On-chip di/dt Detector IP for Power Supply

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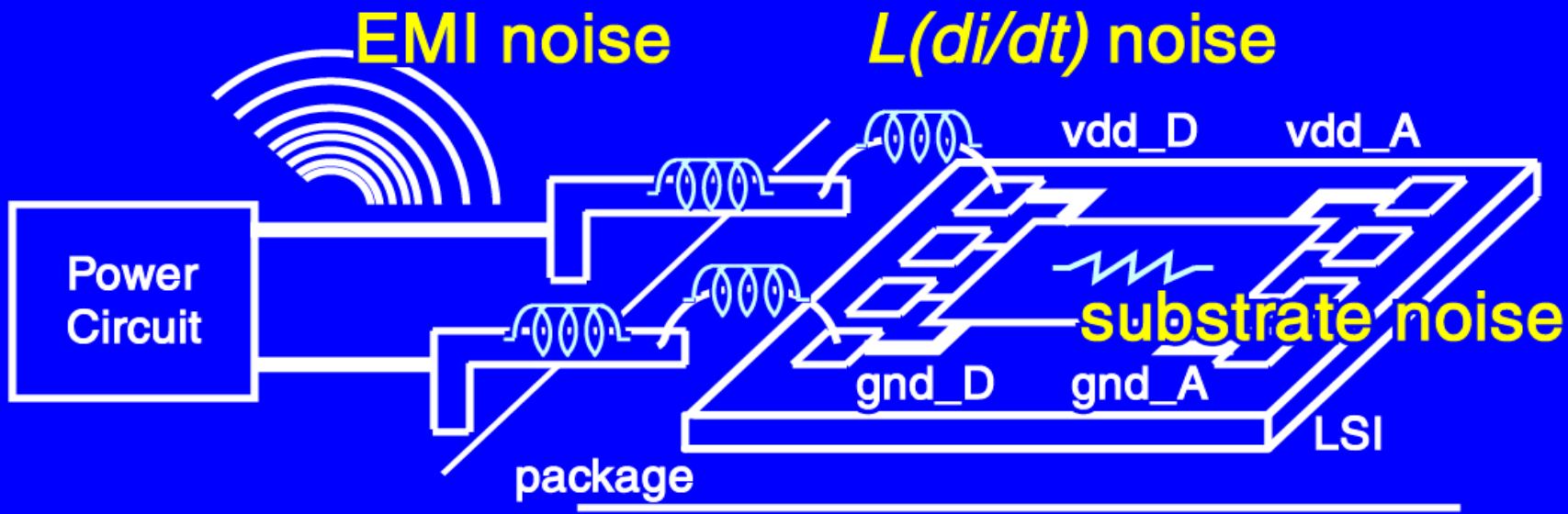
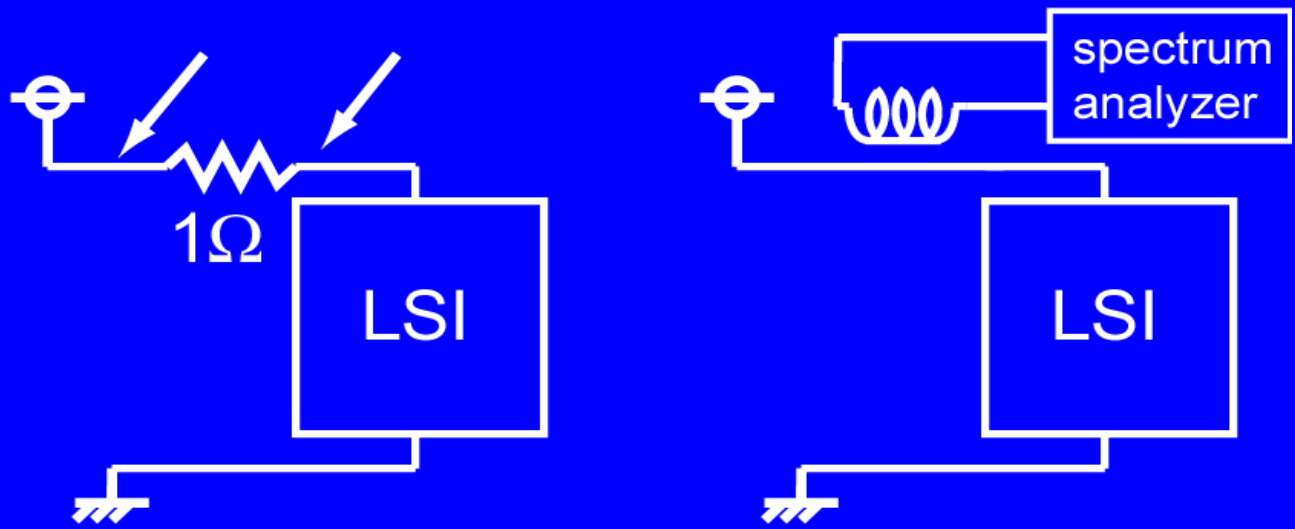
Signal Integrity and di/dt

- Power Supply Noise : L(di/dt)
- EMI Noise : Caused by di/dt
- Substrate Noise : related to Power Supply



Conventional Current Meas.

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

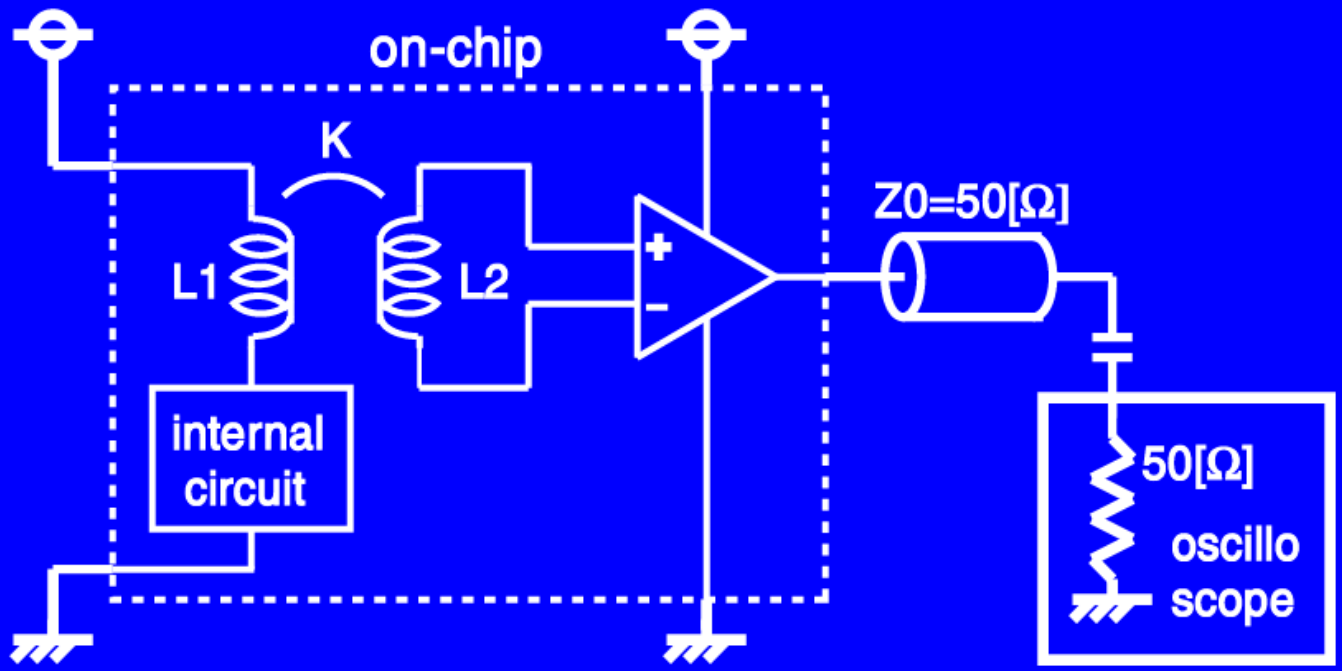


Contents

- di/dt detector circuit design
  - Mutual Inductor
  - Amplifier
  - Setup for measurement
- Measurement results
- Summary

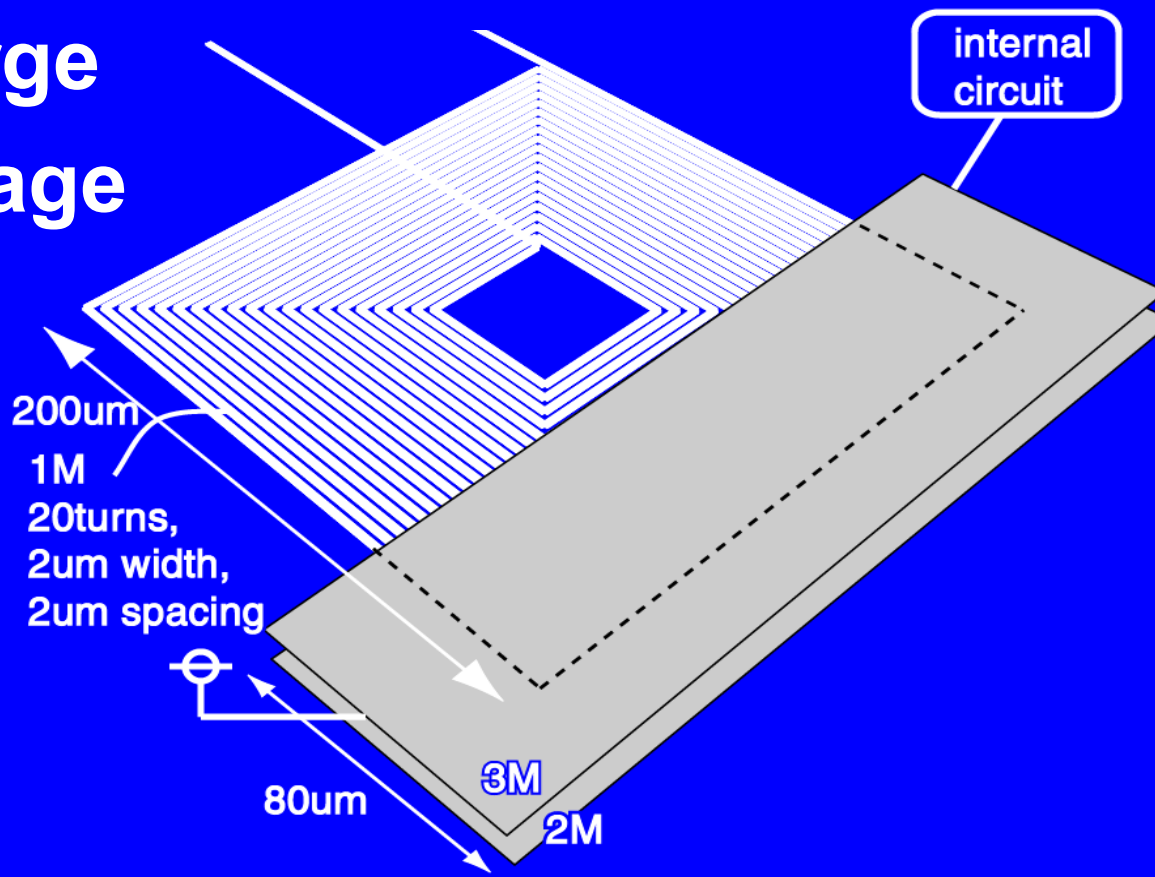
On-chip di/dt Detector

- L2 picks up the di/dt, induces the voltage
- Amplifier amplifies/output the voltage
- Pros: on-chip, real time, high-bandwidth



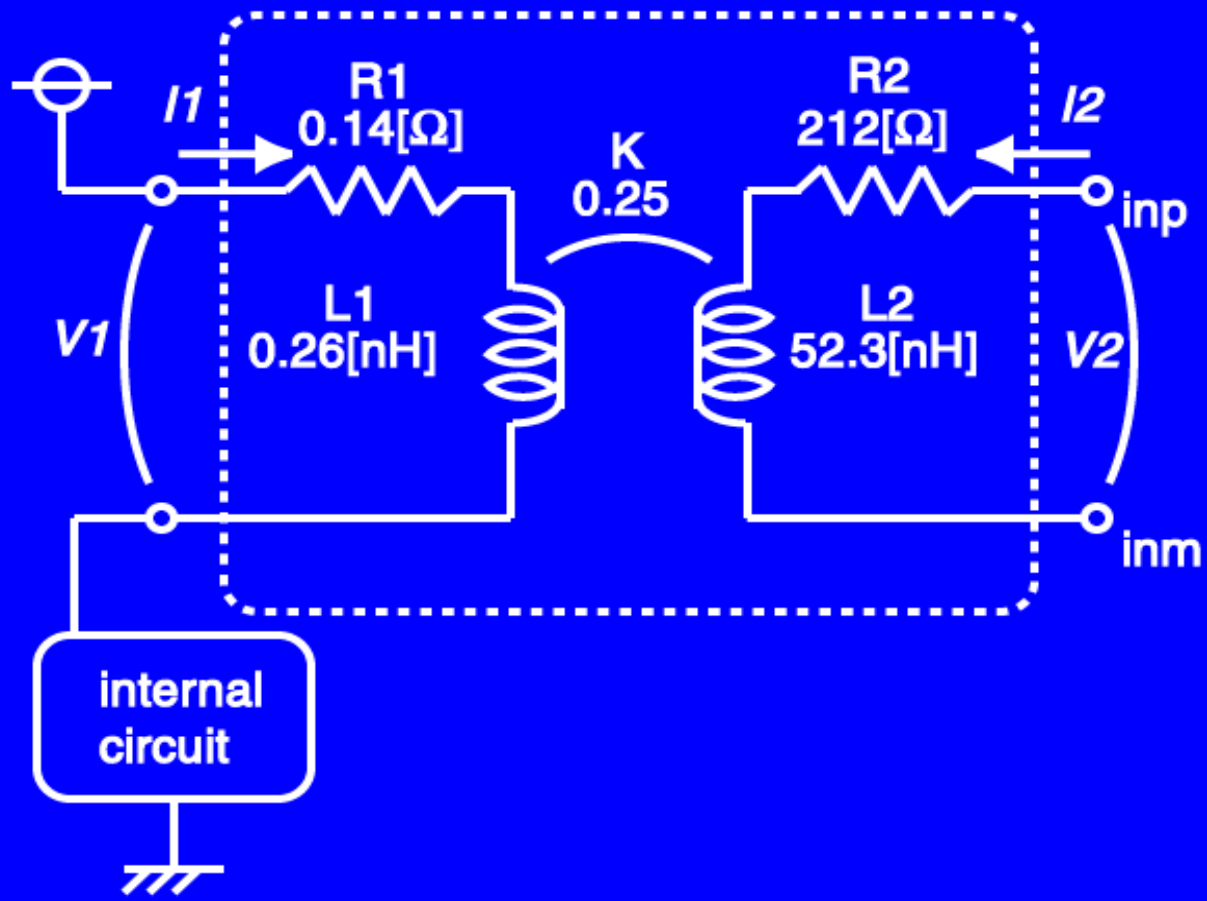
Mutual Inductor Structure

- Primary: in series to the power supply
  → low impedance
- Secondary: large induced voltage
  → large L2, and large K



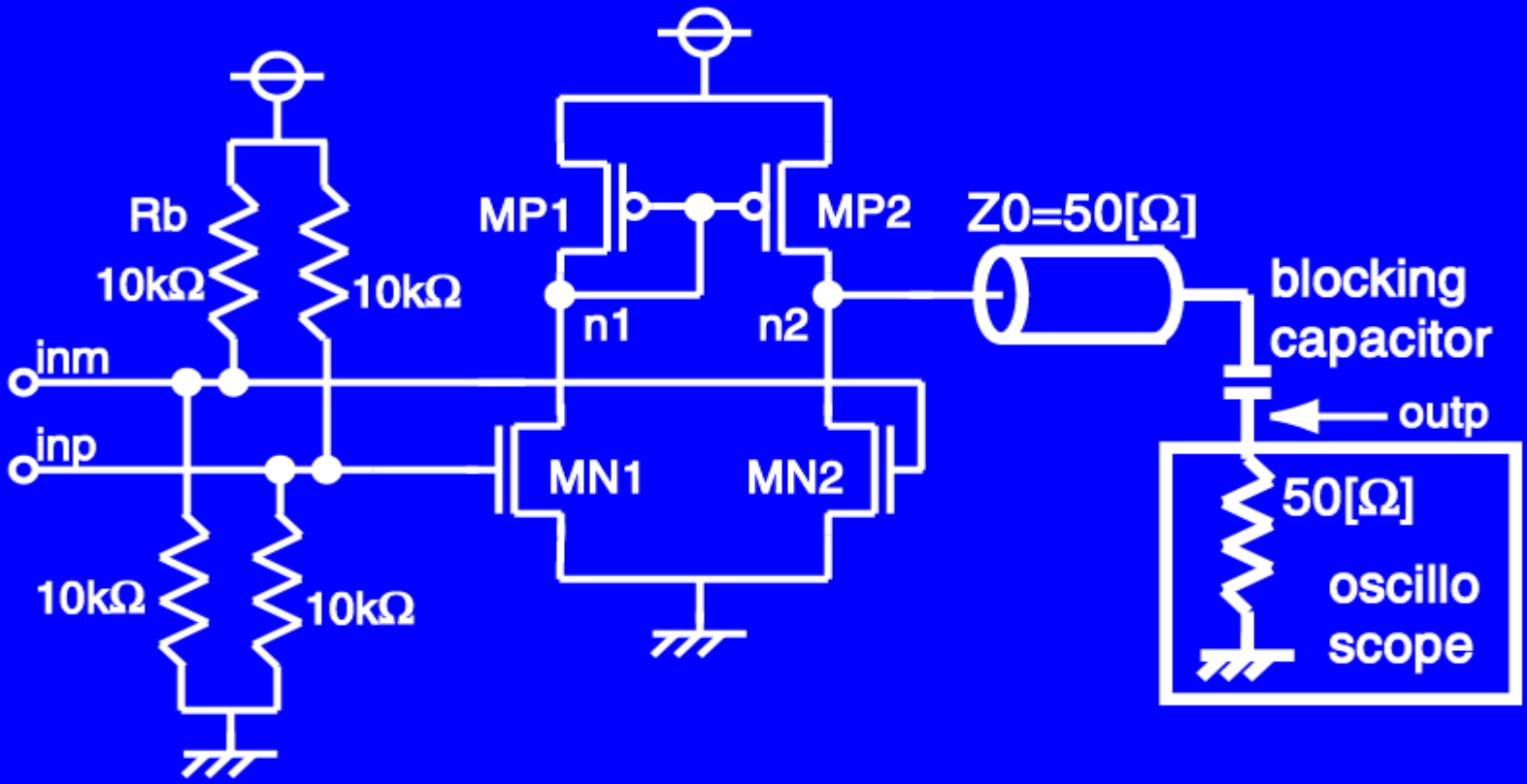
Equivalent Circuit

- Extracted using FastHenry field solver

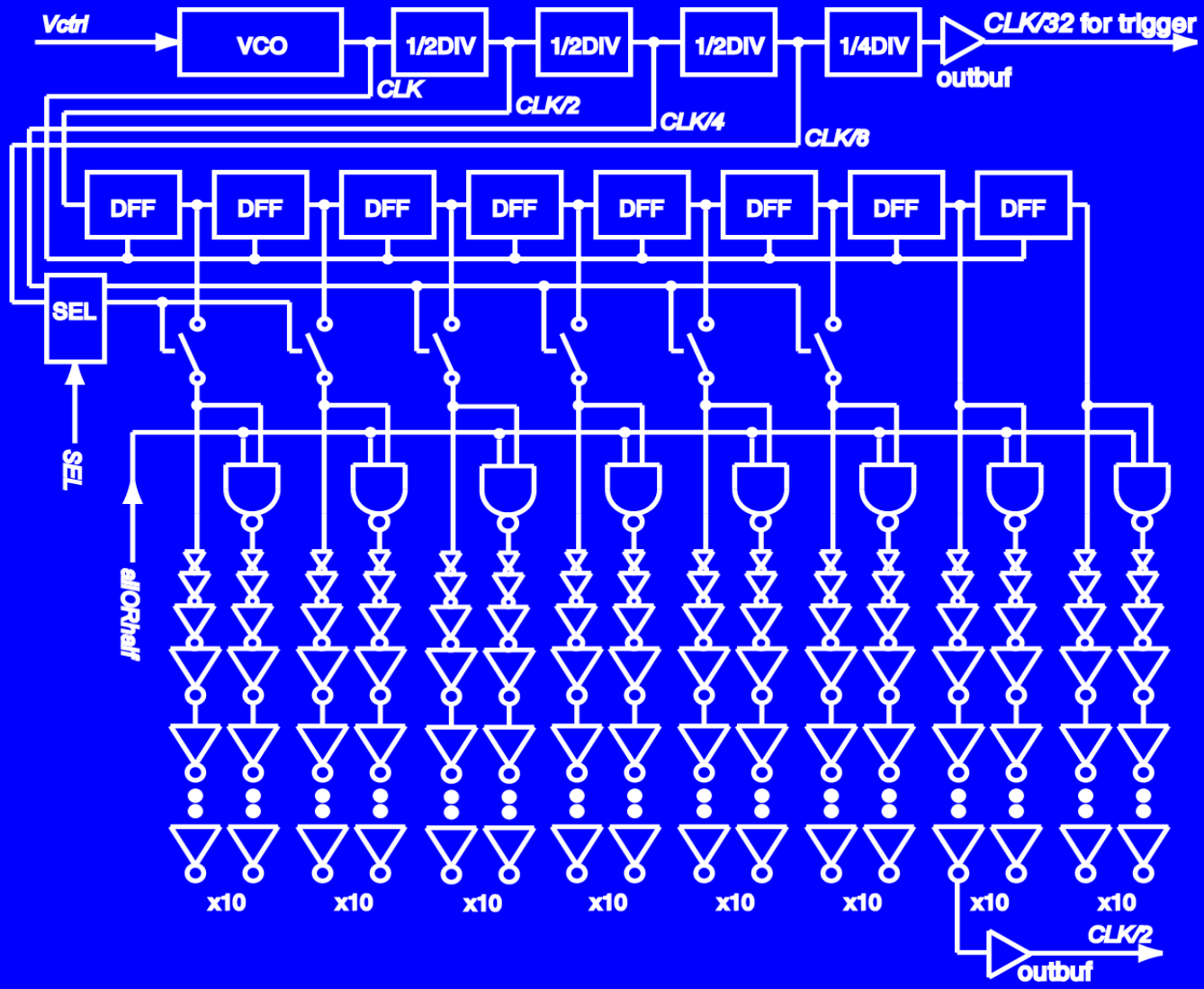


Amplifier / Output buffer

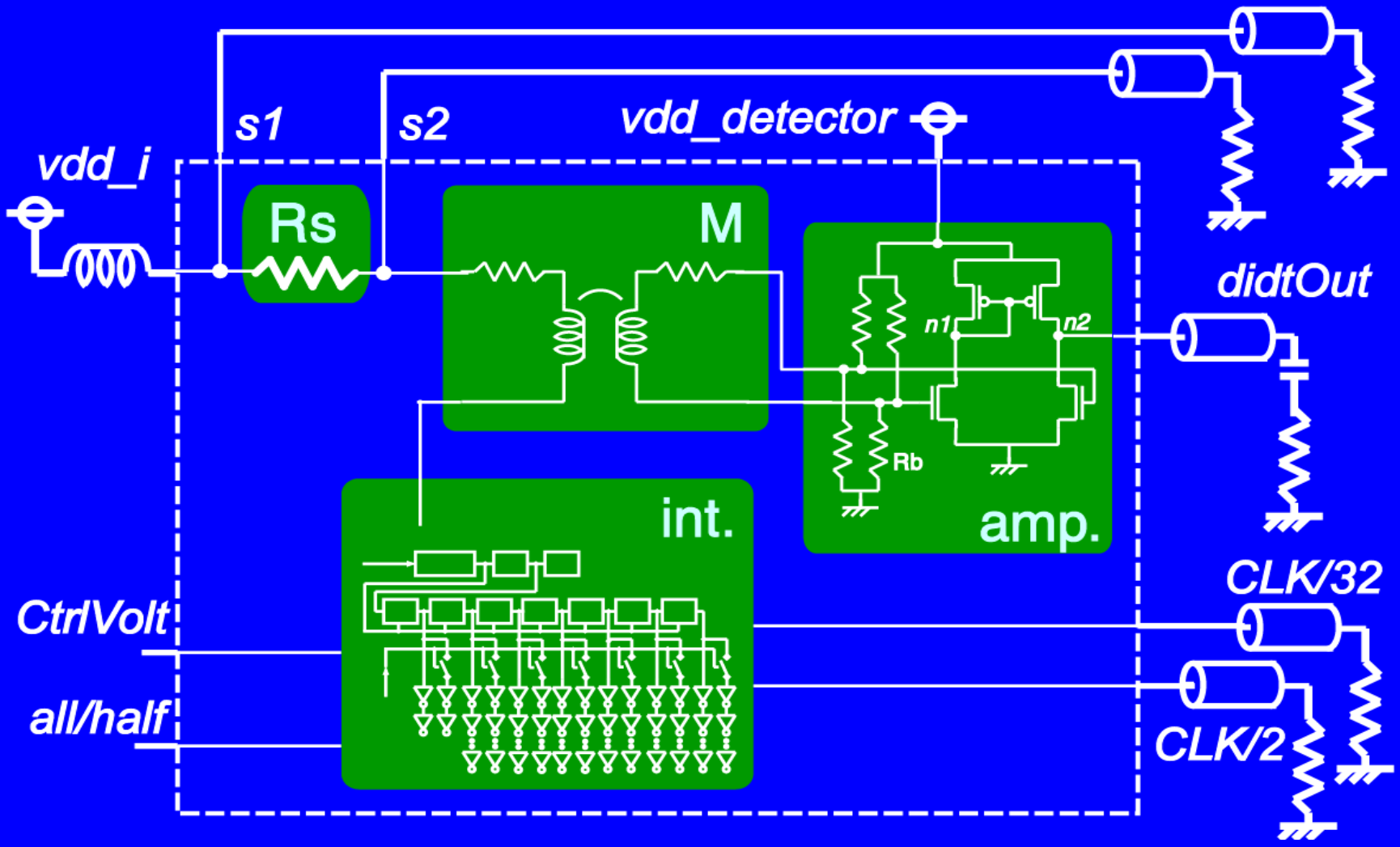
- Gain: 0.76, fcut-off: 3.3GHz
  Linearity: ±0.35V (simulation)



Internal Circuit as Noise Source

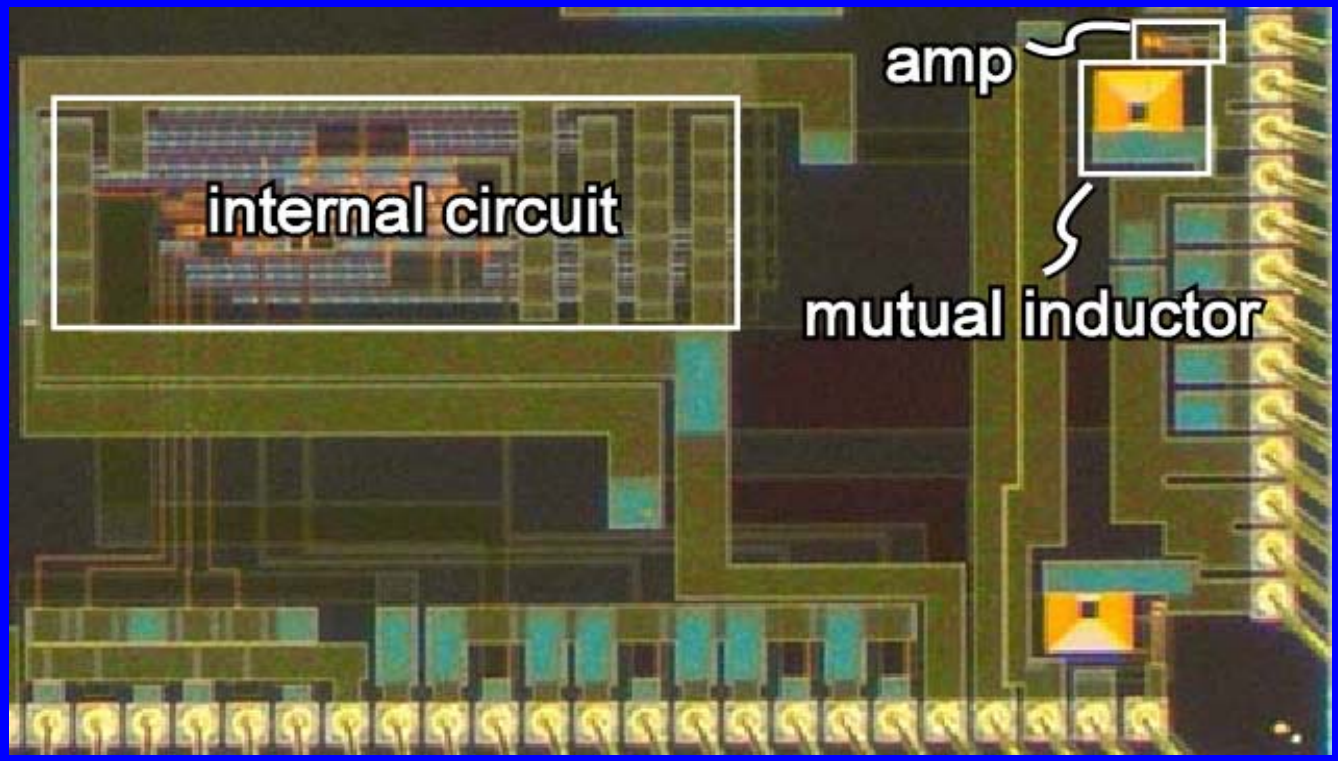


Whole Circuit / Meas. Setup



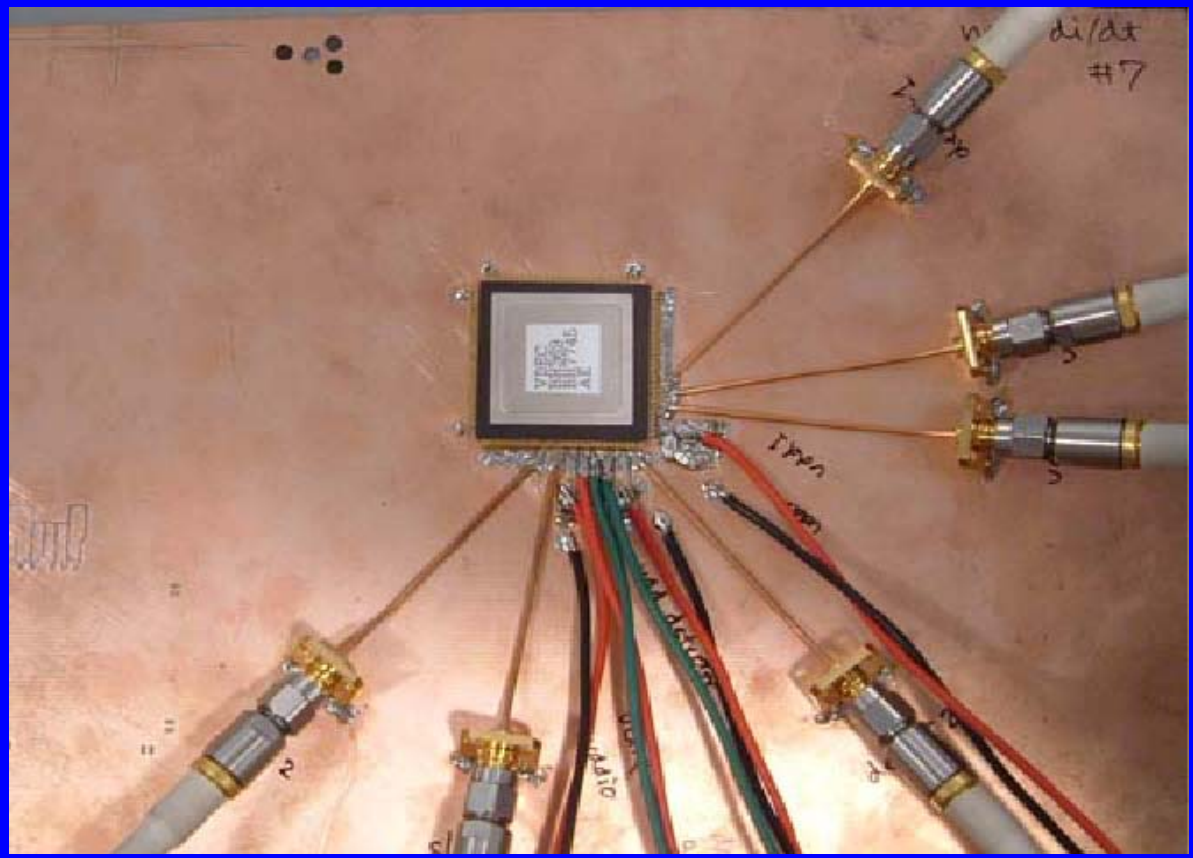
Chip Photograph

- 0.35um 3ML 2P CMOS
  - Circuit area : 3.0mm x 1.8mm.
  - di/dt detector core : 340um x 280um

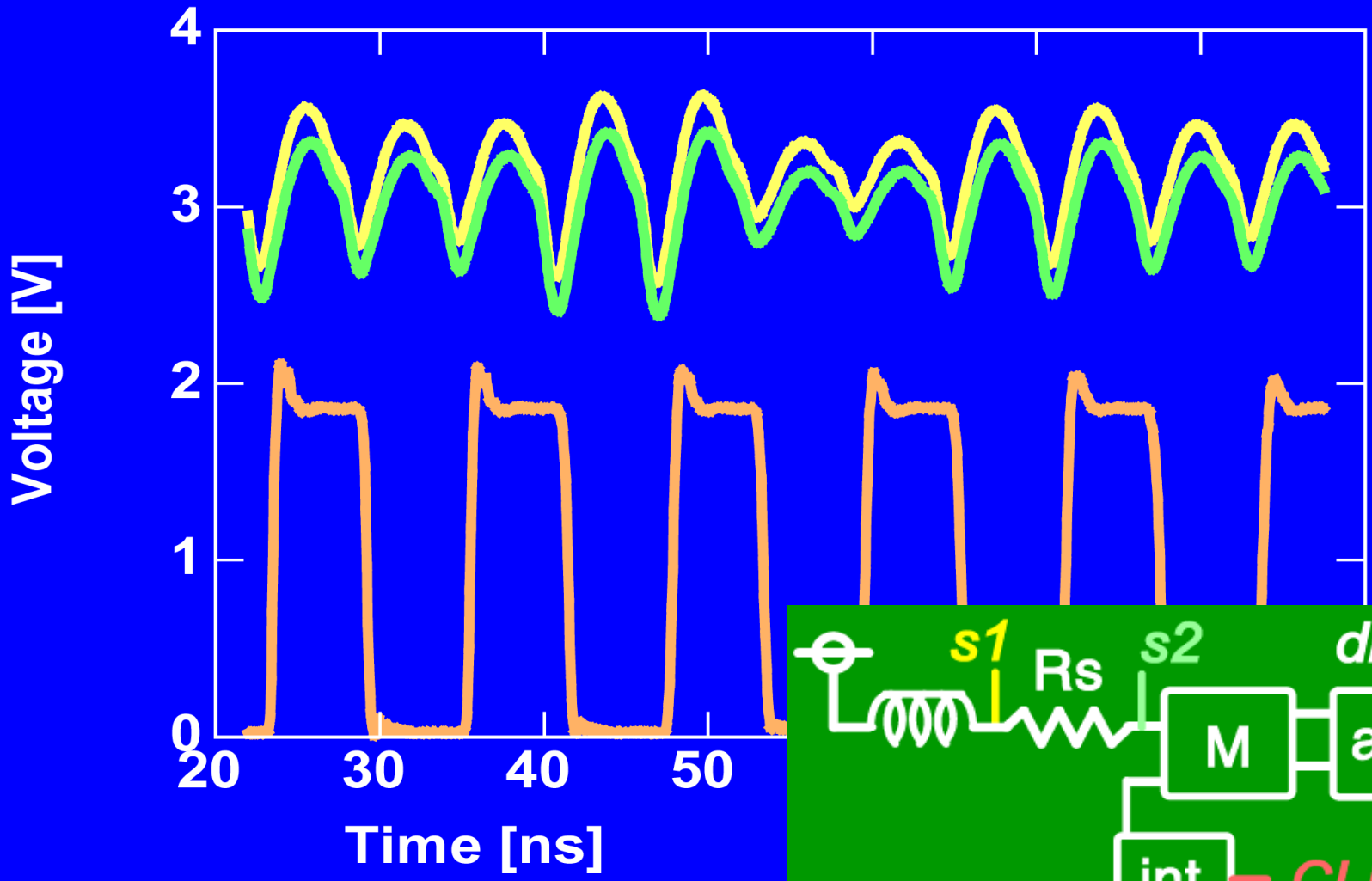


Measurement Setup

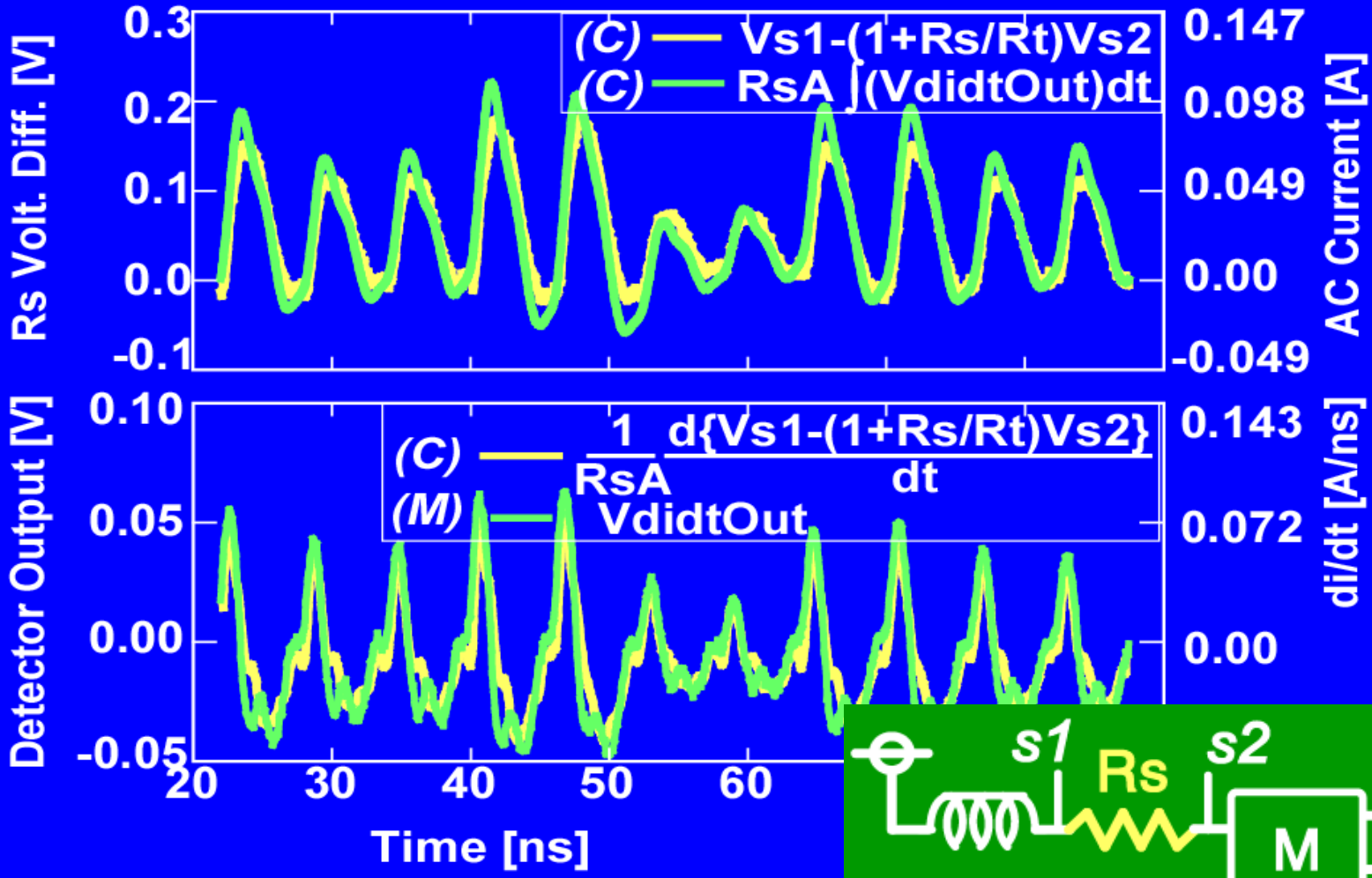
- The chip is mounted on a Cu board
- 50Ω transmission lines are connected

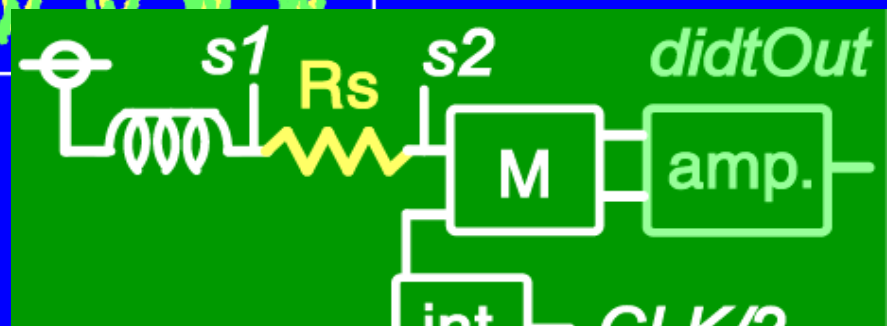


Waveforms #1


Voltage [V]
4
3
2
1
0
20
30
40
50
Time [ns]
s1
Rs
s2
didtOut
M
amp.
int.
CLK/2

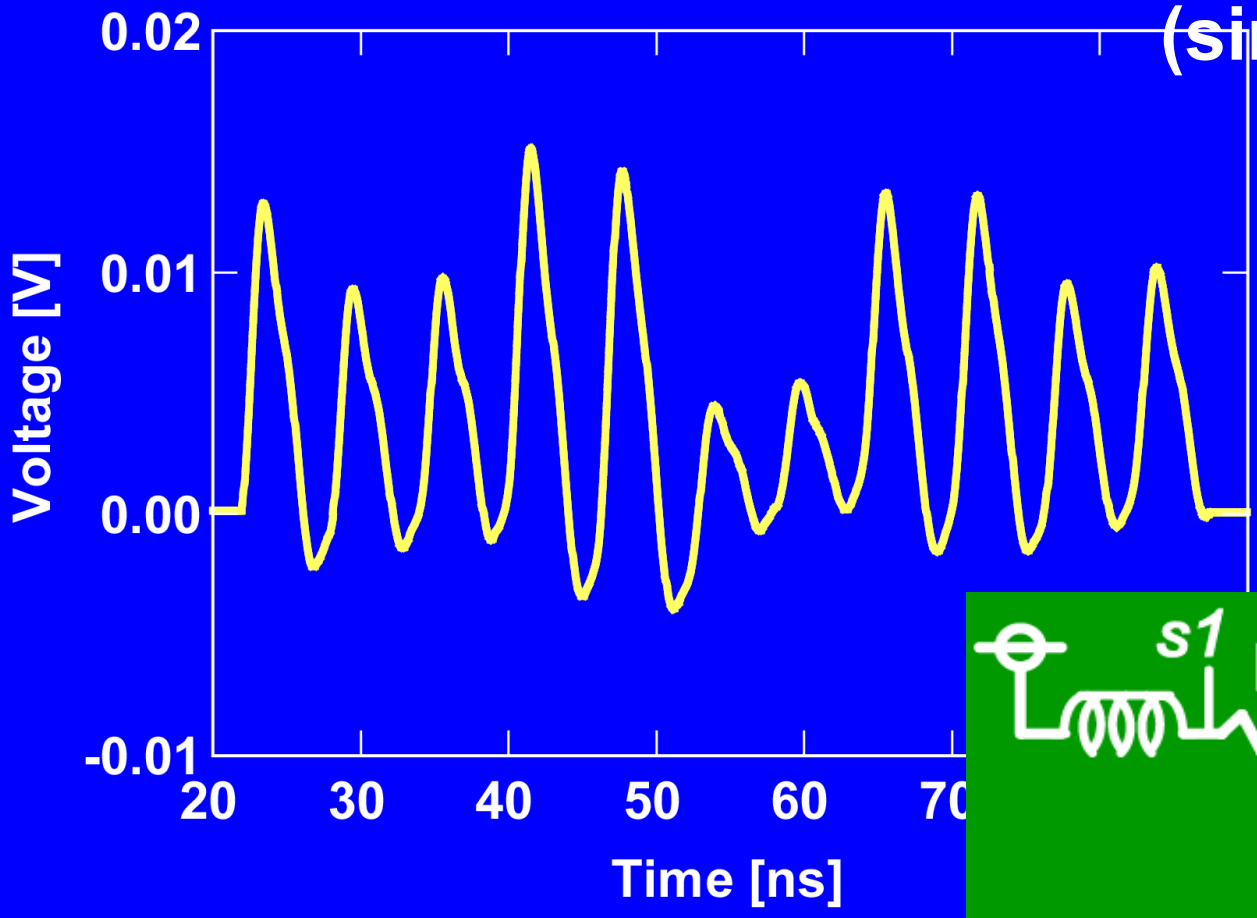
Waveforms #2

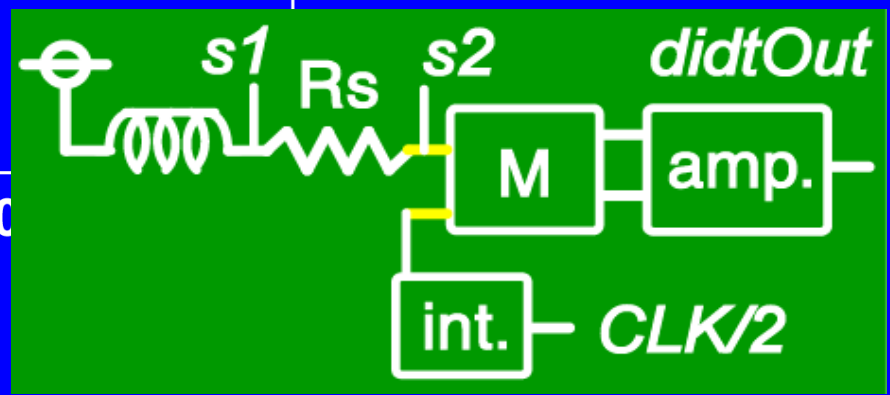

(C) Vs1-(1+Rs/Rt)Vs2
(C) RsA ∫(VdidtOut)dt
Rs Volt. Diff. [V]
AC Current [A]
0.3
0.2
0.1
0.0
-0.1
0.147
0.098
0.049
0.00
-0.049
(C) 1/RsA d{Vs1-(1+Rs/Rt)Vs2}/dt
(M) VdidtOut
Detector Output [V]
di/dt [A/ns]
0.10
0.05
0.00
-0.05
0.143
0.072
0.00
20
30
40
50
60
Time [ns]


s1
Rs
s2
didtOut
M
amp.
int

di/dt Detector Input Impedance

- Voltage drop caused by the di/dt detector (simulation result)





Specifications

- Area : 280um x 340um
- Pin count : 3

  di/dt output, Vdd/Gnd for Amp.
- Input Impedance : R=0.14Ω, L=0.26nH
- Accuracy : 10mA/ns
- Measurable range : 500mA/ns
- Measurable freq. : 3.3GHz

Summary

- On-chip di/dt detector core has been developed
- It consists of a power supply line, underlying spiral inductor, an amplifier
- di/dt waveforms obtained from the di/dt detector and the resistor agree well
- Current waveform can be calculated by integrating the detector output by time