Feedforward Active Substrate Noise Cancelling Technique using Power Supply di/dt Detector

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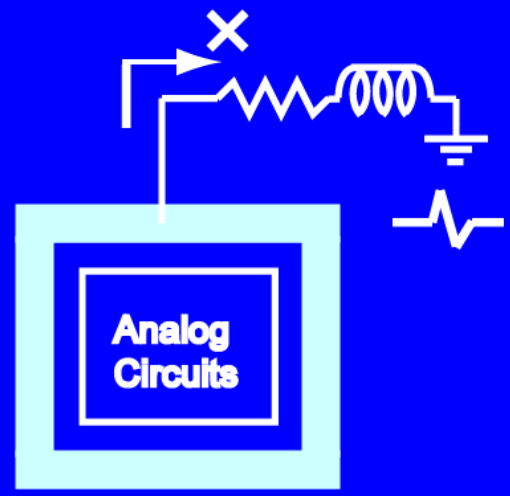
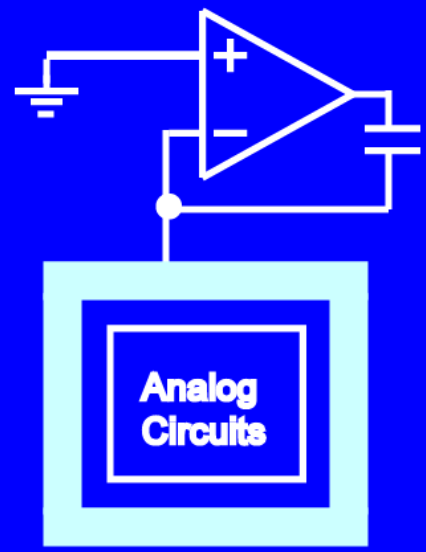
Background -- Substrate Noise

- Guard ring
  - Parasitic inductance prevents the absorption
  - Noisy ground could increase the substrate noise
- Self-detect and dynamic
  - Feedback system
    → low bandwidth, unstable



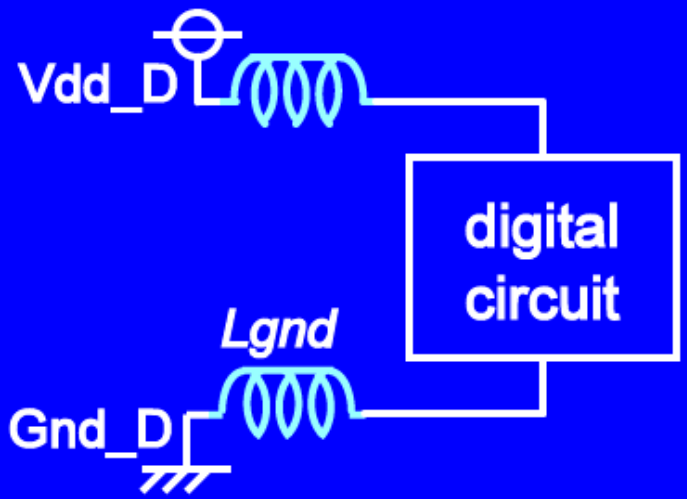


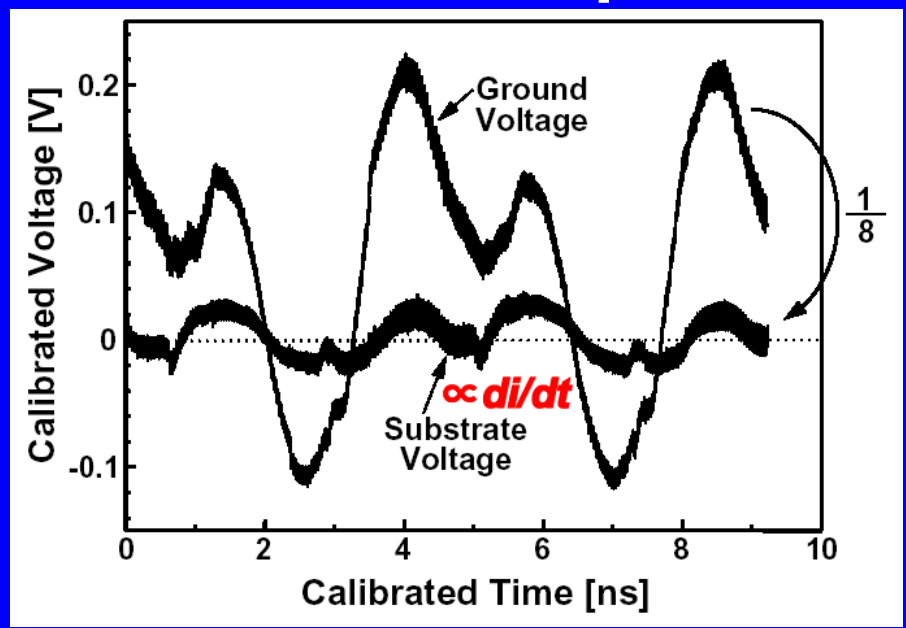
Contents

- Feedforward active substrate noise cancelling technique using a di/dt detector
- Substrate noise probing
- Measured substrate noise waveforms with the active cancelling ON/OFF
- Summary

Substrate Noise ∝ di/dt

- Gnd noise is proportional to di/dt
  - Inductance is dominant in Zgnd
- Gnd/substrate noise have the same shape
  - Gnd and substrate is tied with low impedance

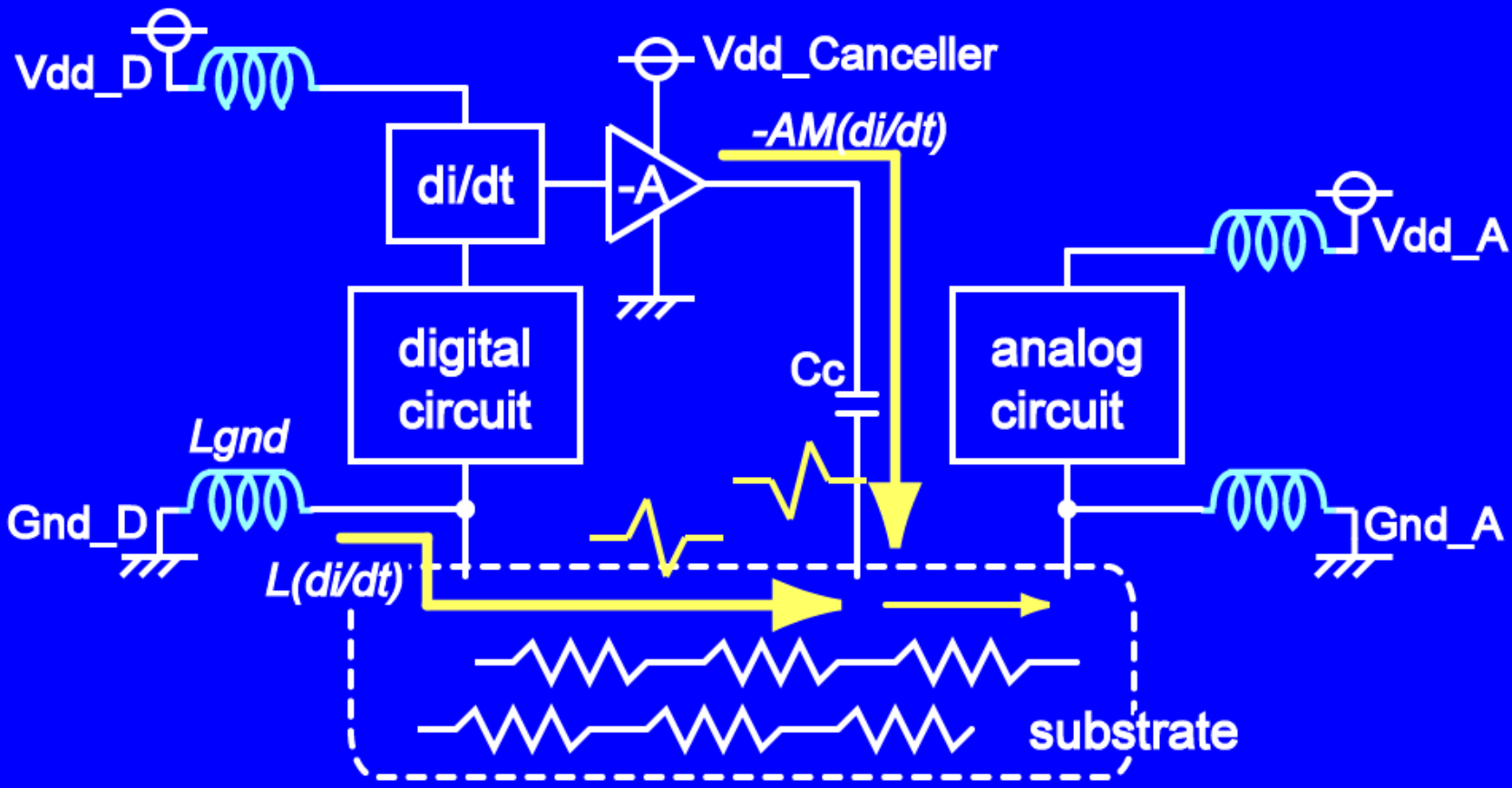




M. Takamiya, et al. ISSCC, Feb., 2003

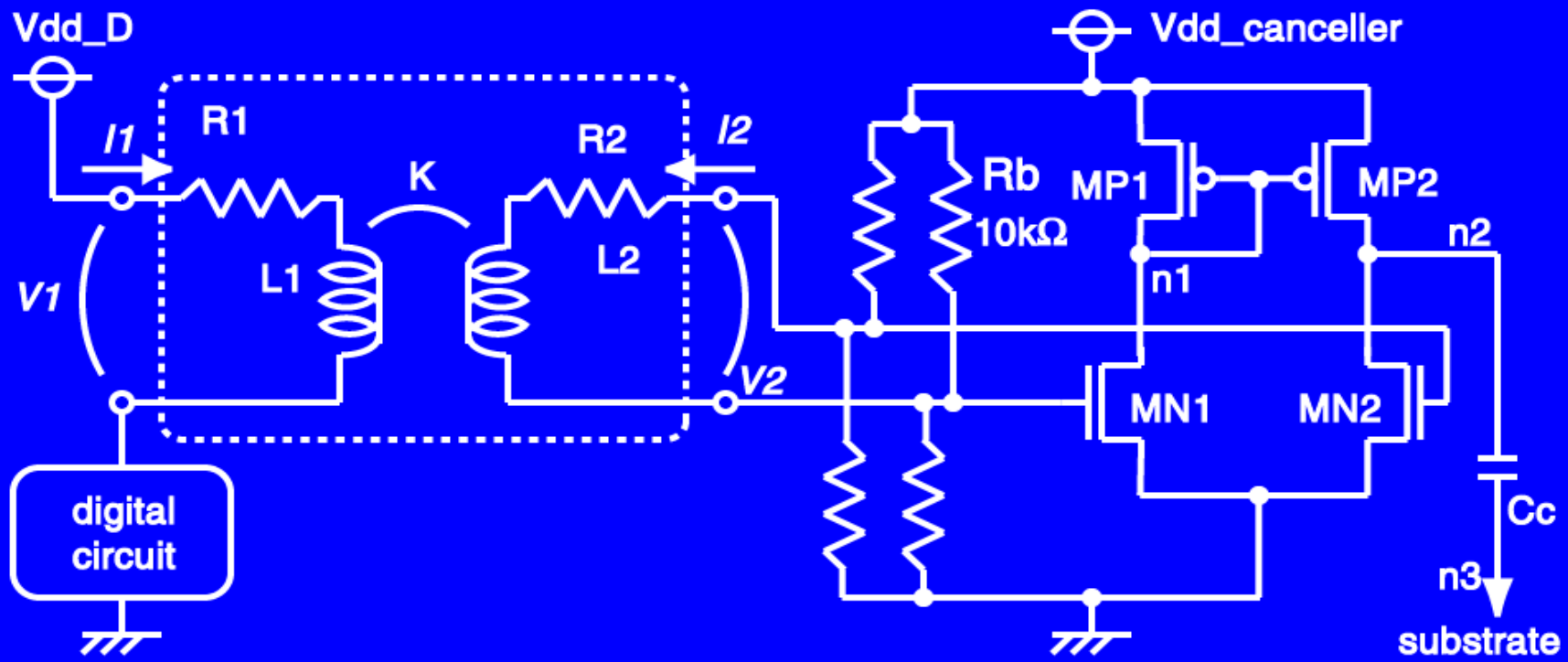
F.F. Active Noise Cancelling

- di/dt detector makes anti-phase signal
  - no feedback → stable, high bandwidth

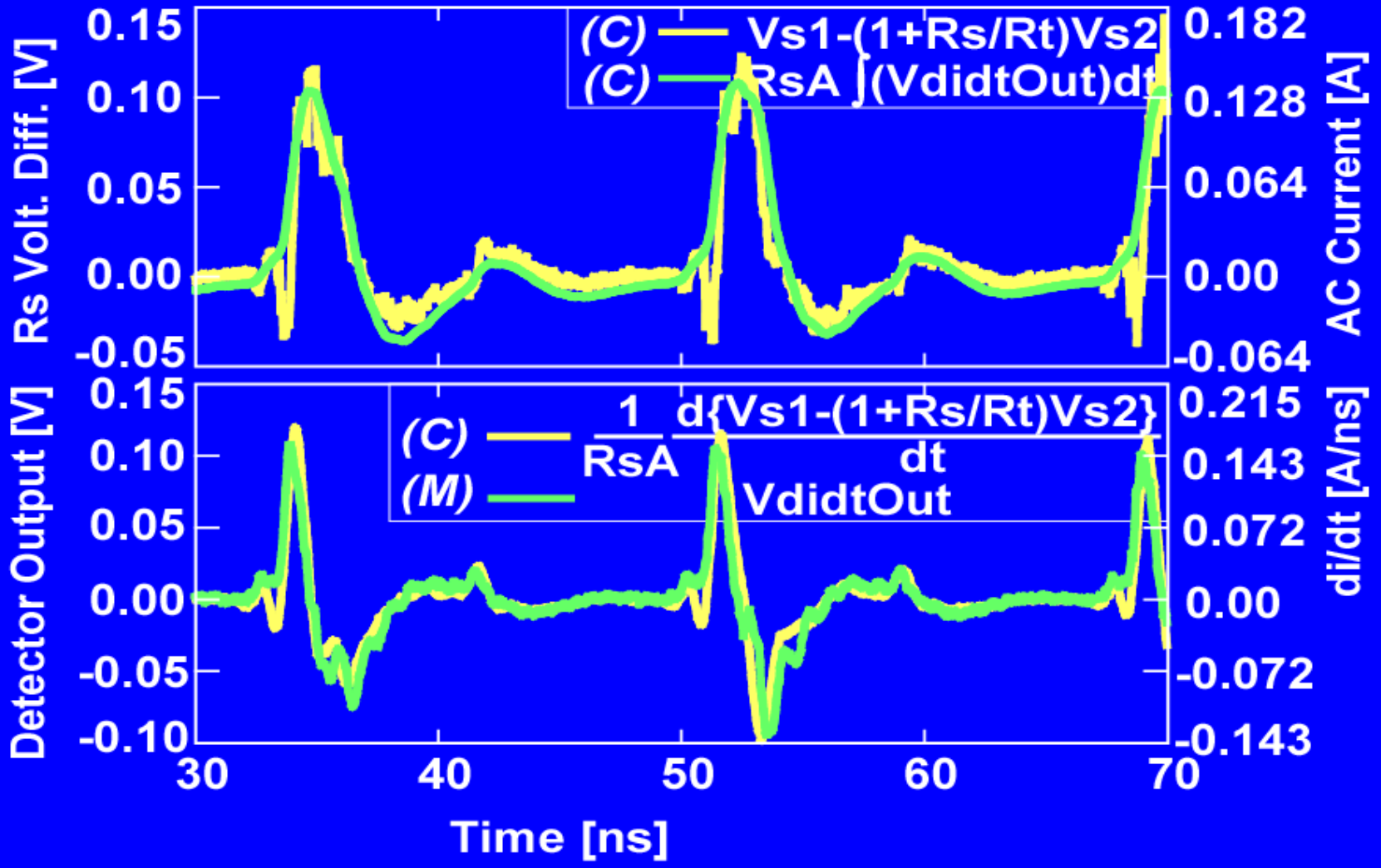


di/dt Detector / Noise Canceller

- Anti-phase signal to di/dt is generated
- Cc is large enough to be considered as short for over 100MHz AC signals



di/dt Waveforms



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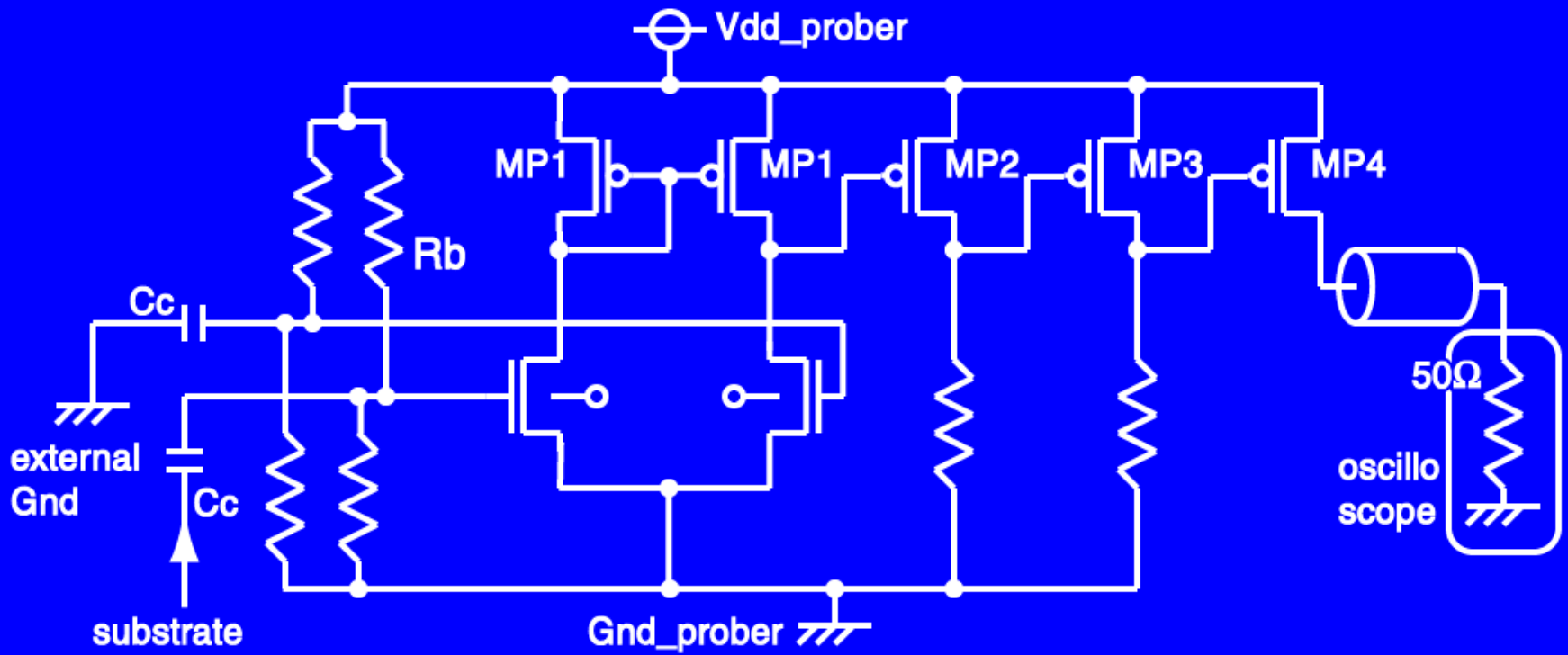
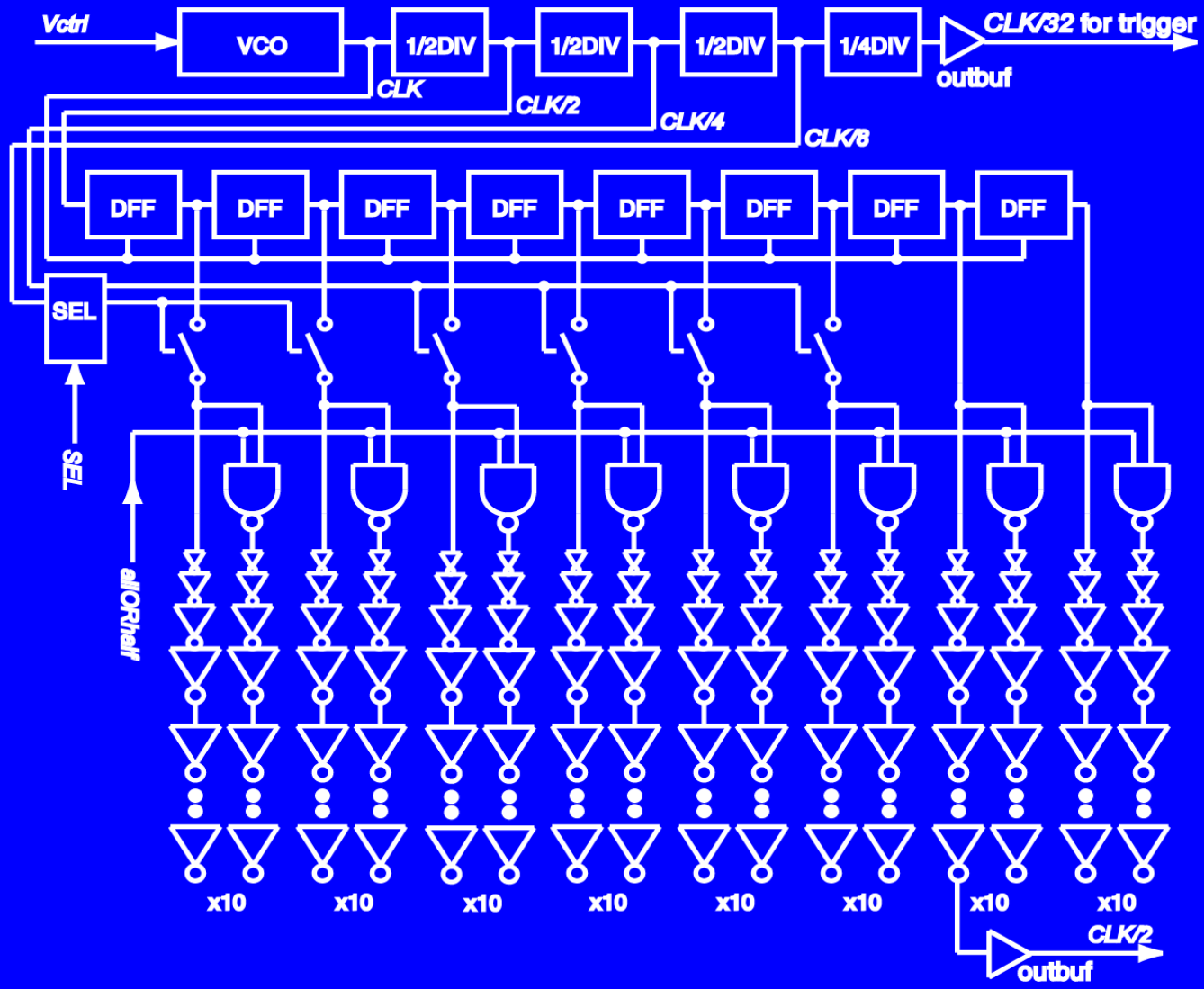
Noise Probing for Verification

- Differential amplifier connected to the substrate and the external Gnd
- No body contact for NMOS

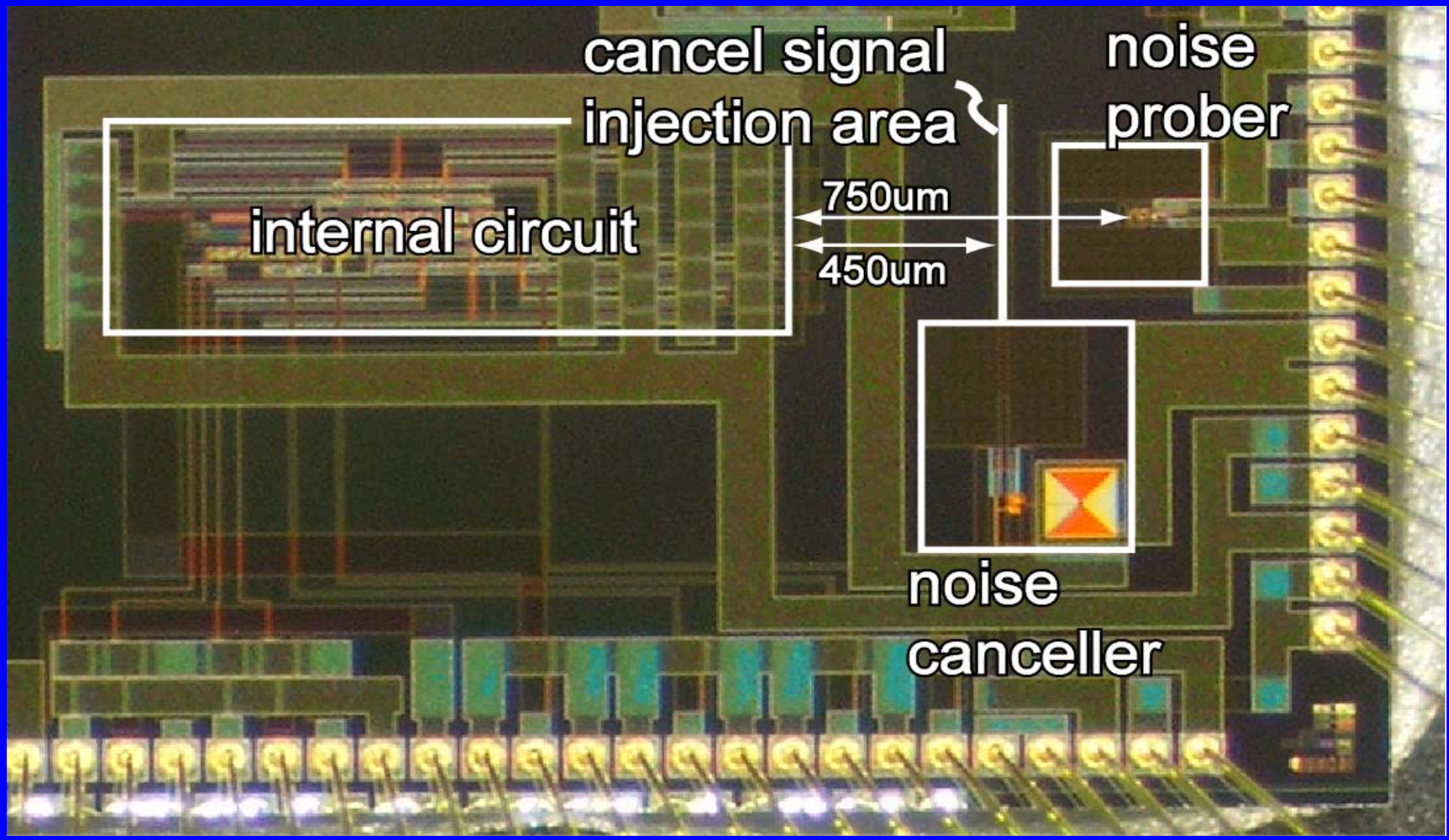


Internal Circuit as Noise Source



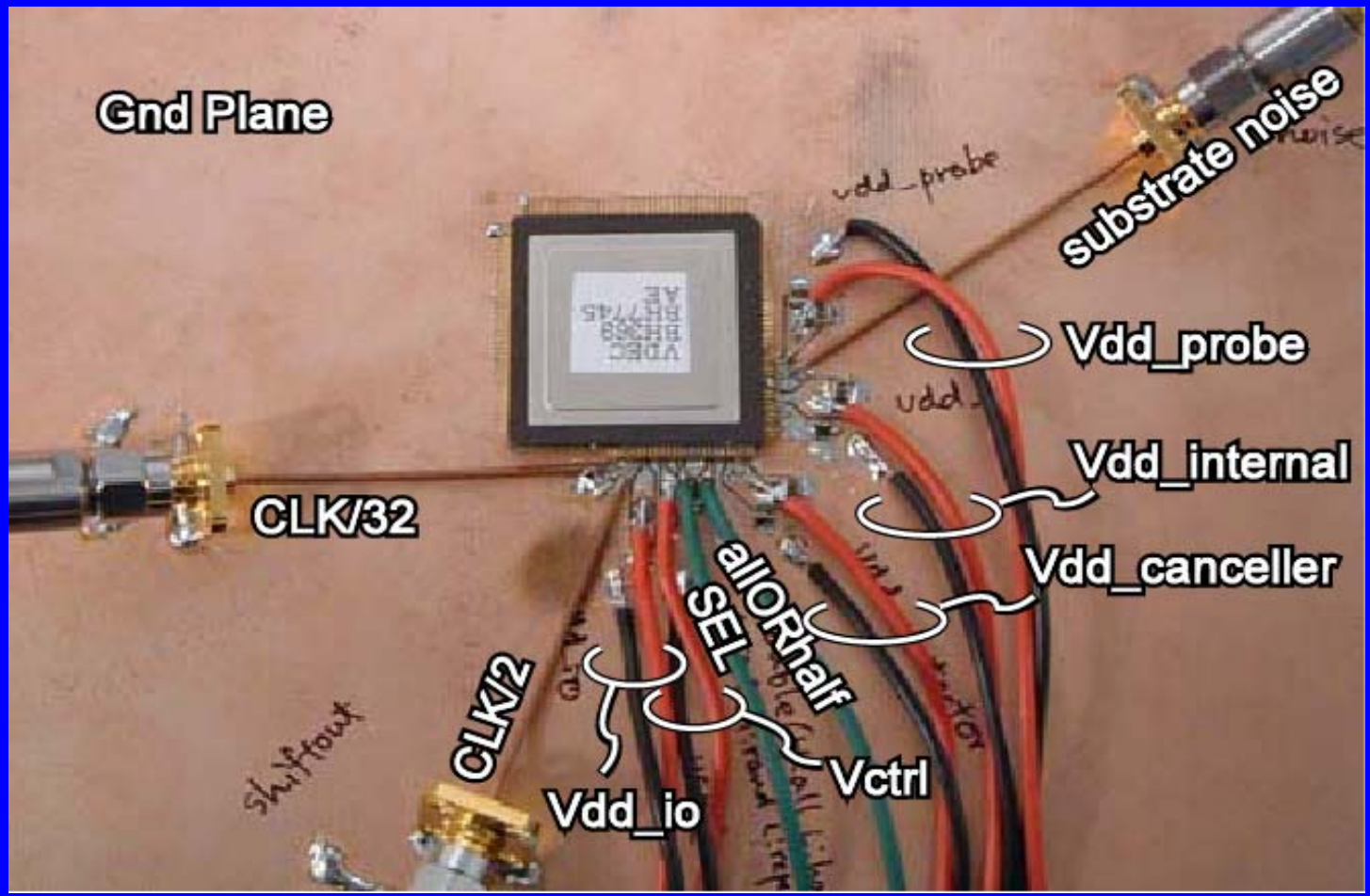
Chip Photograph & Floor Plan

- 0.35um 3ML 2P CMOS (3.0mm x 1.8mm)

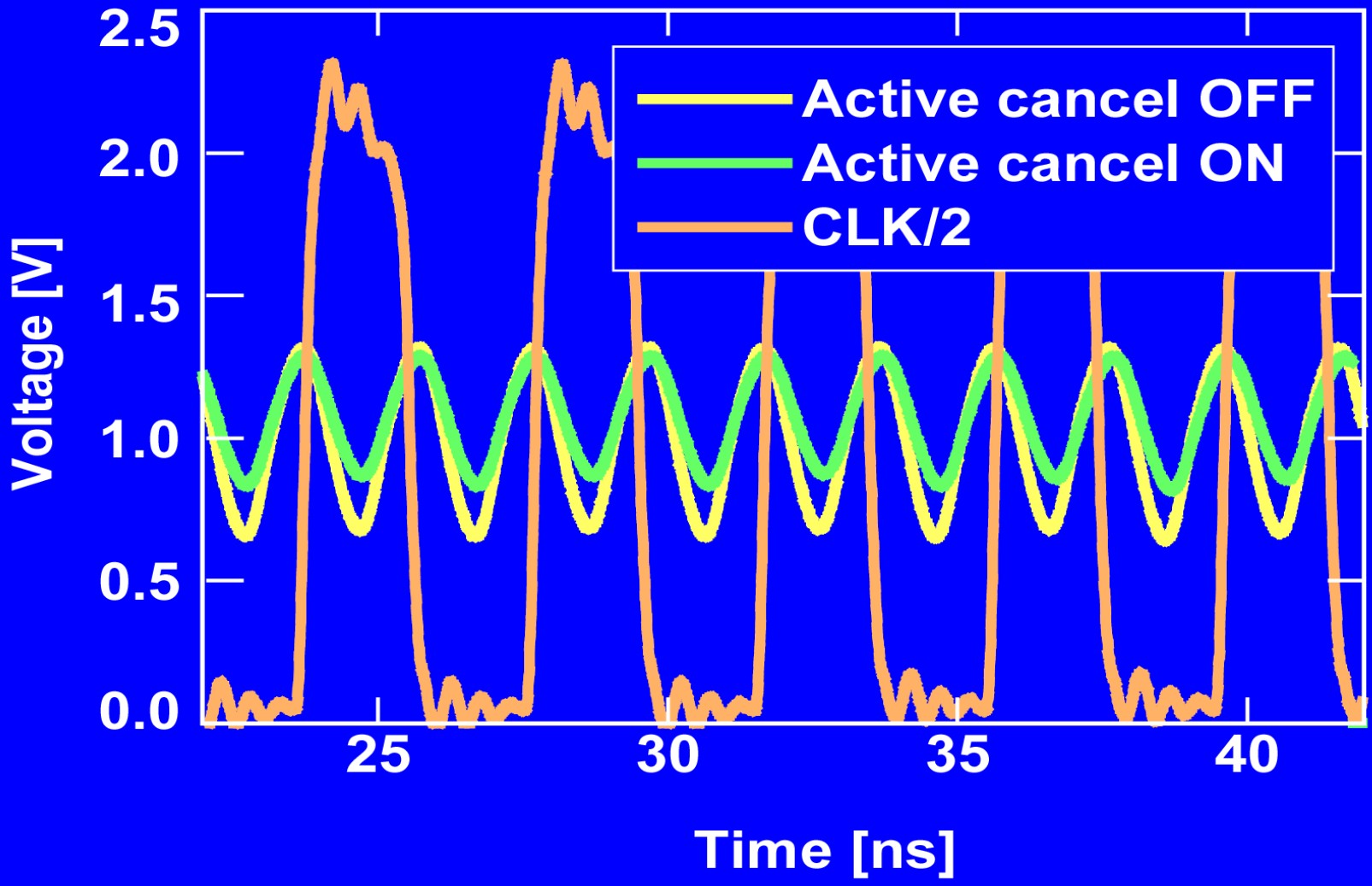


Measurement Setup

- The test chip is mounted on a Cu board

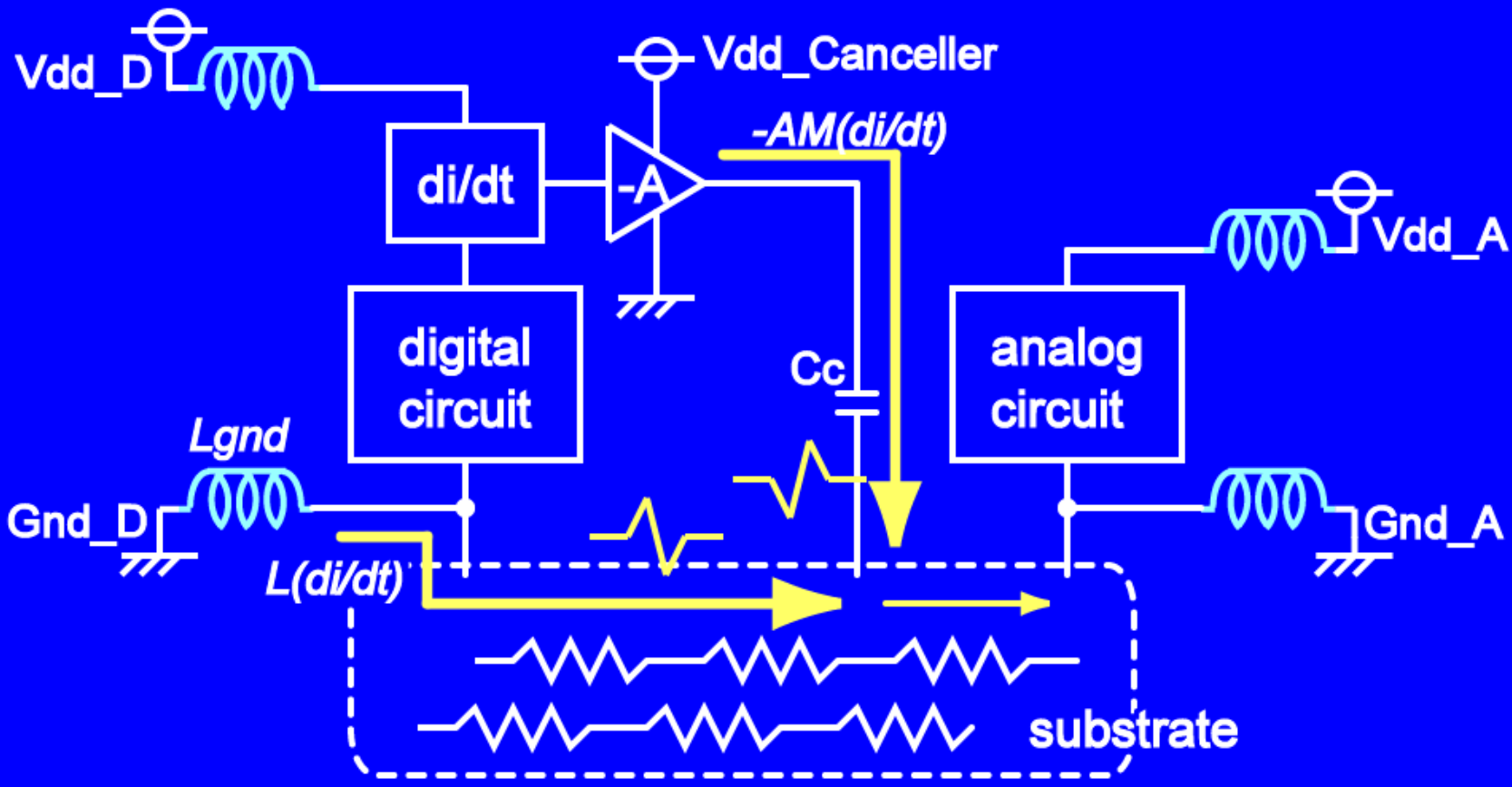


Waveform (Repeat@500MHz)

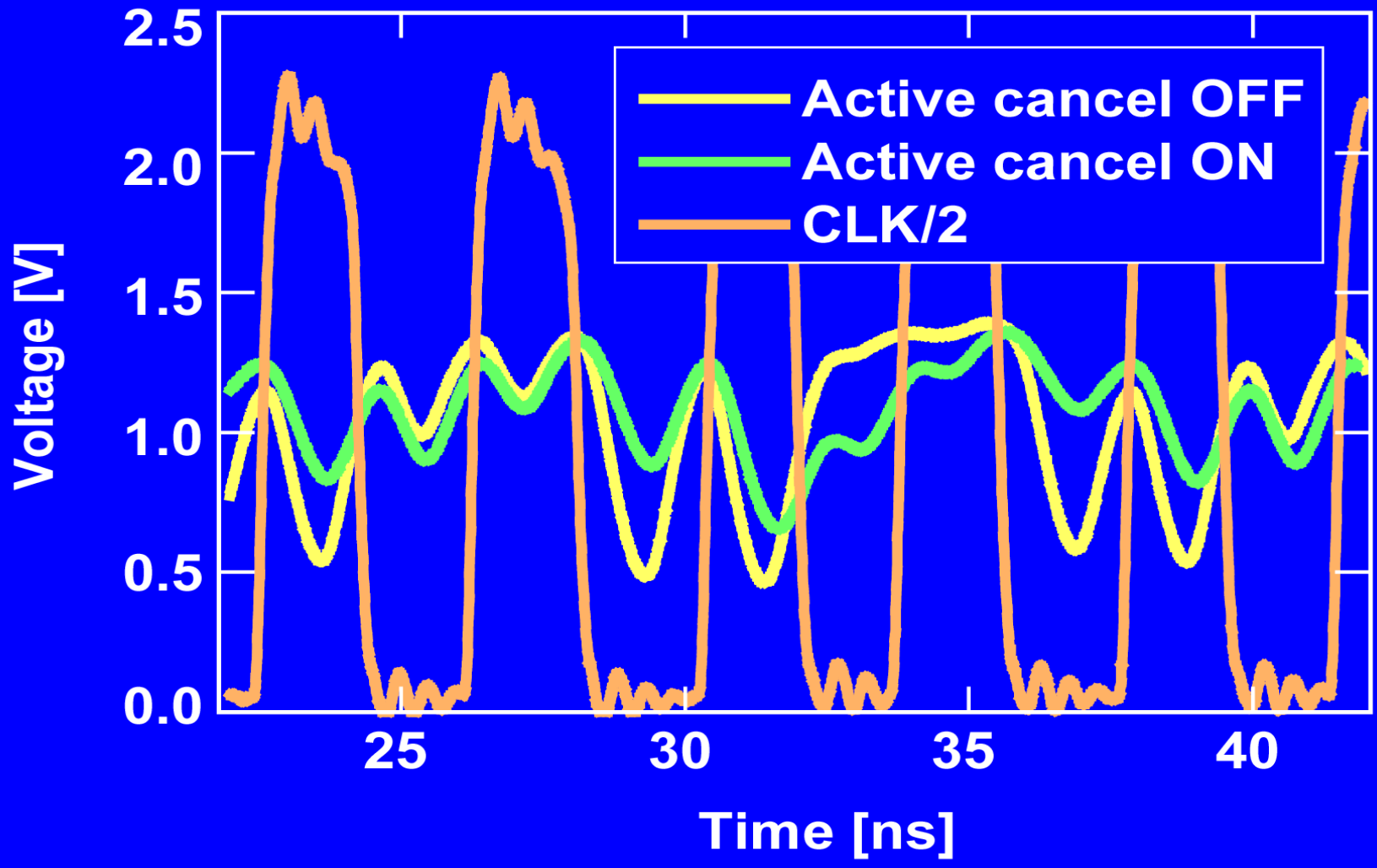


Active Cancel ON/OFF

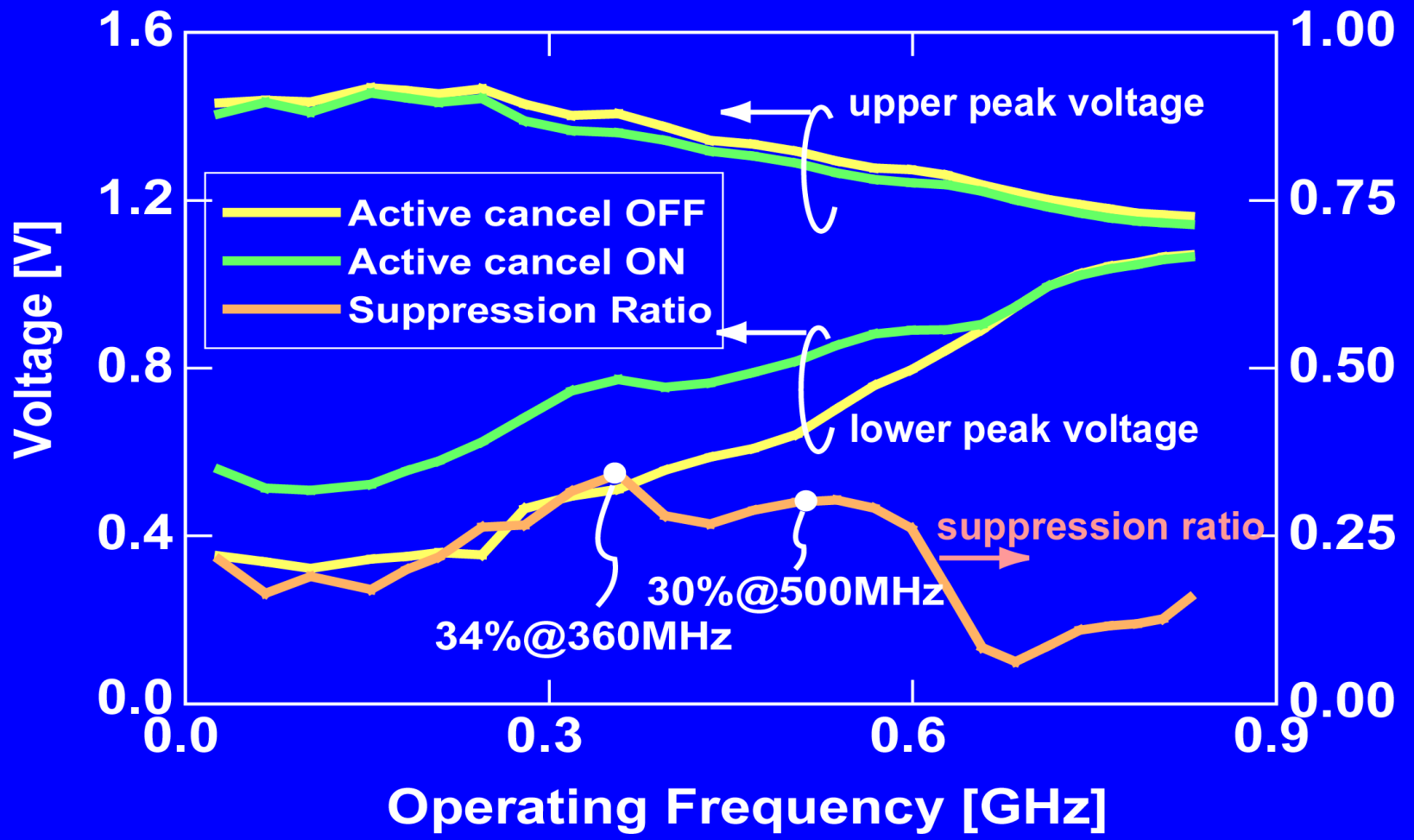
- ON, OFF means Vdd_Canceller=3.3V, 0V



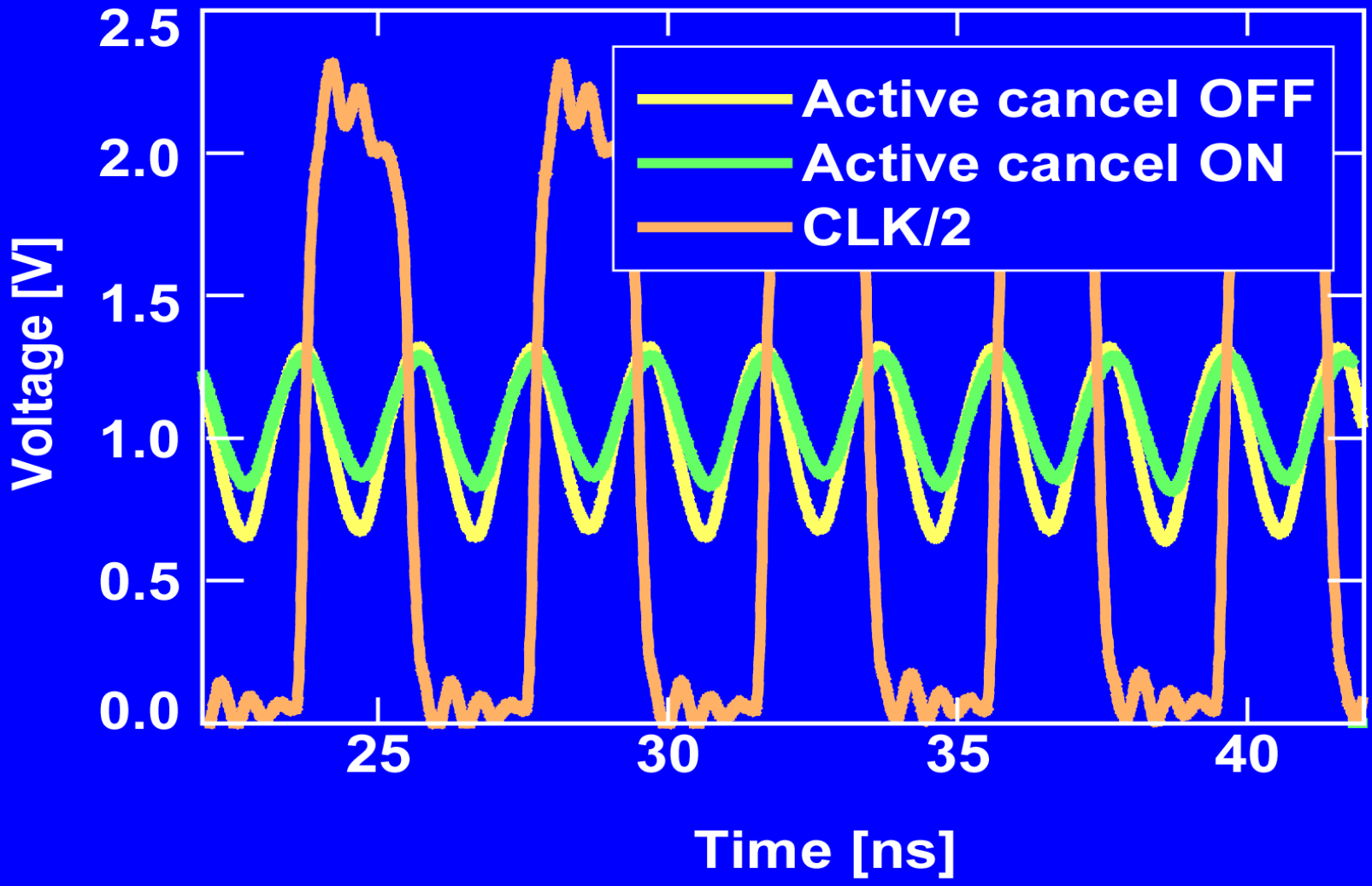
Waveform (Random@500MHz)



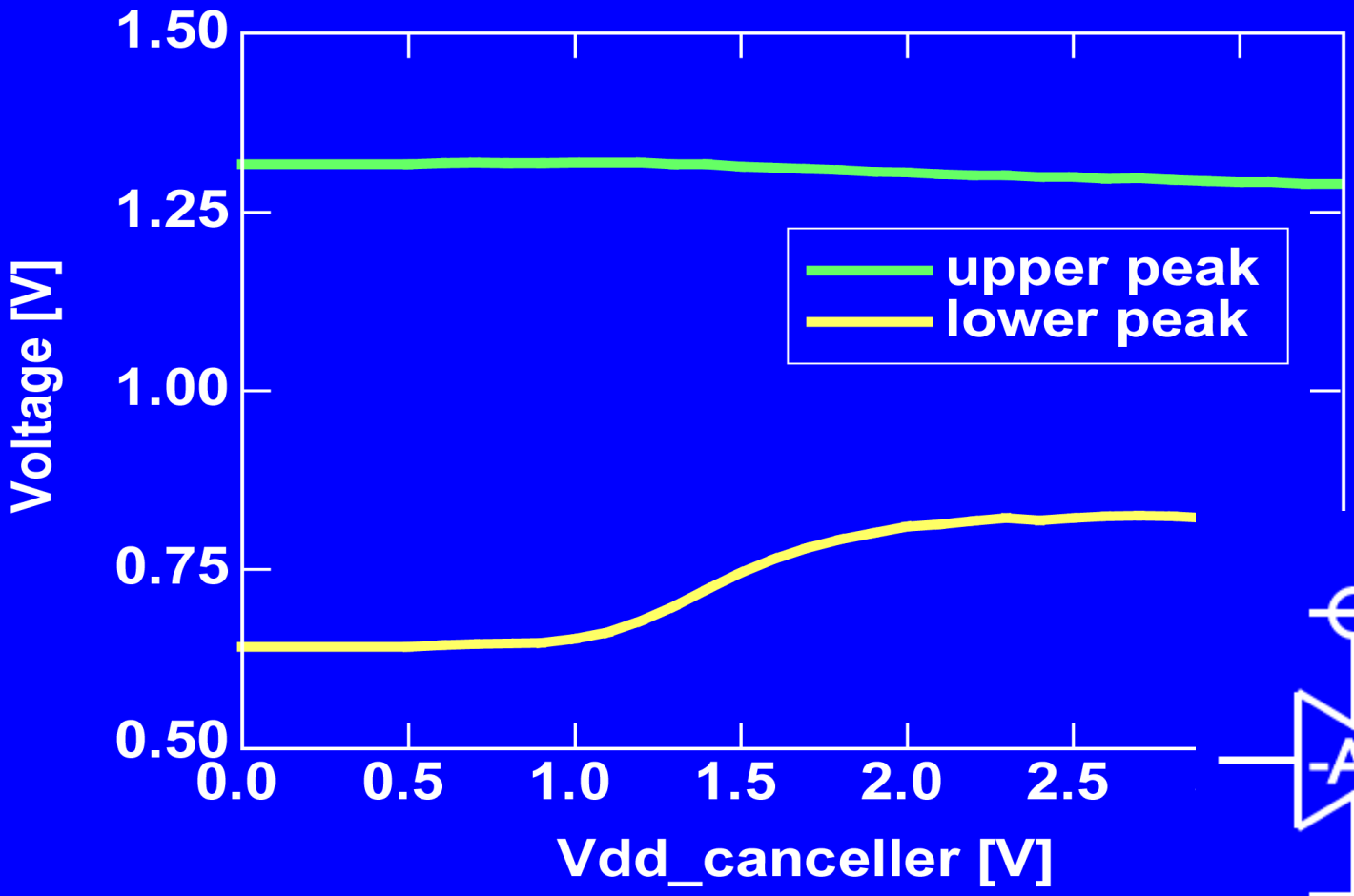
Frequency Dependence (repeat)

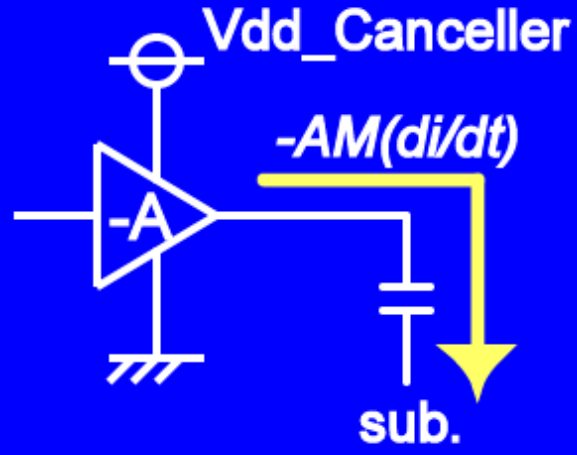


Waveform (Repeat@500MHz)

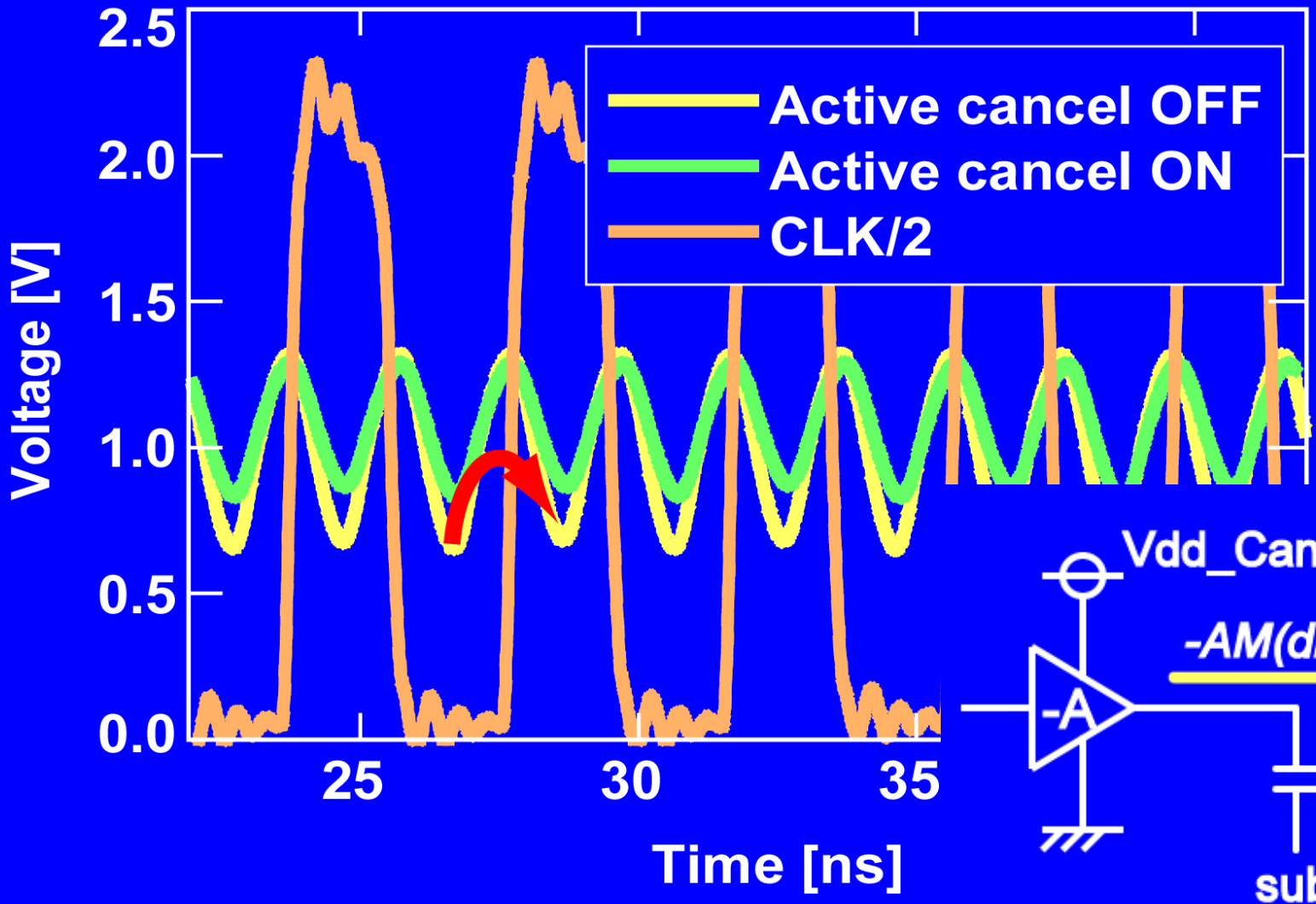


Noise Amplitude Change



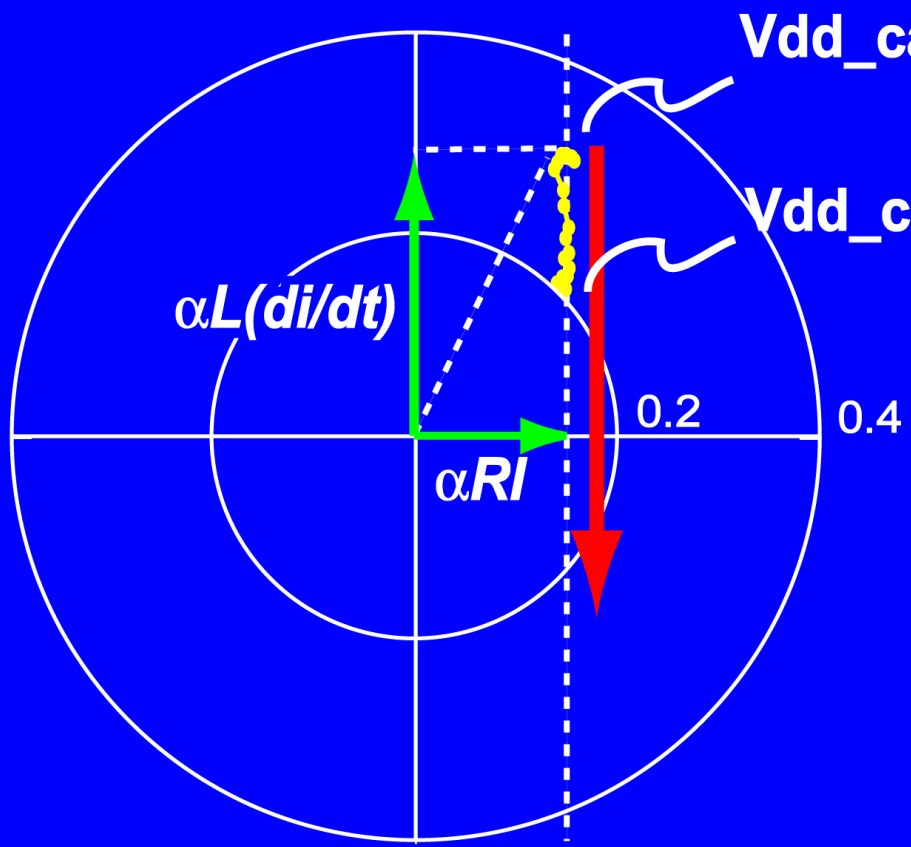


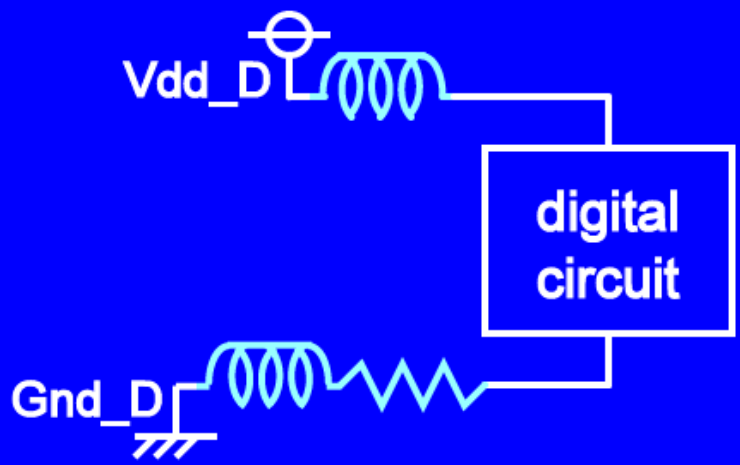
Substrate Noise Change



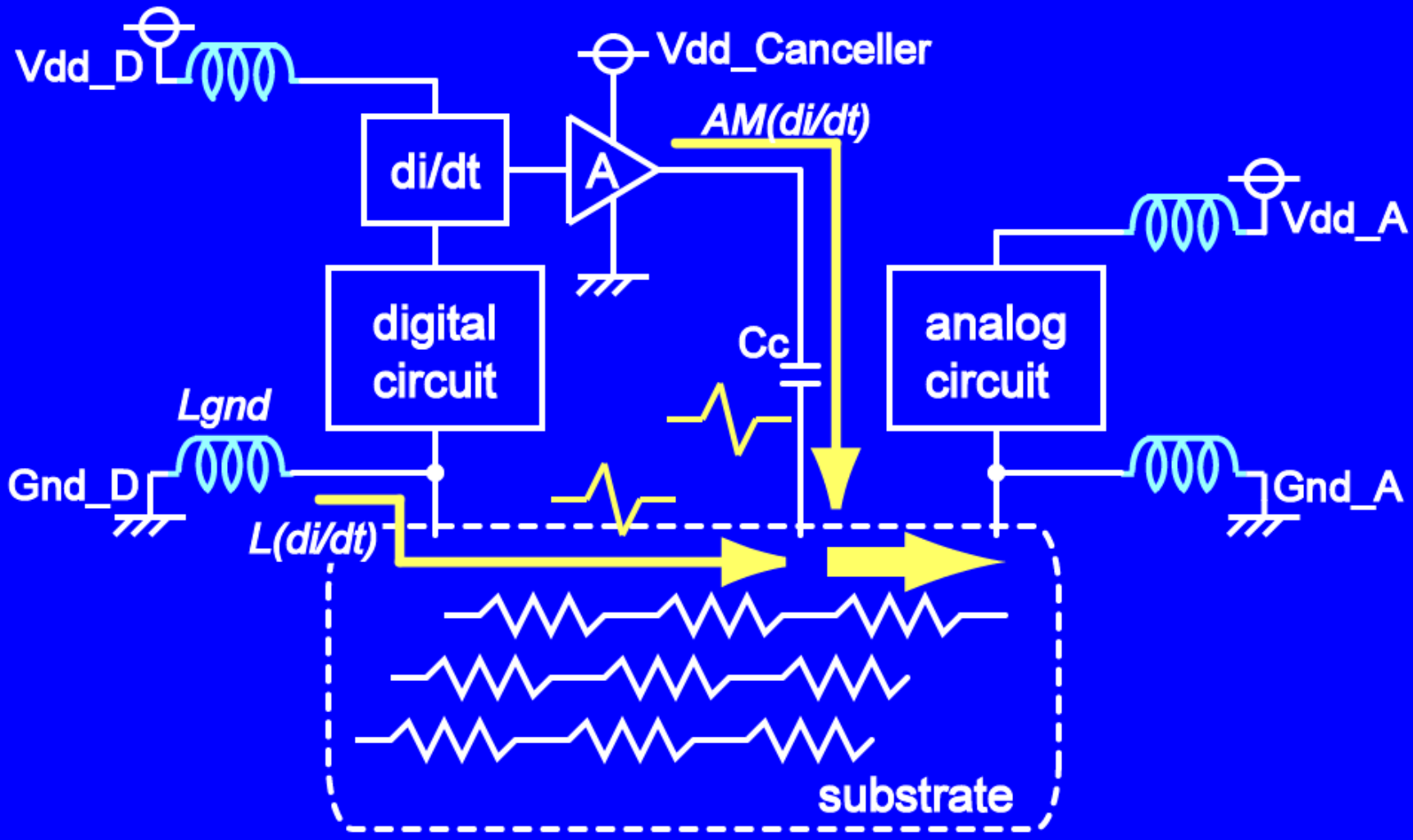
Phasor of the Substrate Noise

- 54% noise reduction would be achieved by optimizing the amplifier design

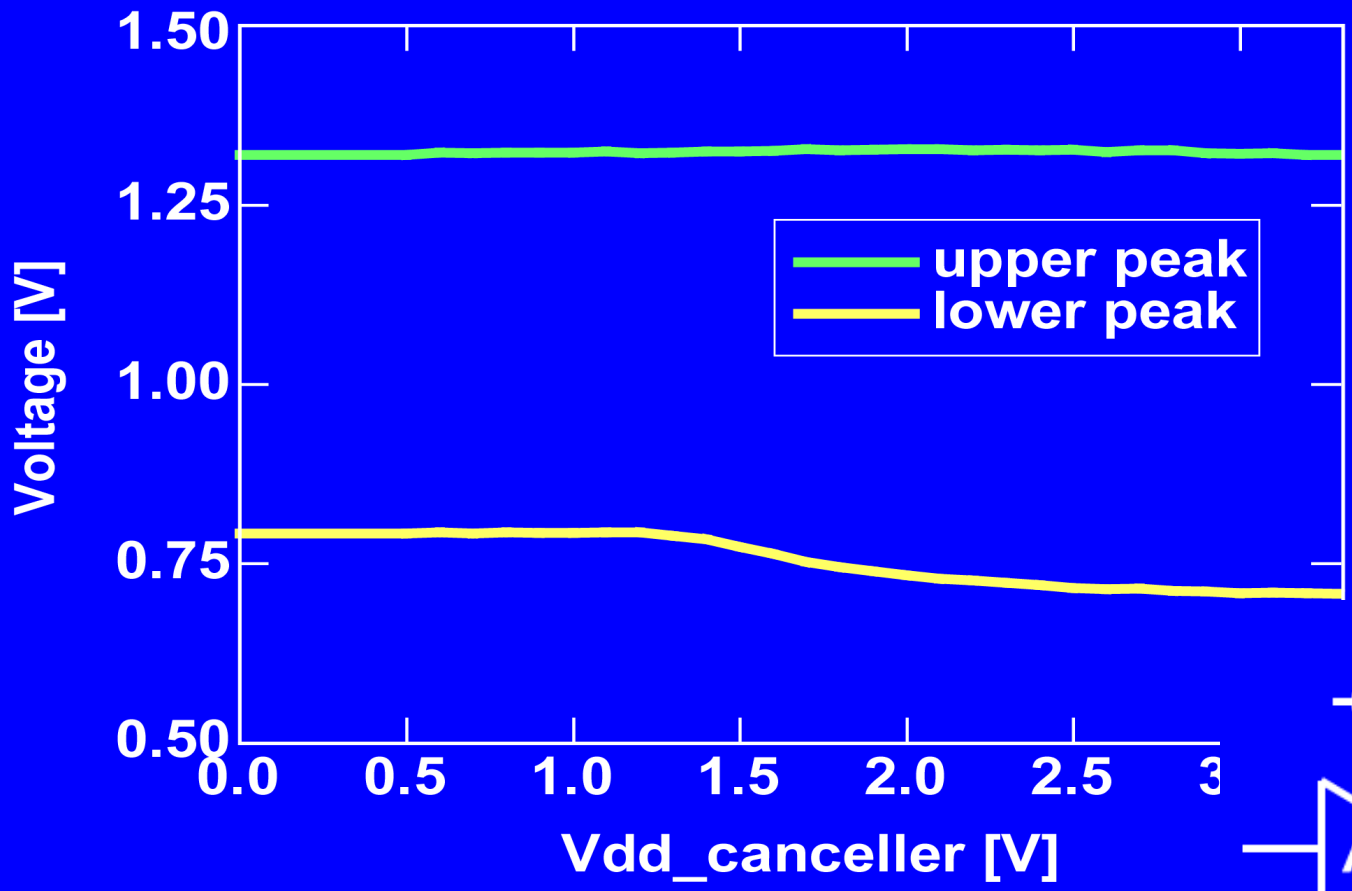


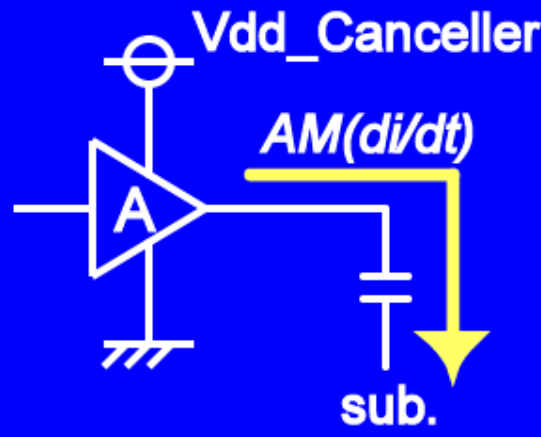


In-phase Current Injection



In-phase Current Injection





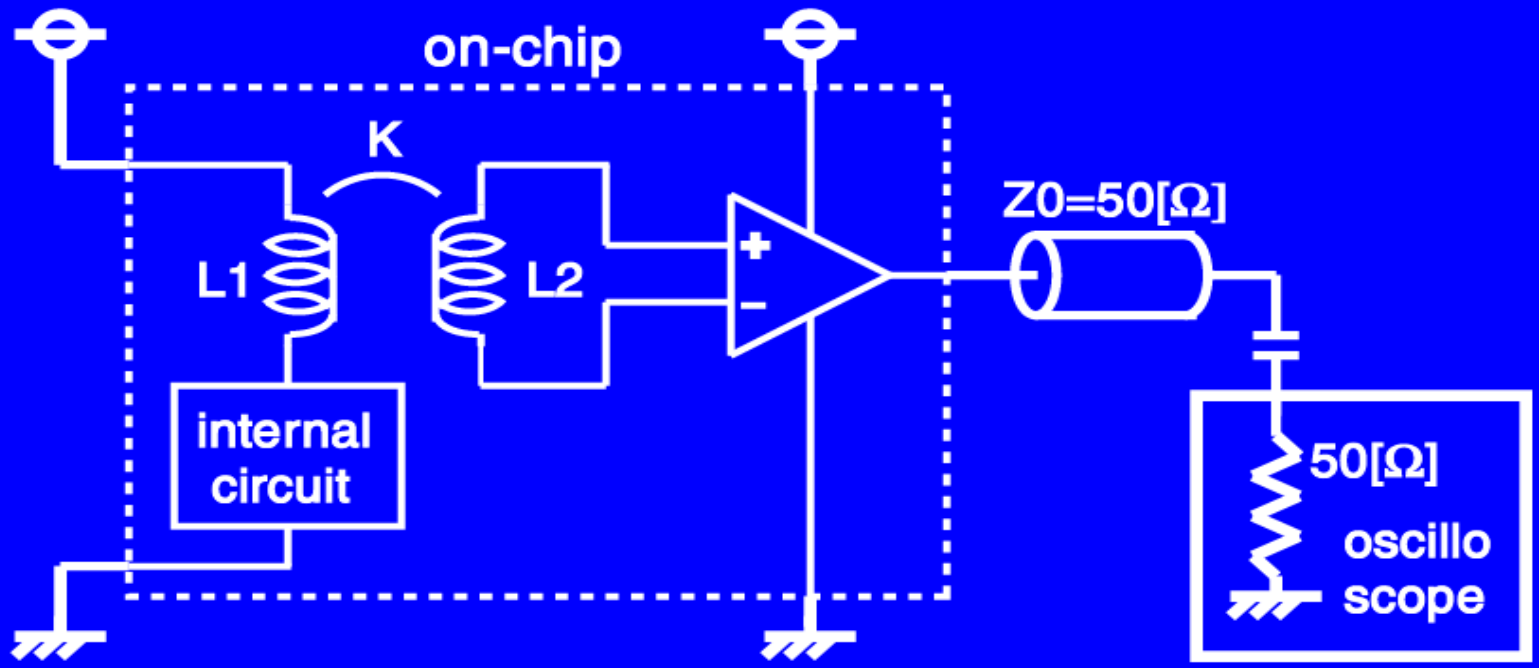
Summary

- Feedforward active substrate noise cancelling technique is demonstrated
- A di/dt detector generates anti-phase signals, and injected into the substrate
- Measurement results show that 17% to 34% of the substrate noise reduction is achieved from 100MHz to 600MHz range
- Optimized injector design will enhance the noise suppression ratio up to 56%

Q&A

di/dt Detector Block Diagram

- L2 picks up the di/dt, induce the voltage
- Amplifier amplifies/output the voltage



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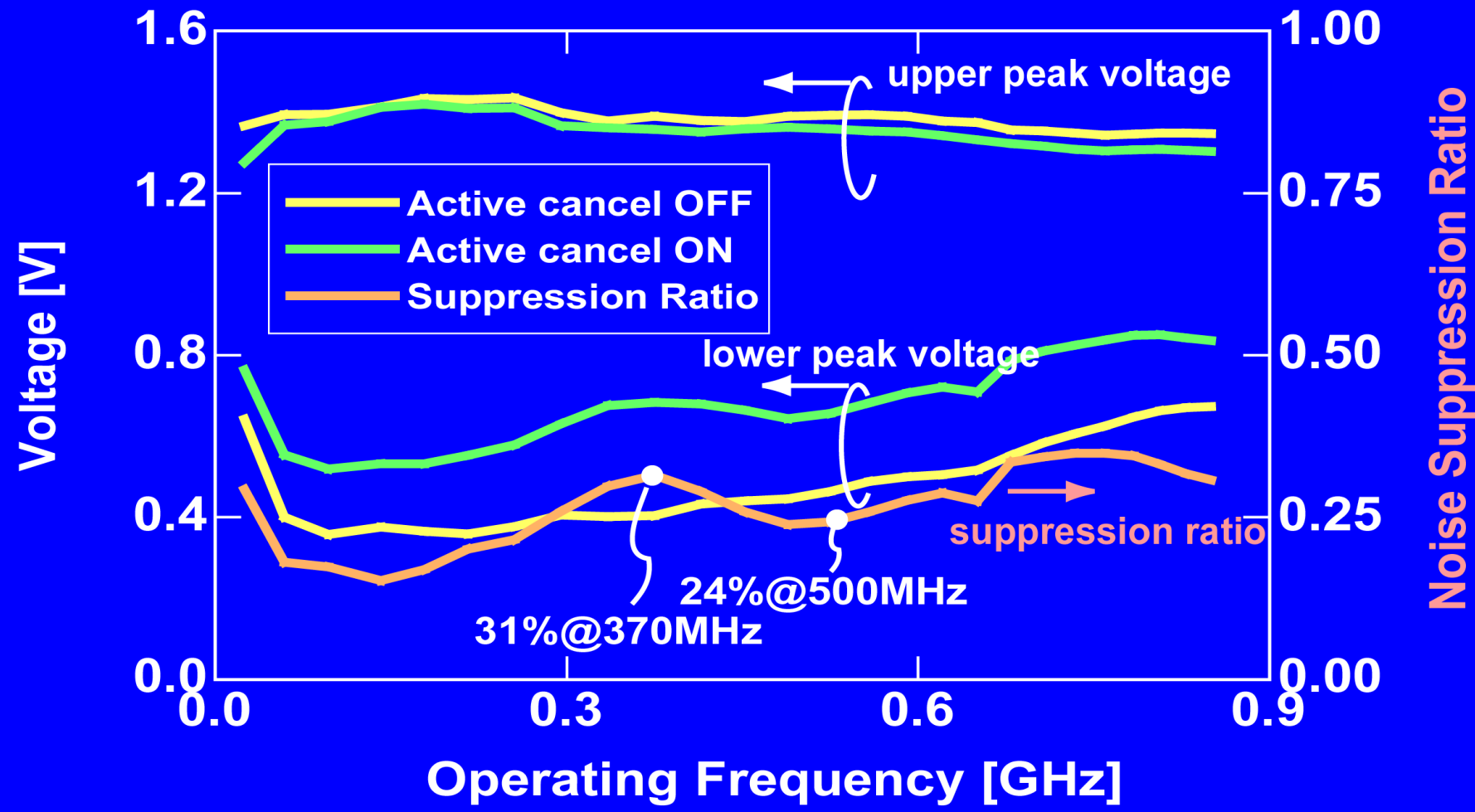
Frequency Dependence (random)



Overall Circuit

- Change the Gnd line impedance by the chip mount