Measurement of Timing Error Detection Performance of Software-based Error Detection Mechanisms and Its Correlation with Simulation

Yutaka Masuda, Masanori Hashimoto, Takao Onoye

Dept. of Information Systems Eng., Osaka University

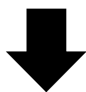
{masuda.yutaka, hasimoto}@ist.osaka-u.ac.jp

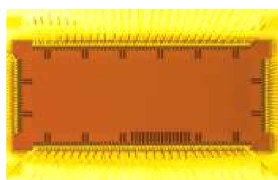
Agenda

- Background and objective
- Silicon measurement
- Correlation between silicon measurement and simulation
- Conclusion

Challenges in Post-Silicon Validation

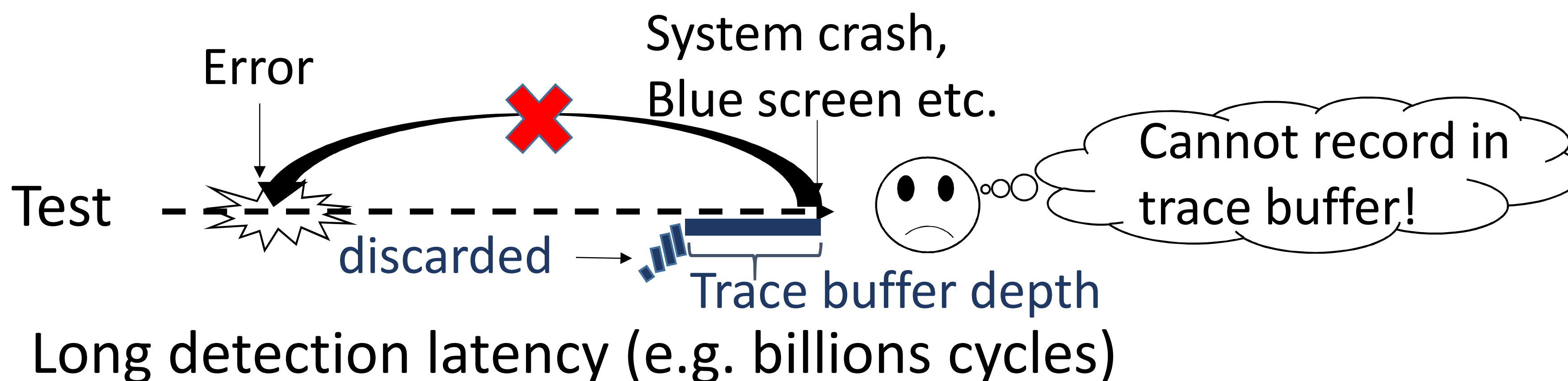
A number of tests





Unexpected behavior happens due to
- logic bug
- Electrical timing error (This work)

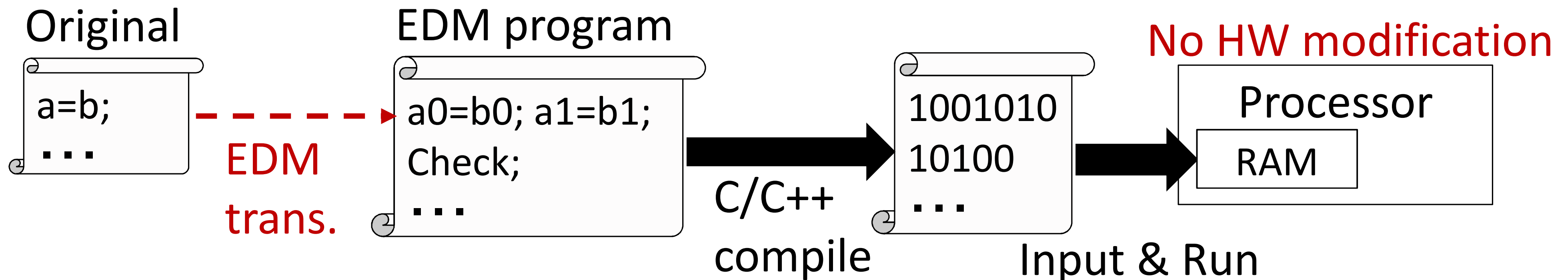
To localize errors w/ trace buffer, we need to quickly detect errors !!



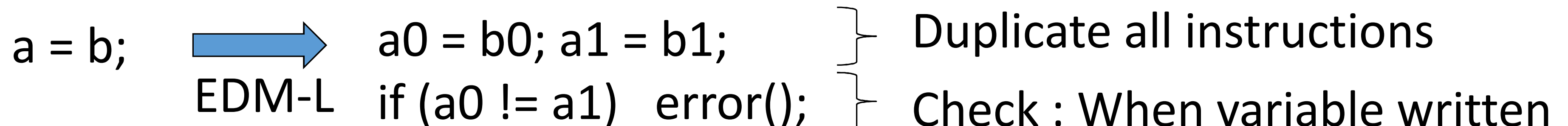
Long detection latency (e.g. billions cycles)

EDM* Trans. for quick error detection

(*) Error Detection Mechanisms, one of SW-based error detec. tech.



Eg. EDM-L (EDM for short Latency) [1]



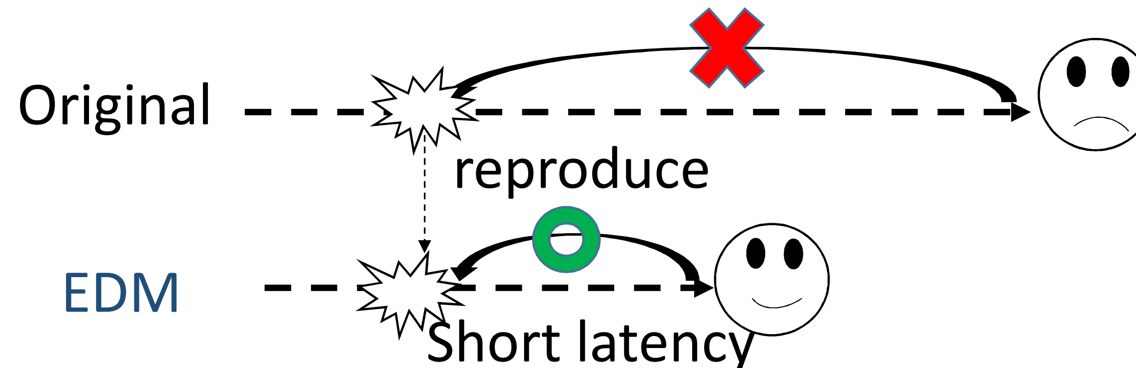
EDM-L quickly detects 86 % of elect. timing errors that vary exec. results [1]. (only evaluated in simulation.)

[1] Y. Masuda, M. Hashimoto, and T. Onoye, “Performance Evaluation of Software-based Error Detection Mechanisms for Localizing Electrical Timing Failures under Dynamic Supply Noise,” *Proc. ICCAD*, 2015.

Objective

1. To answer **"How much electrical errors can EDM* localize?"** based on **silicon measurement**!
2. To evaluate correlation between sim. and silicon results.

Scenario 1 : Localize electrical errors in original program.



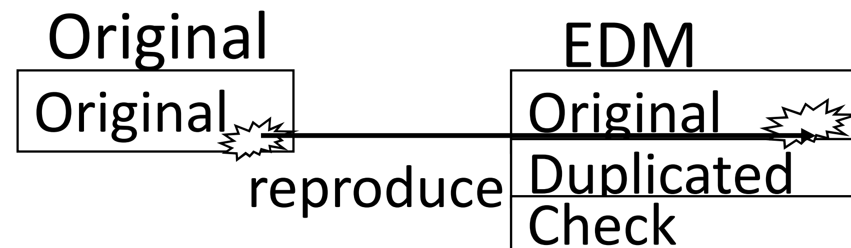
Scenario 2 : Localize electrical errors that vary exec. results.

Reproducibility and Detectability

For making EDM work well, 2 conditions should be satisfied.

COND1 : Reproducibility

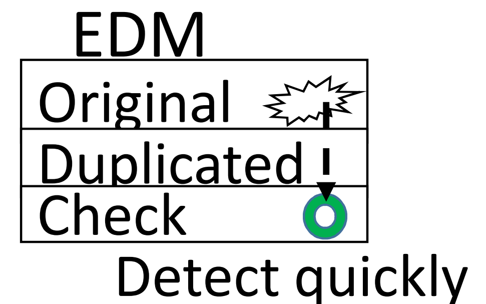
(necessary for Scenario1)



COND2 : Detectability

(necessary for Scenario1 and Scenario2)

error latency ≤ 1000 cycles → satisfied



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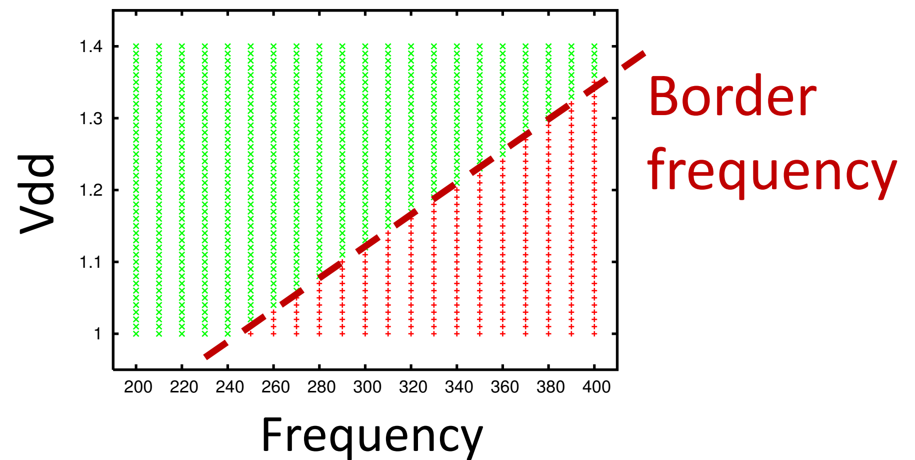
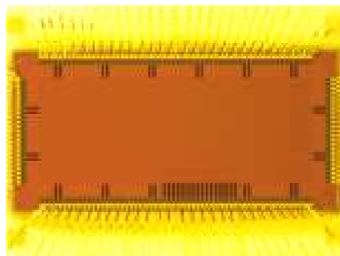
Preparation

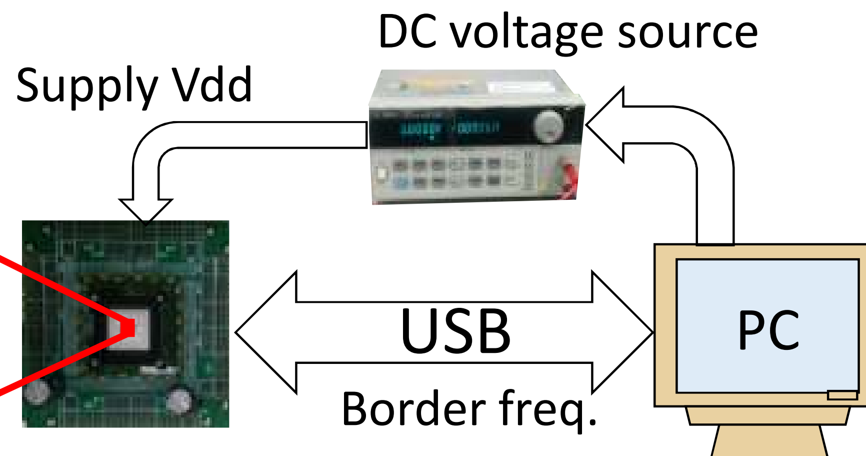
Evaluate error occurrence border freq. for each workload and Vdd



Test chip

(MeP processor fabricated in 65nm)

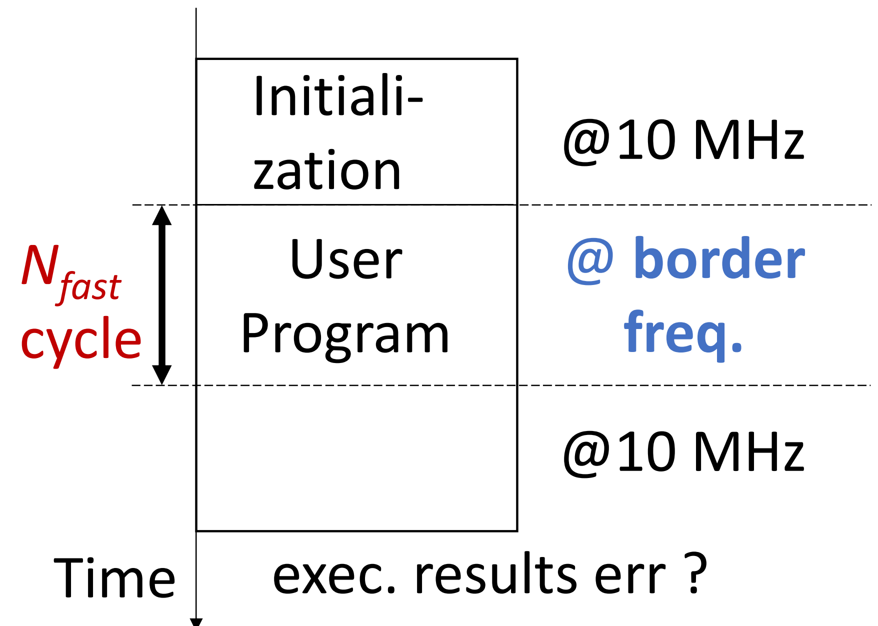




Measurement

Evaluate error occurrence time for computing error detection latency.

- repeat program execution by changing *N_{fast}* in binary search manner

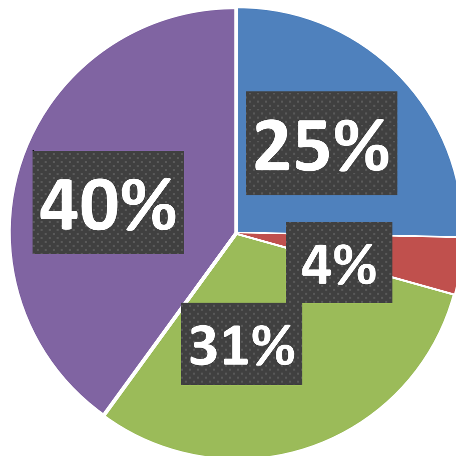


Total : 75 measurements

- User program : dijkstra, sha, crc (MiBench)
- Supply voltage : 1.0 - 1.4 V with 0.1V interval
- Test chip : 5 chips

Evaluation Result

Scenario1

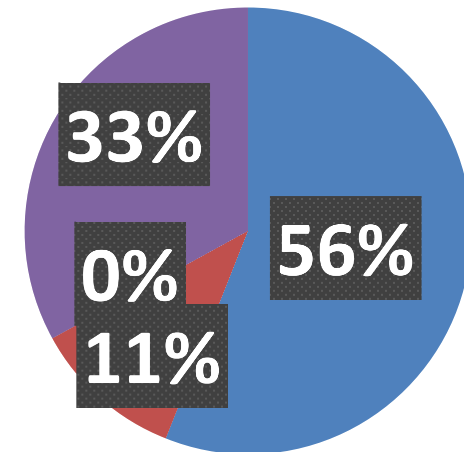


COND1 : Reproducibility
COND2 : Detectability

- Both COND1 and COND2 satisfied
- Only COND1 satisfied
- Only COND2 satisfied
- Neither COND1 nor COND2 satisfied

Detect 25 % of original errors.

Scenario2



- Detected & Latency < 1000 cycles
- Detected & latency > 1000 cycles
- Not detected & correct results
- Not detected & incorrect results

Detect 56 % of errors varying results.

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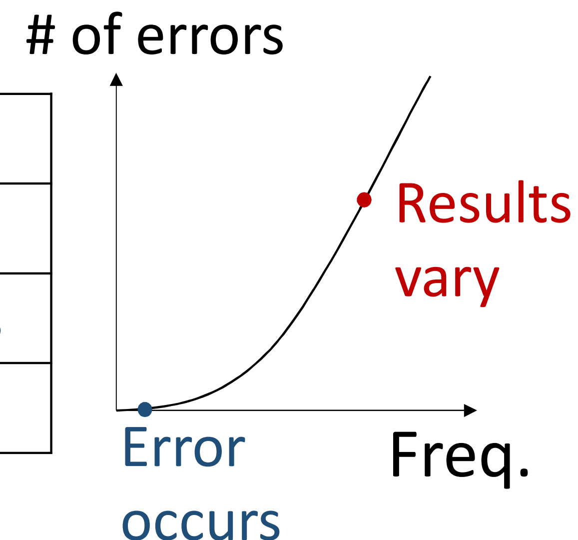
Simulation setup

Consider 2 simulation setup

1. Previous Sim.[1]
2. Sim. which updates PDN and definition of border freq.

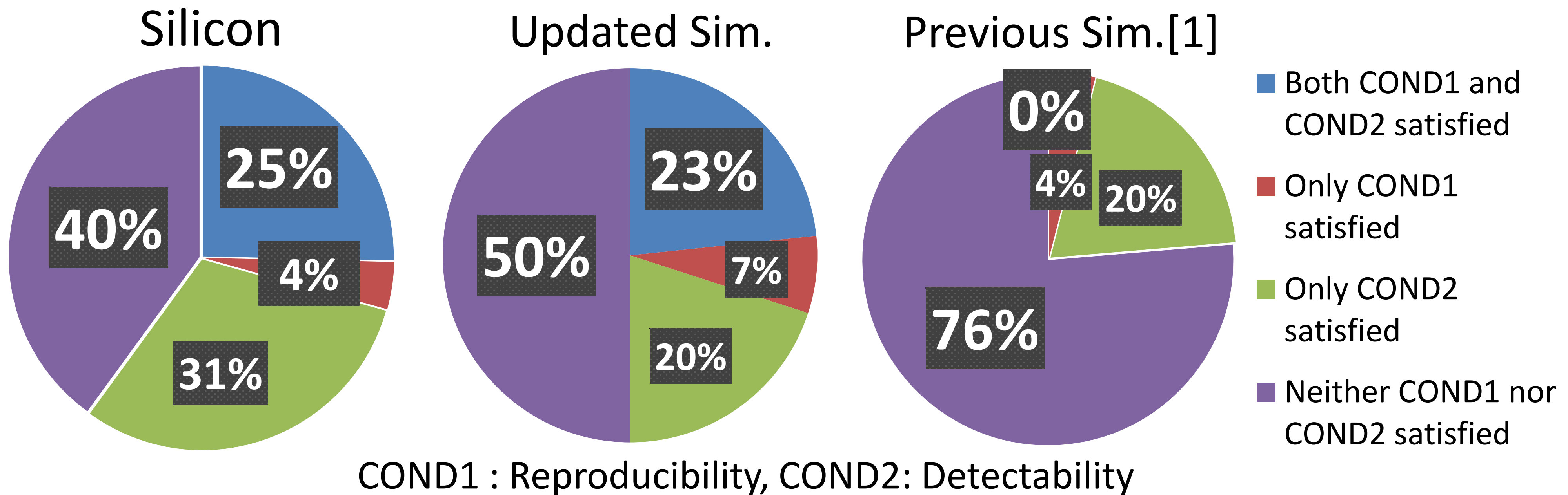
Evaluation setup

	PDN design	Border freq.
Silicon	Low noise	Exec. results vary
Previous Sim.[1]	3% - 7% Vdd drop	Timing error occurs
Updated Sim.	Zero noise	Exec. results vary



Correlation between silicon and sim. (Scenario1)

(Localize electrical timing errors in original program)

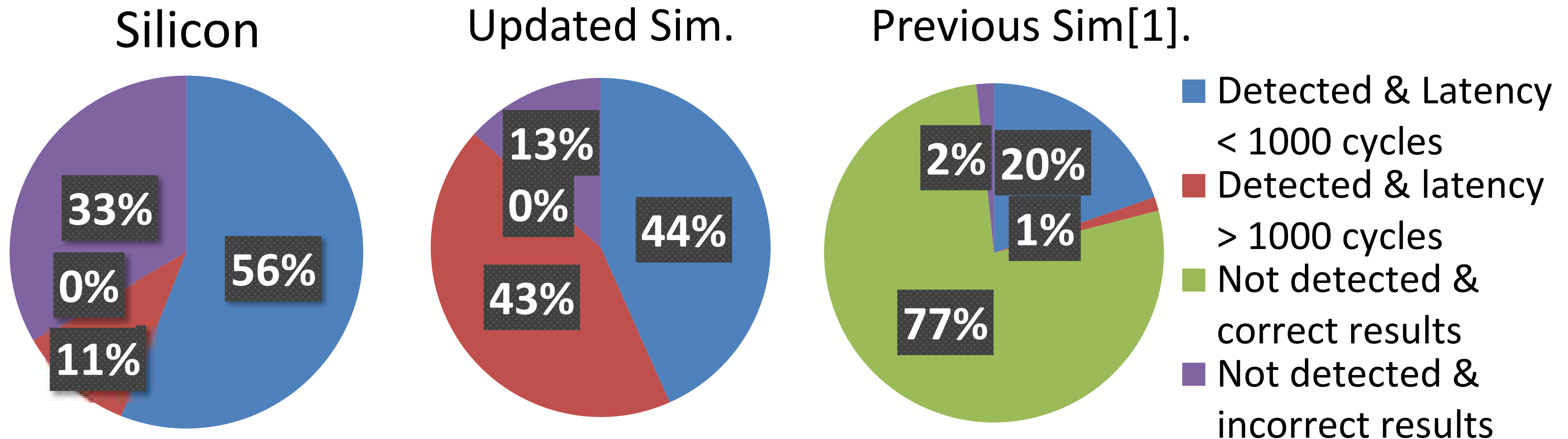


COND1 : Reproducibility, COND2: Detectability

- Consistent between updated sim. and silicon
  - Detectability for original errors : 25%(Silicon)
    23%(updated Sim.)

Correlation between silicon and sim. (Scenario2)

(Localize potential errors that vary results)



- Consistency improvement by simulation update

For errors varying results, EDM detects 56 % (Silicon)

44 % (Updated Sim.)

87 % $= \frac{0.2}{1-0.77}$ (Previous Sim.)

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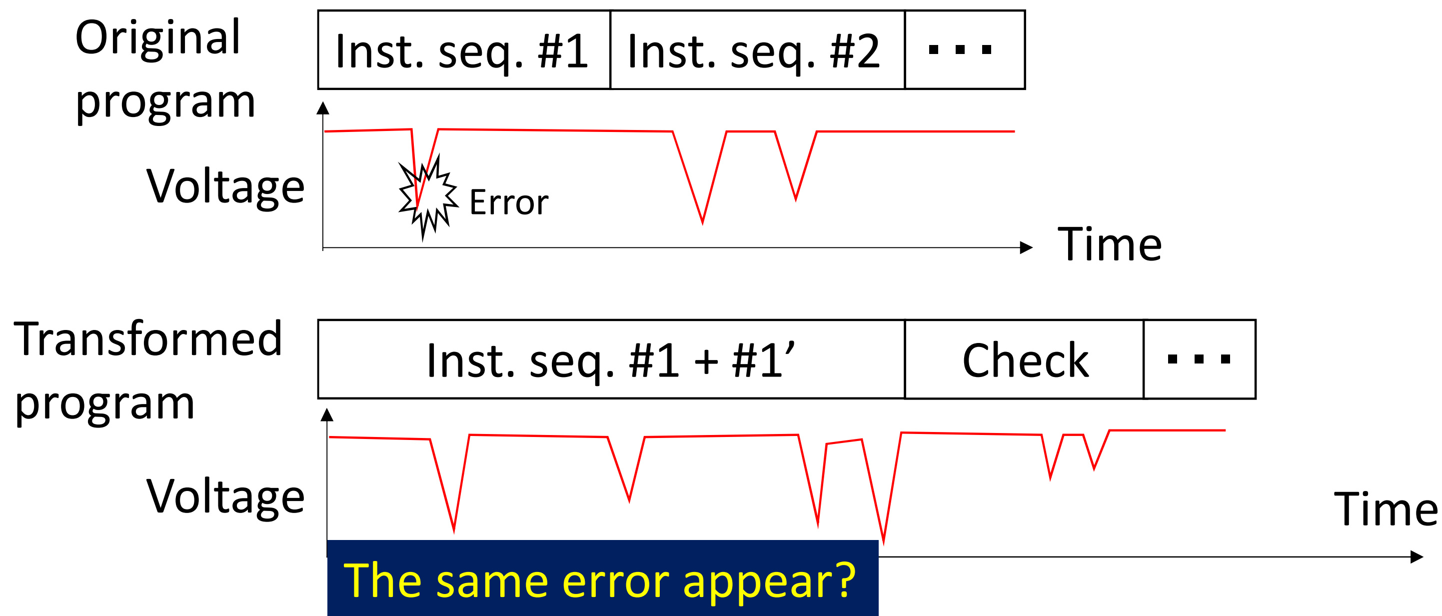
Conclusion

- Evaluated error detection performance of EDM transformation for supply noise induced timing errors based on silicon measurement.
  - Considered two EDM usage scenarios
  - In scenario1, EDM detected 25% of original errors.
  - In scenario2, EDM detected 56% of errors varying results.
- Evaluate correlation of EDM performance between sim. and silicon.
  - Update PDN design and definition of border frequency.
  - Consistent between updated sim. and silicon.

Backup Slide
Difficulty of Electrical Error Localization

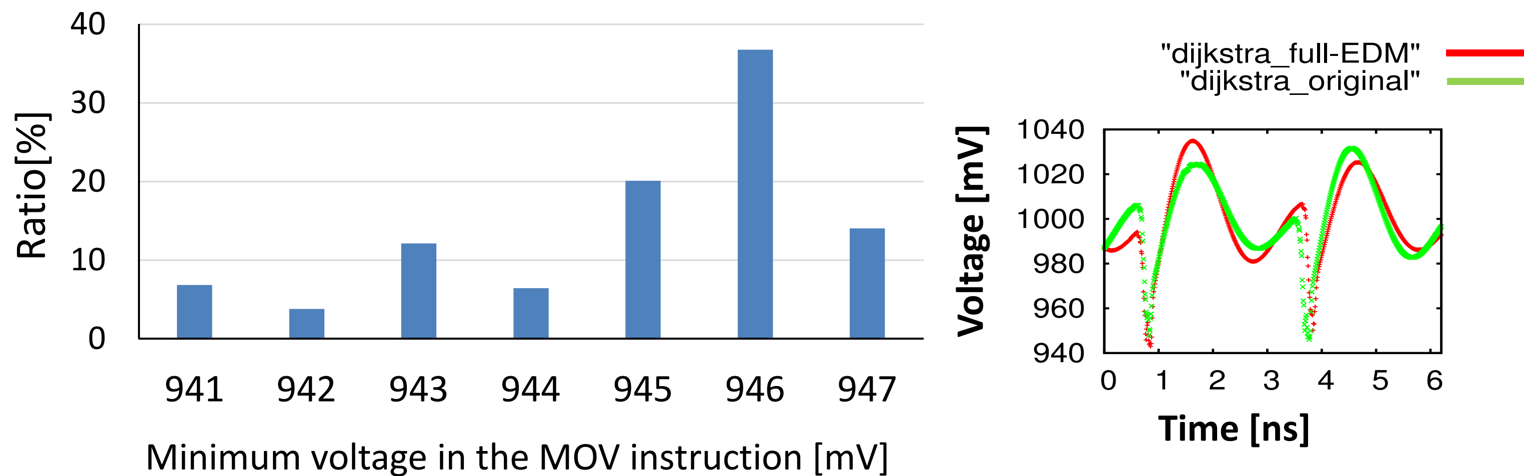
Program transformation change inst. sequence.

Supply voltage varies.



Can SW-based trans. debug the original error ?

Backup Slide
Why low reproduction ratio?



Even when the same instructions are executed, memory and registers usage changes.

⇒ EDM changes inductive noise and this prevents the error reproduction.