On-chip di/dt Detector Circuit for Power Supply Line

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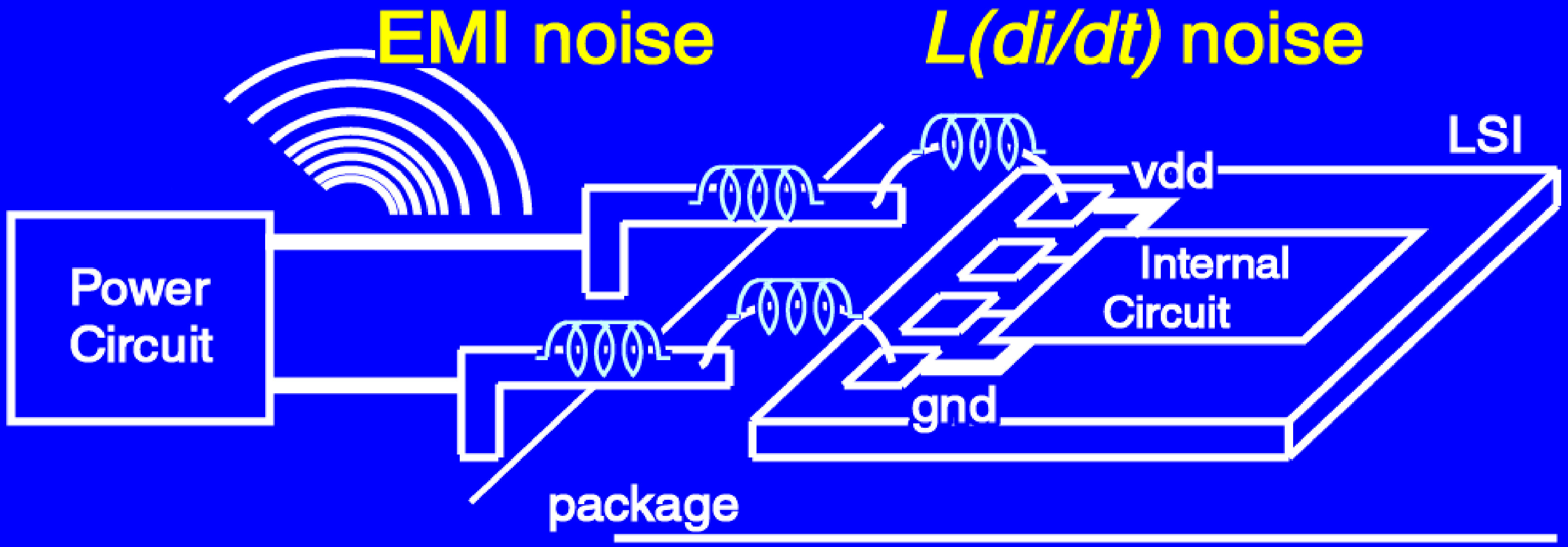
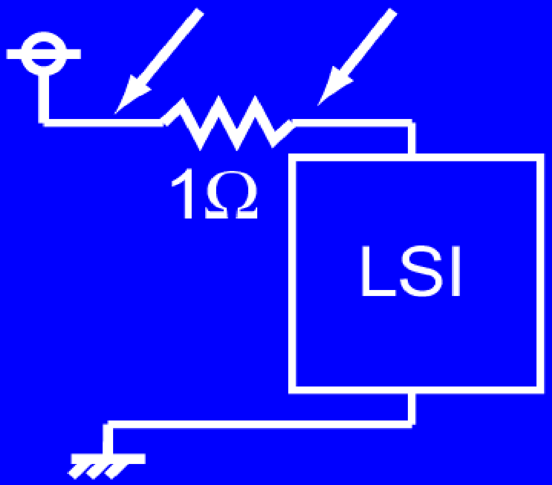
Background

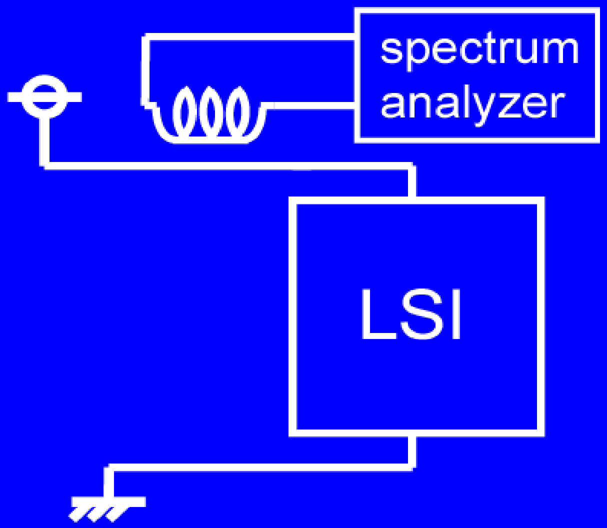
- di/dt is becoming a critical issue
  - L(di/dt) noise of low voltage LSIs
  - EMI noise of high-speed operation LSIs
- Need to measure the di/dt



Conventional Current Meas.

- Probe the voltage difference of the R
  - Needs numerical calculation
- Probe the magnetic field by pickup coil
  - Phase information is lost



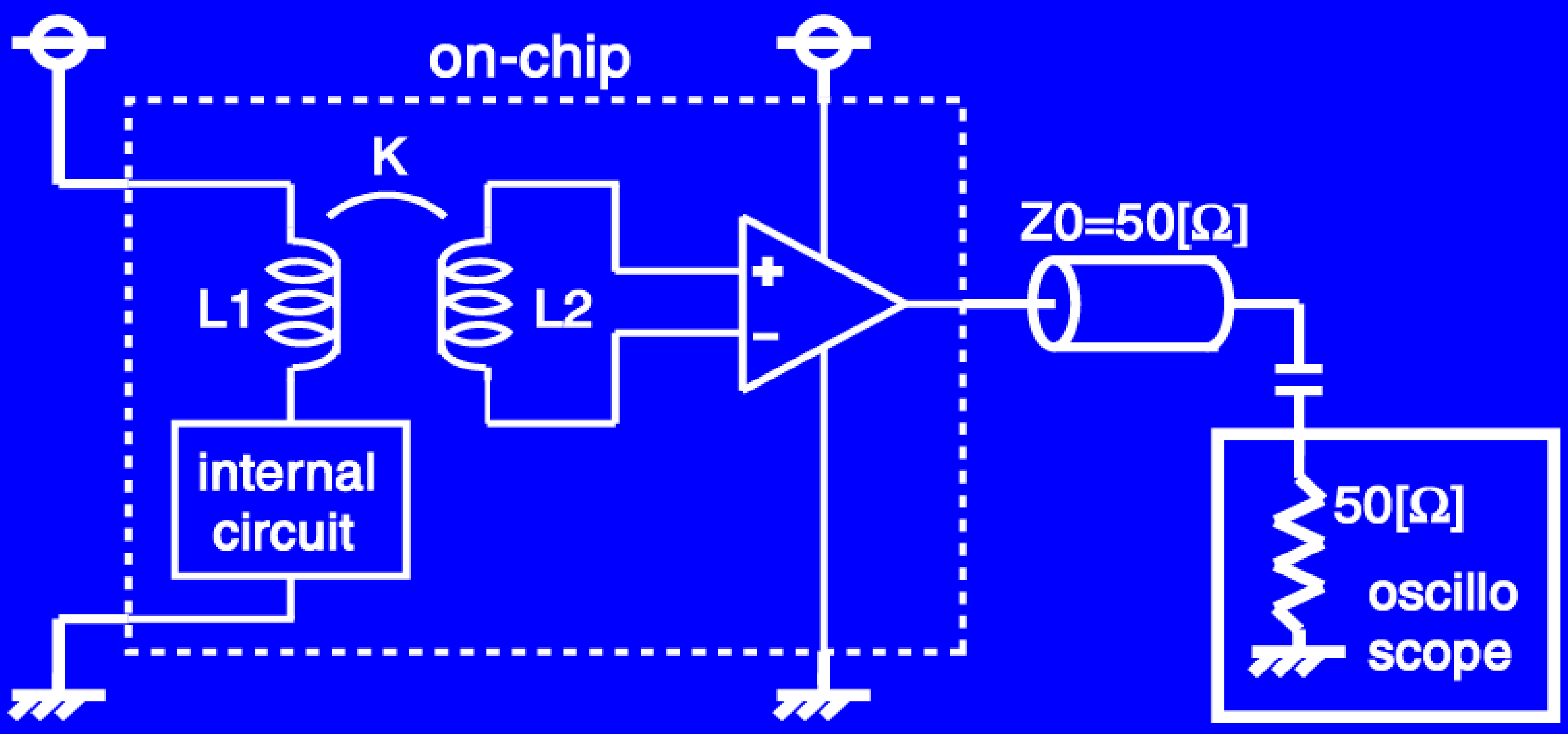


Contents

- Introduction of our di/dt detector circuit
  - Mutual Inductor
  - Amplifier
  - Setup for measurement
- Simulation Waveforms
- Summary

Block Diagram

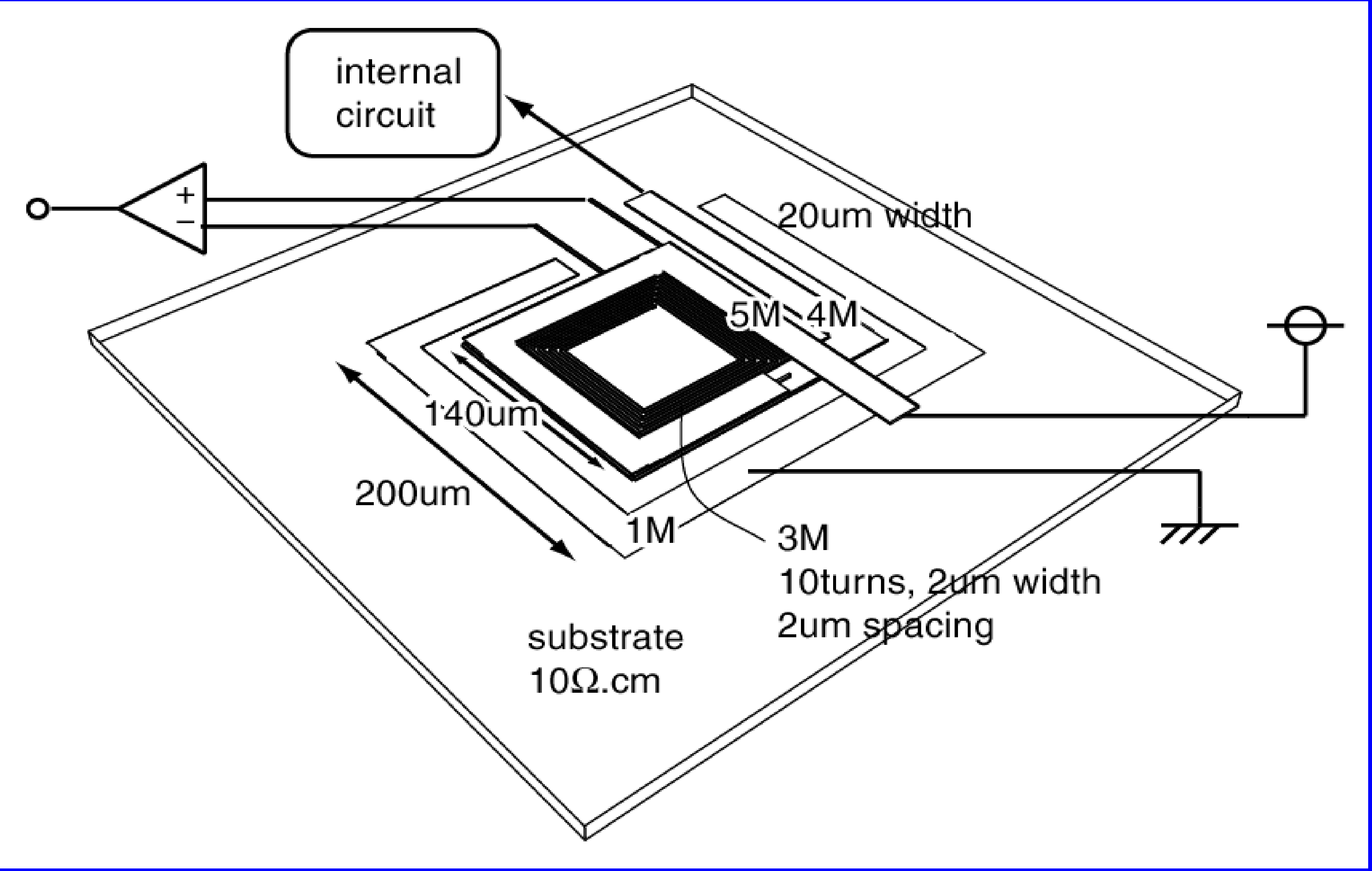
- L2 picks up the di/dt, induce the voltage
- Amplifier amplifies/output the voltage



Advantage

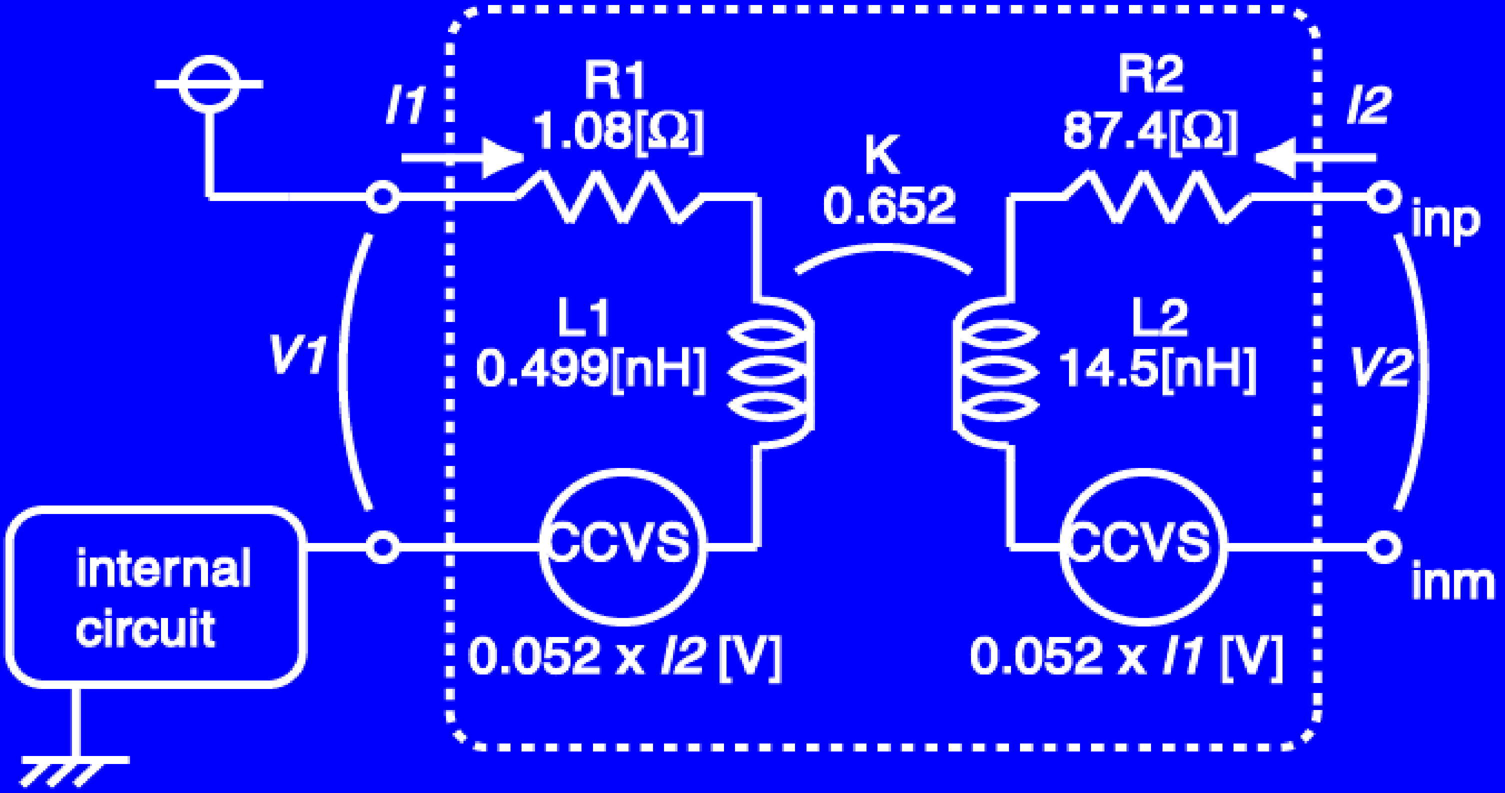
- On-chip
- di/dt waveform without numerical calculation
- Real time
- Feedback di/dt control is possible

Mutual Inductor

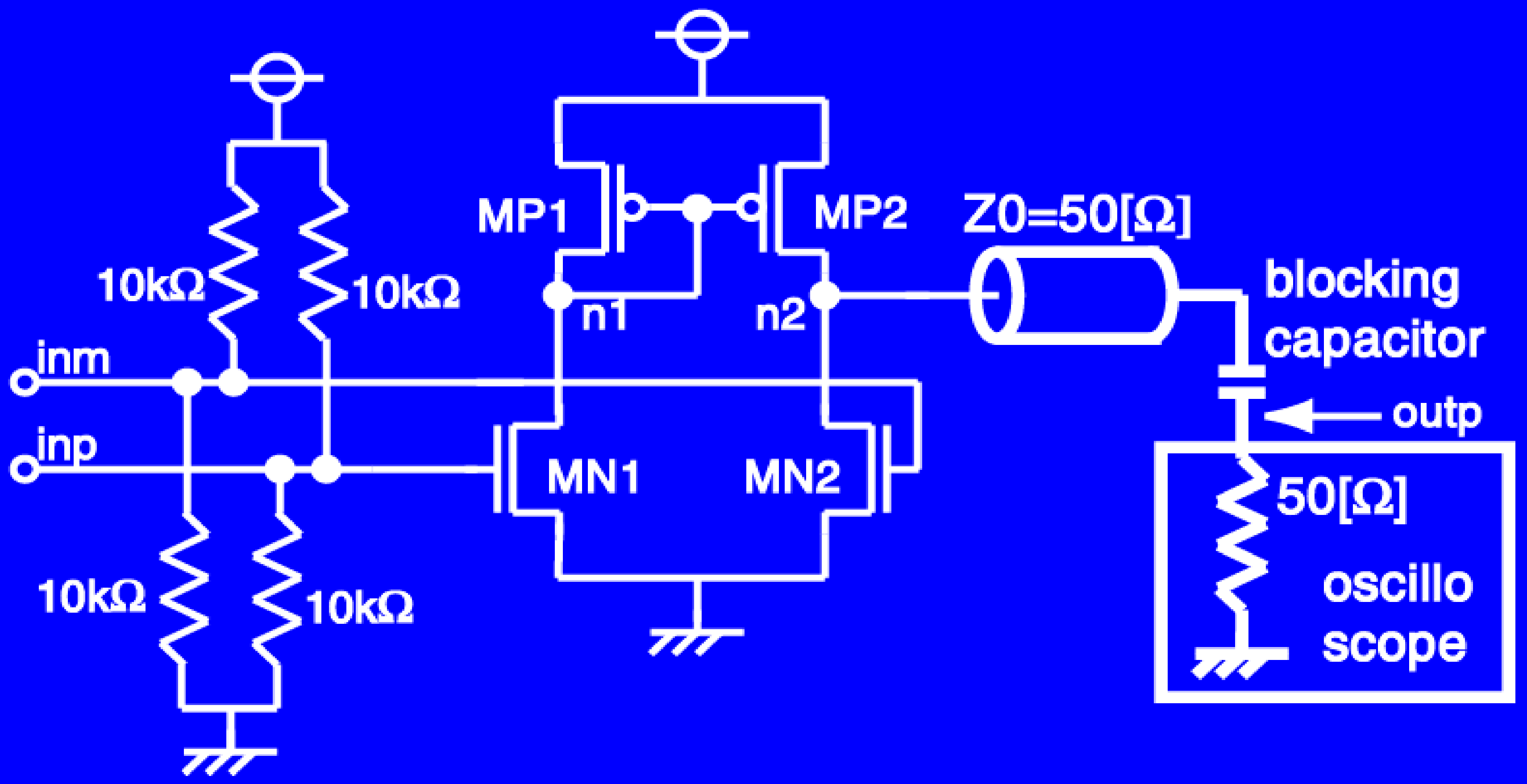


Equivalent Circuit

- Extracted by FastHenry

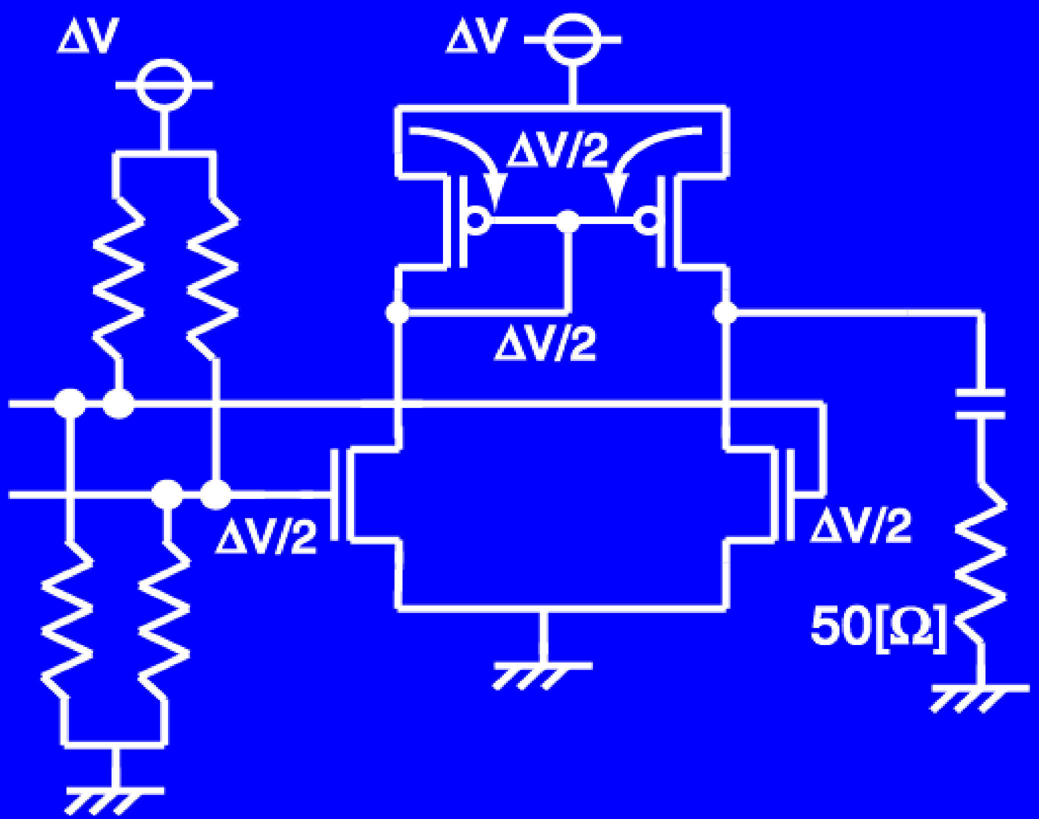


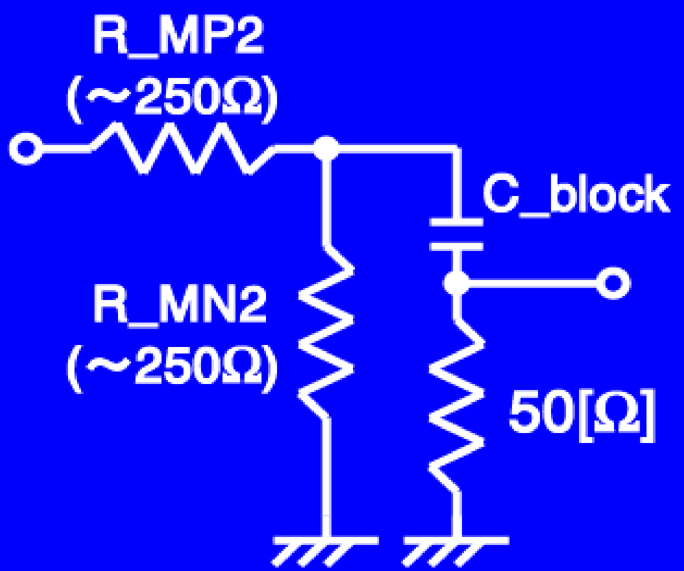
Amplifier/Output buffer



Noise Tolerance

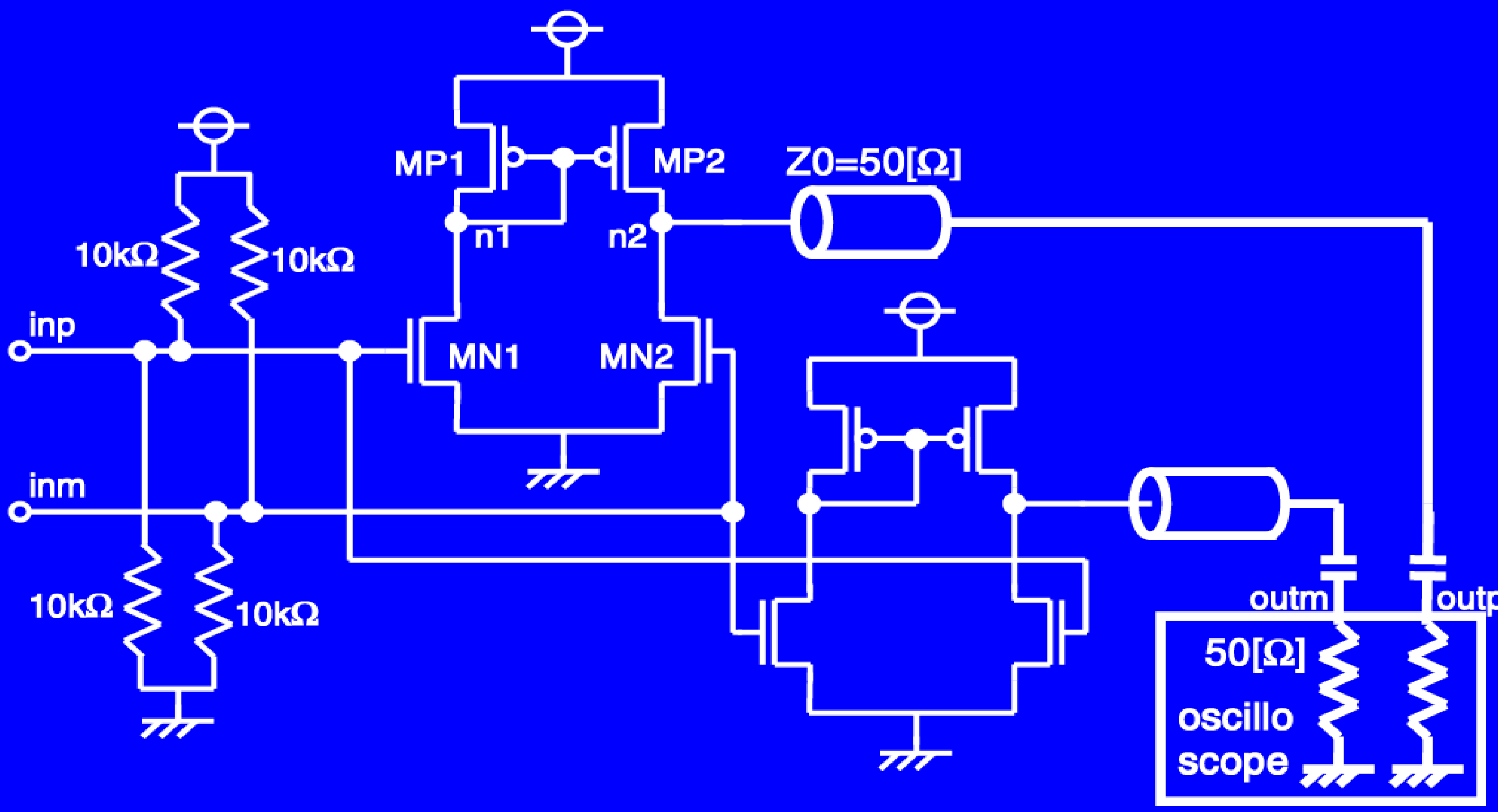
- Common mode noise is eliminated
- Vdd noise is suppressed to 14% (by 86%)





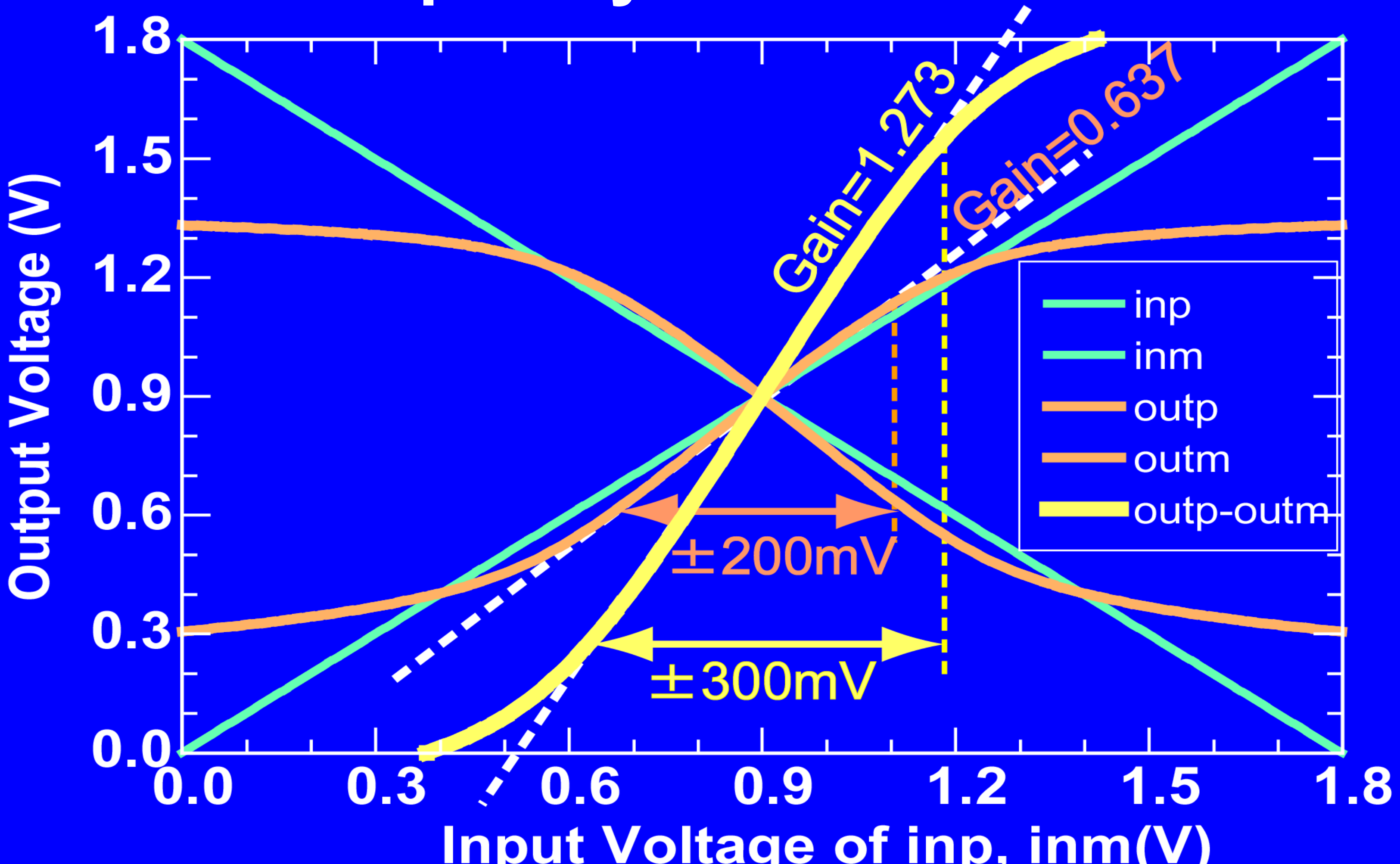
Single or Dual?

- Noise immunity, Sensitivity, Symmetric
- Require two pins, numerical calculation



Linearity of the Amplifier

- Cut-off frequency is over 10GHz



Sensitivity

- L1=0.499nH, L2=14.5nH, K=0.652, G=1.273

$$V_{inp} - V_{inm} = K\sqrt{L_1L_2}\frac{dI_1}{dt}$$

$I = 1\sin 2\pi 1e9t \rightarrow$

$dI/dt = 2\pi 1e9\cos 2\pi ft$

$$V_{out} = G(V_{inp} - V_{inm})$$

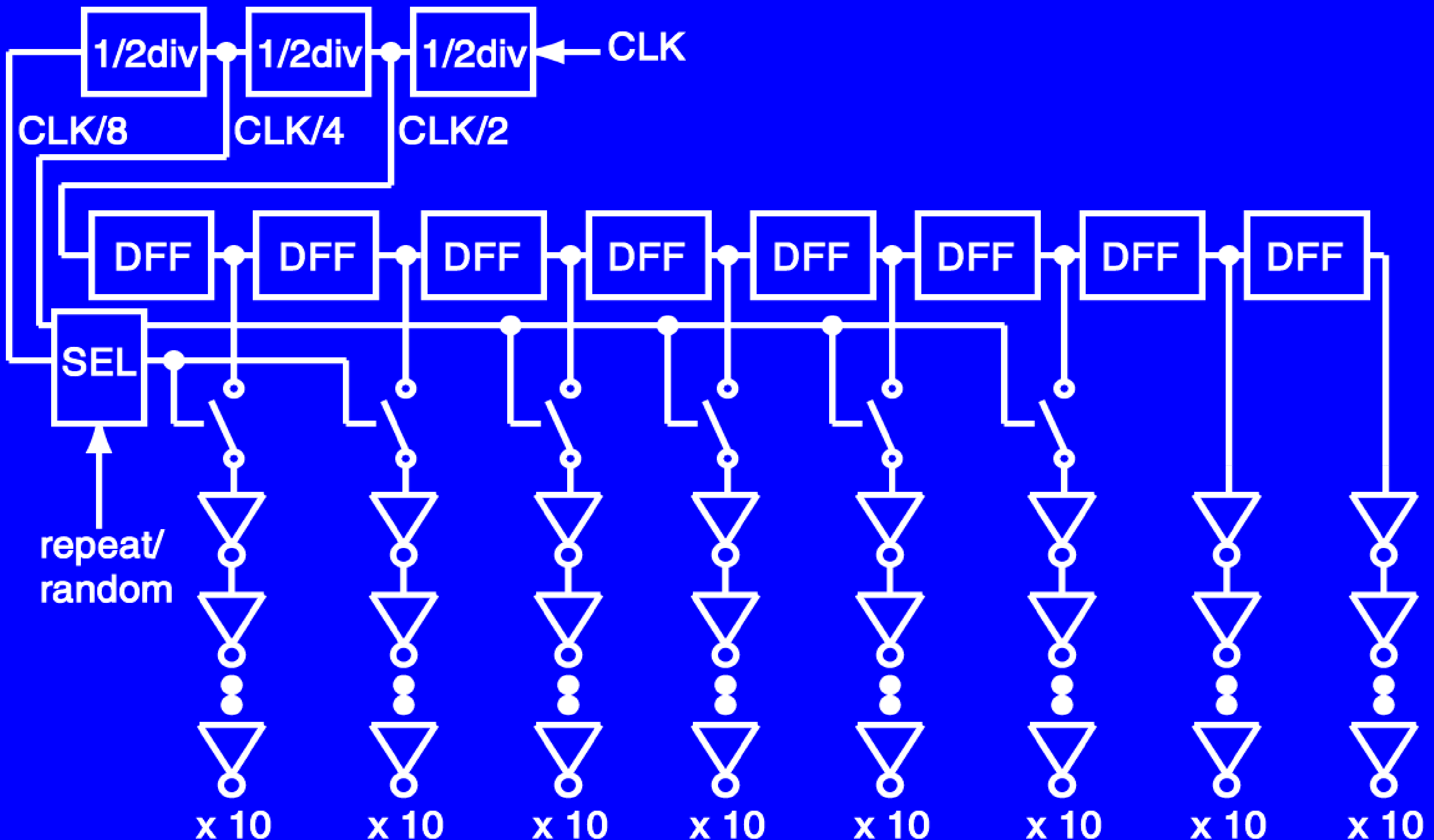
$$V_{out} = GK\sqrt{L_1L_2}\frac{dI_1}{dt} = A_{didt2vout}\frac{dI_1}{dt} = 2.23\text{x}10^{-9}\frac{dI_1}{dt}$$

$$\frac{dI_1}{dt} = \frac{1}{A_{didt2vout}}V_{out} = 4.48\text{x}10^{8}\ V_{out}$$

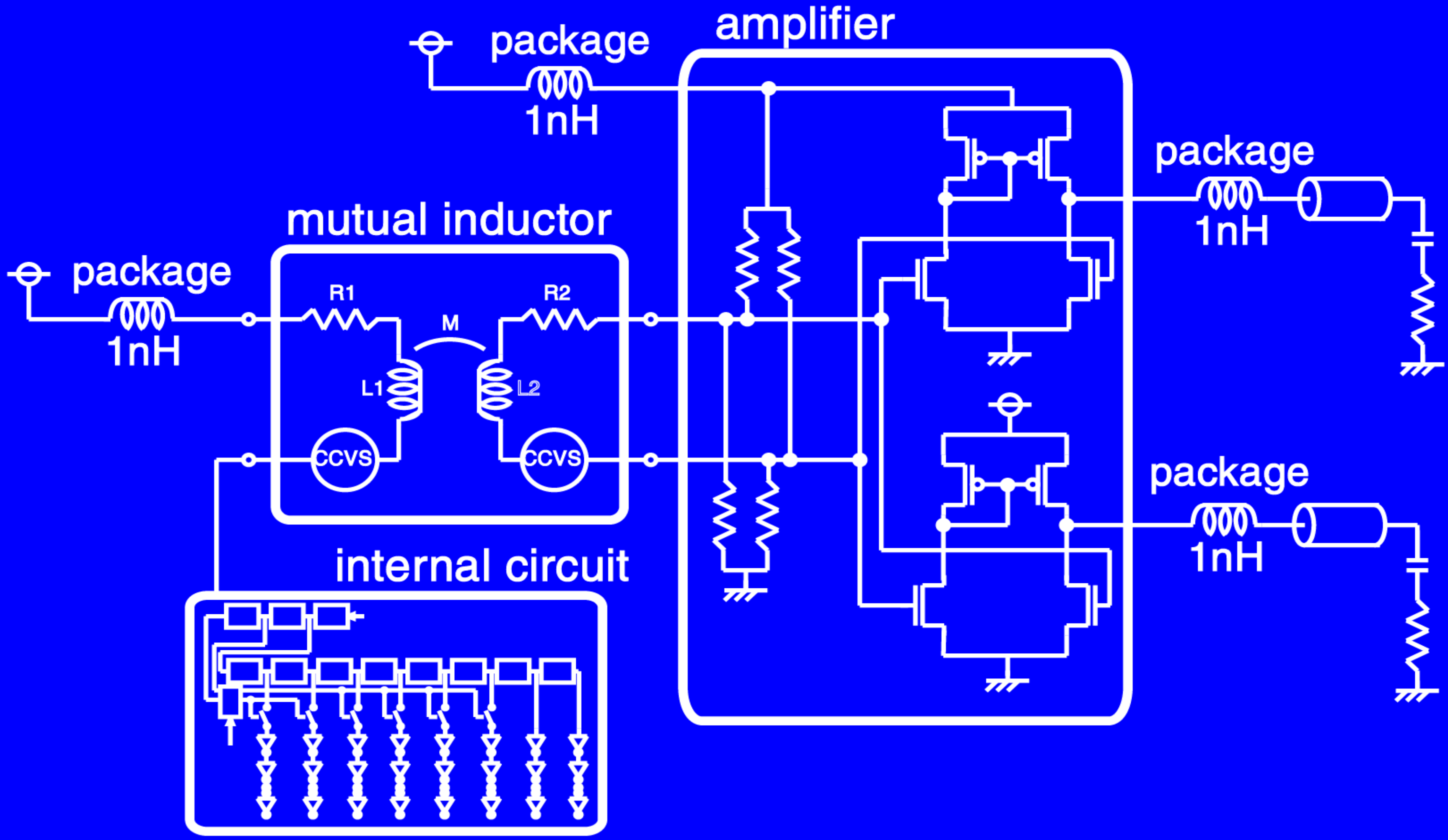
$$\frac{dI_1}{dt}_{lim} = \pm\frac{1}{K\sqrt{L_1L_2}}V_{amp\_in\_lin} = \pm\ 1.71\text{x}10^{8}\ [\text{A/s}]$$

$$\frac{dI_1}{dt}_{res} = \frac{1}{A_{didt2vout}}V_{out\_res} = 4.48\text{x}10^{6}\ [\text{A/s}] \quad (V_{out\_res} = 10\text{mV})$$

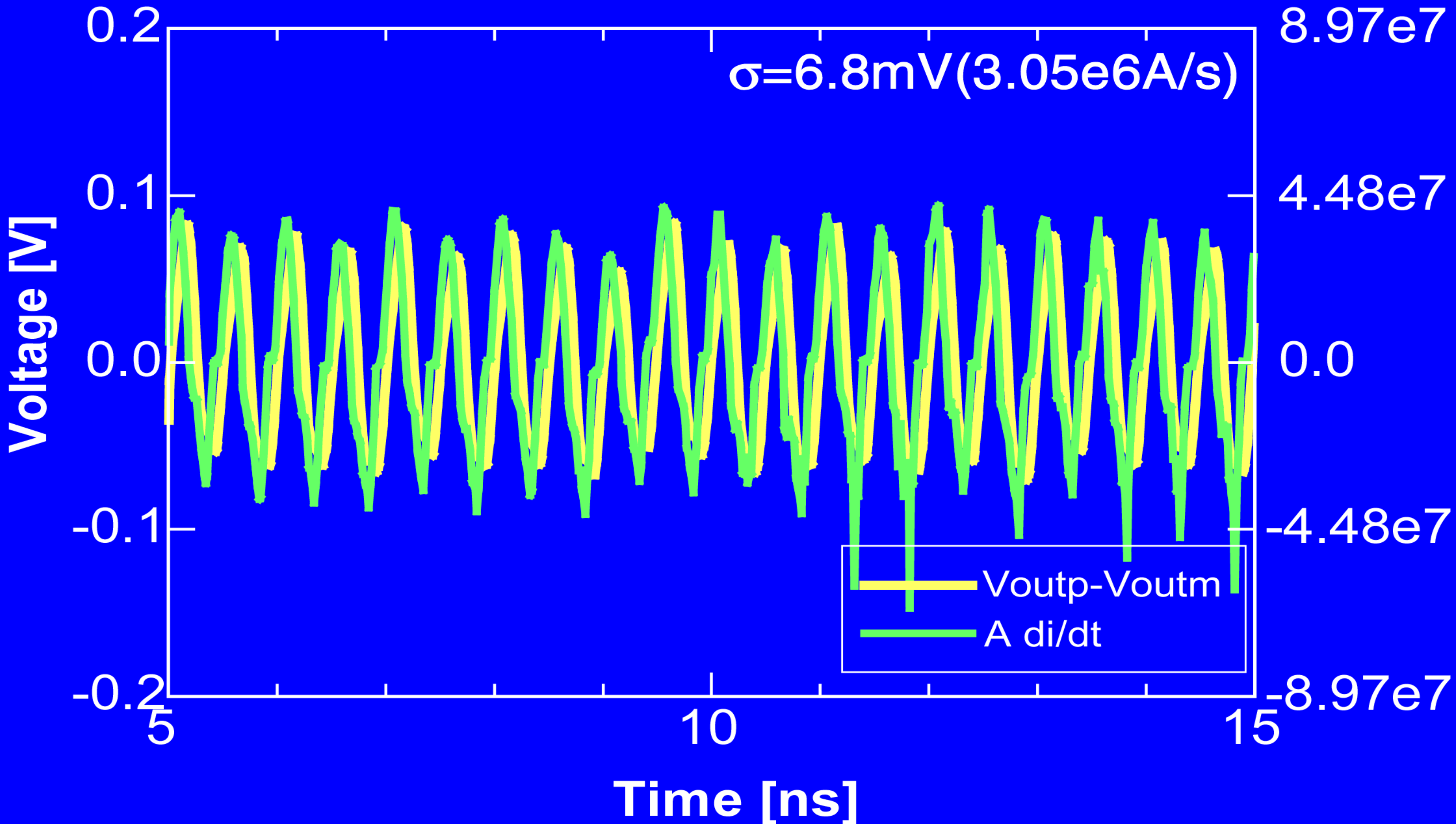
Test Circuit



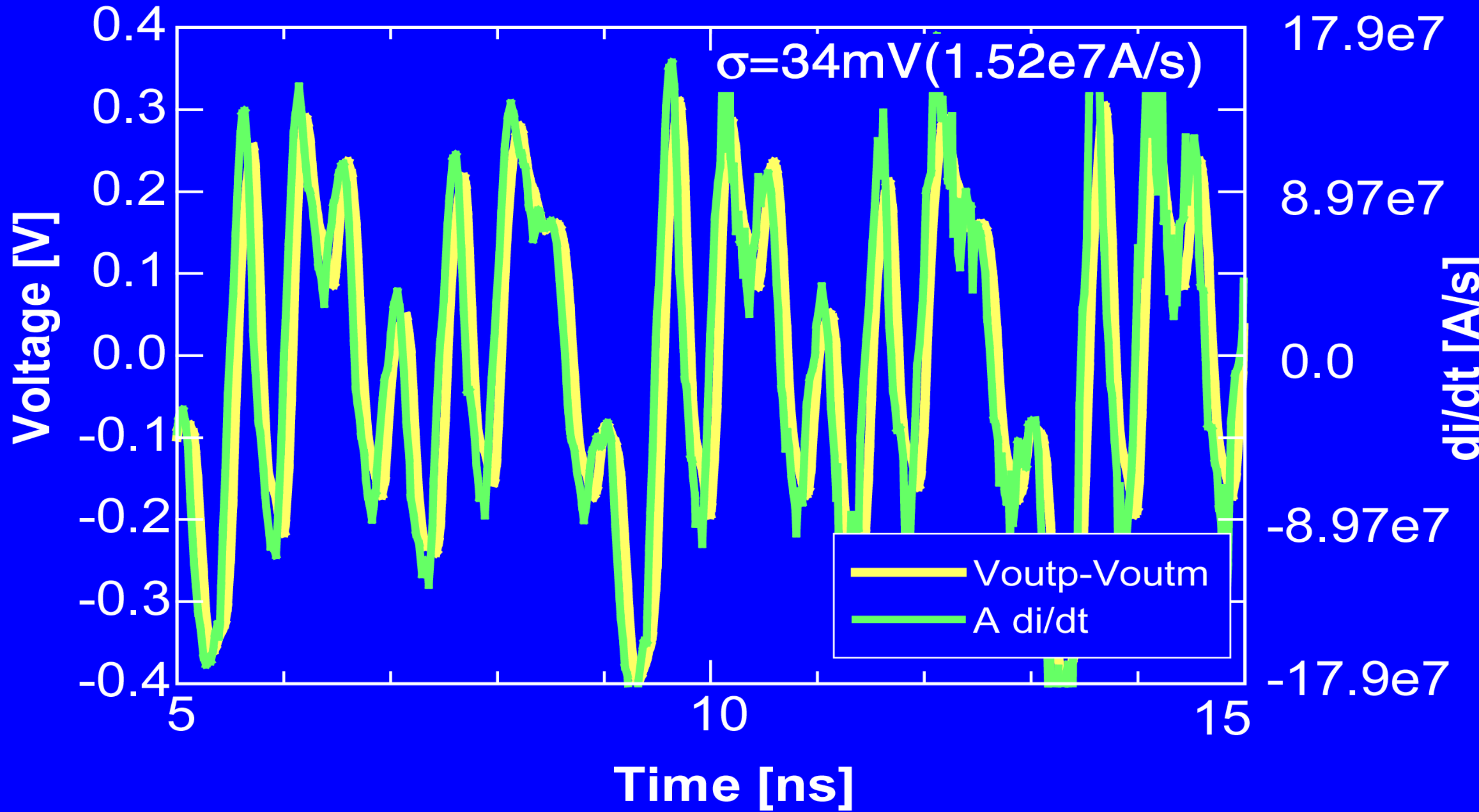
Whole Test Circuit



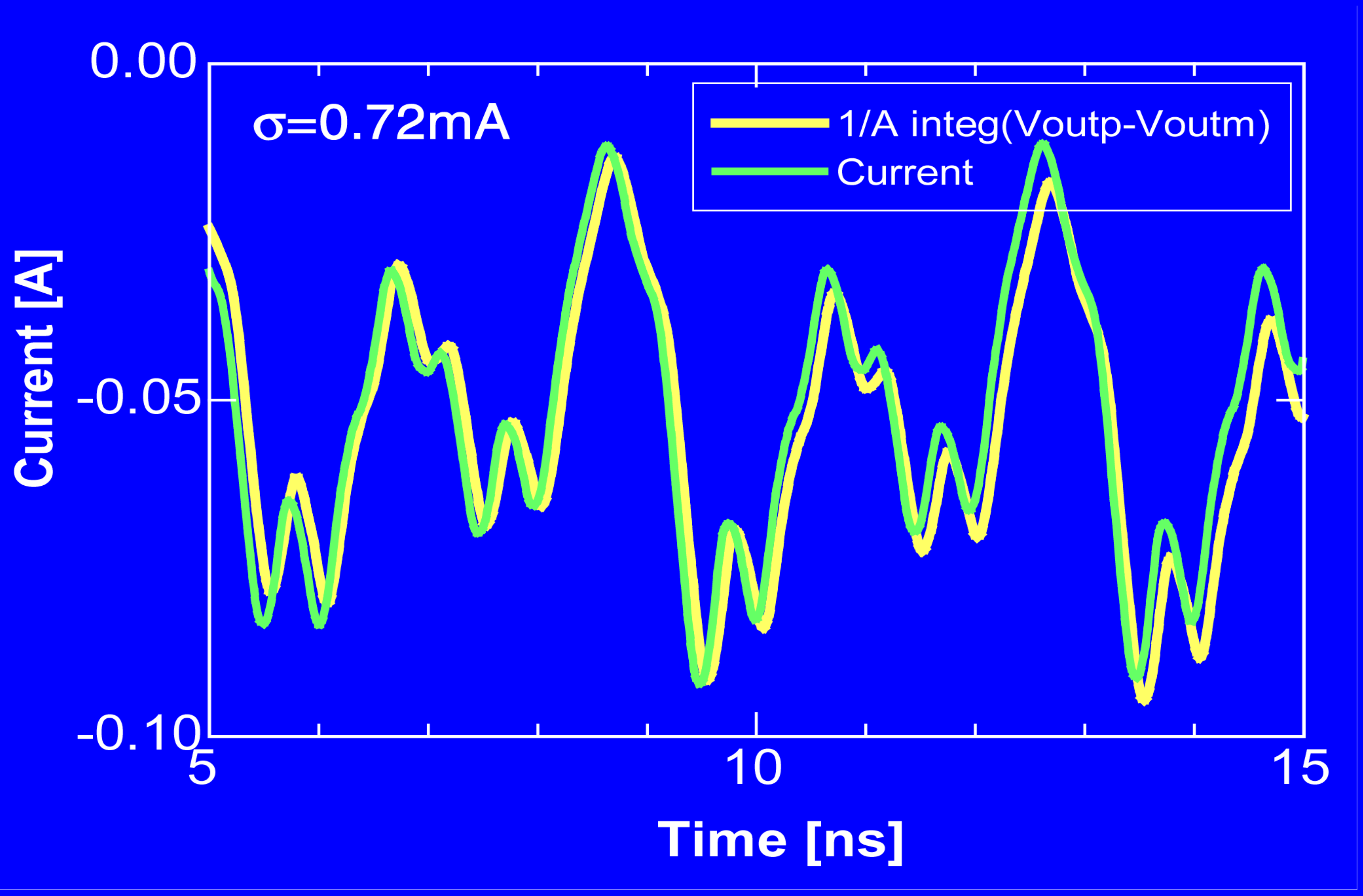
di/dt Waveform (repeat)



di/dt Waveform (random)



Current Waveforms



Summary

- An on-chip di/dt detector is proposed.
- It consists of a spiral inductor and an amplifier.
- The accuracy is 1.52×10^7 A/s by an HSPICE simulation (random case).
- Current waveform can be obtained by integration of the di/dt output, with the accuracy of 0.72mA.

Q&A