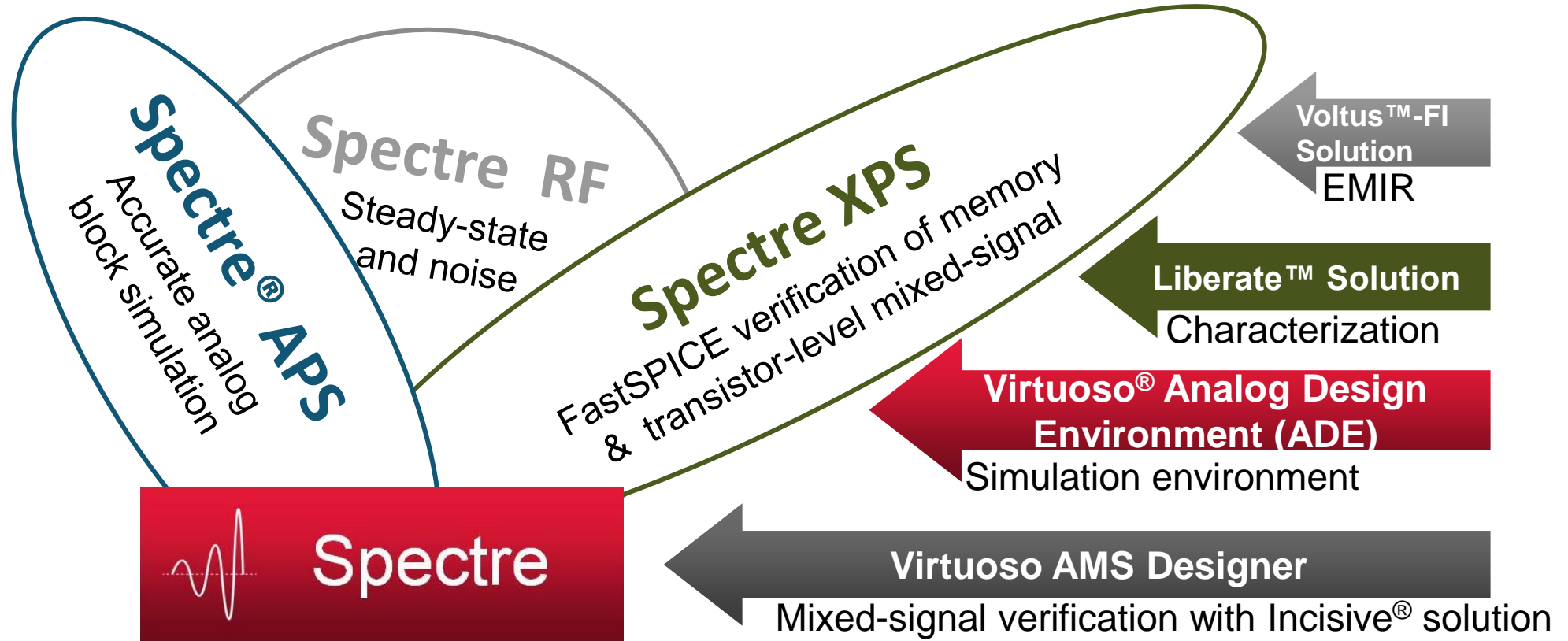
Dynamic Comparator Noise Analysis

Summary

- Both transient noise and periodic noise can be used to simulate dynamic comparator noise
 - Both methods produce the same results
- Transient noise analysis
 - Can be challenging when trying to get high accuracy results
 - Does not provide designers insight into the noise sources
 - Can be used for both dynamic comparator and ADC noise analysis
- Periodic noise analysis
 - Provides designers insight into noise sources
 - Can't be used for ADC noise analysis

Spectre simulation platform

Complete solution for analog, mixed-signal and memory verification



- Comprehensive analysis ⇒ cover all simulation needs
- Common infrastructure ⇒ ensures consistent results
- MMSIM flexible license ⇒ reduces cost of ownership

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