Fuzzing for Discovering Bugs and Side Channels in Processors

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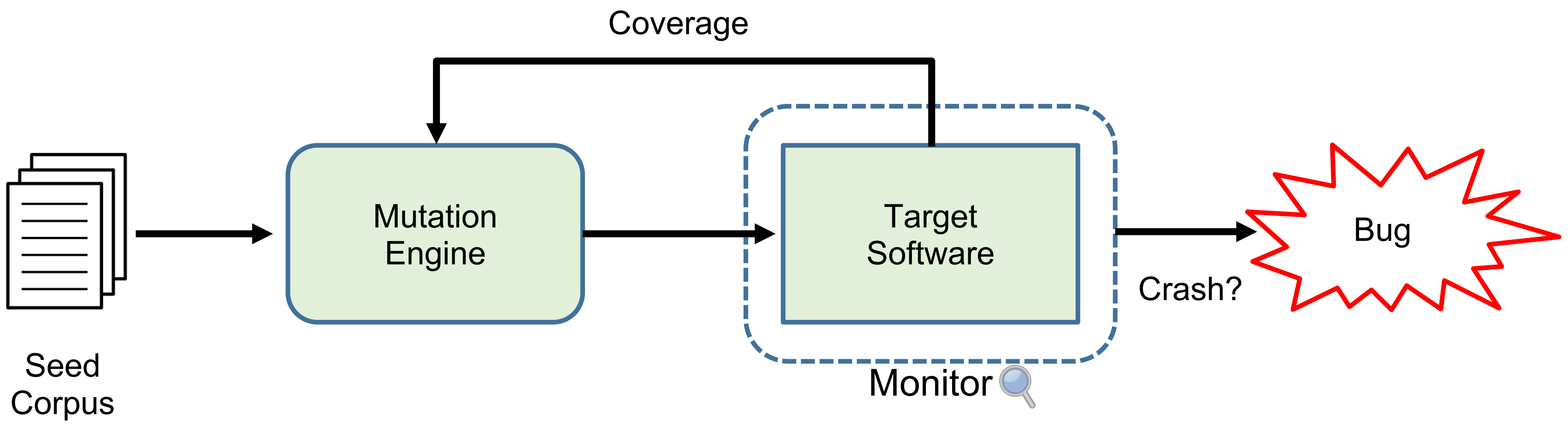
Outline

- What is Fuzzing?
- ProcessorFuzz: Processor Fuzzing with Control and Status Registers Guidance [1]
- SIGFuzz: A Framework for Discovering Microarchitectural Timing Side Channels [2]
- Summary

What is Fuzzing?

- Fuzzing/fuzz testing:
  - Running the target software with random or mutated inputs.

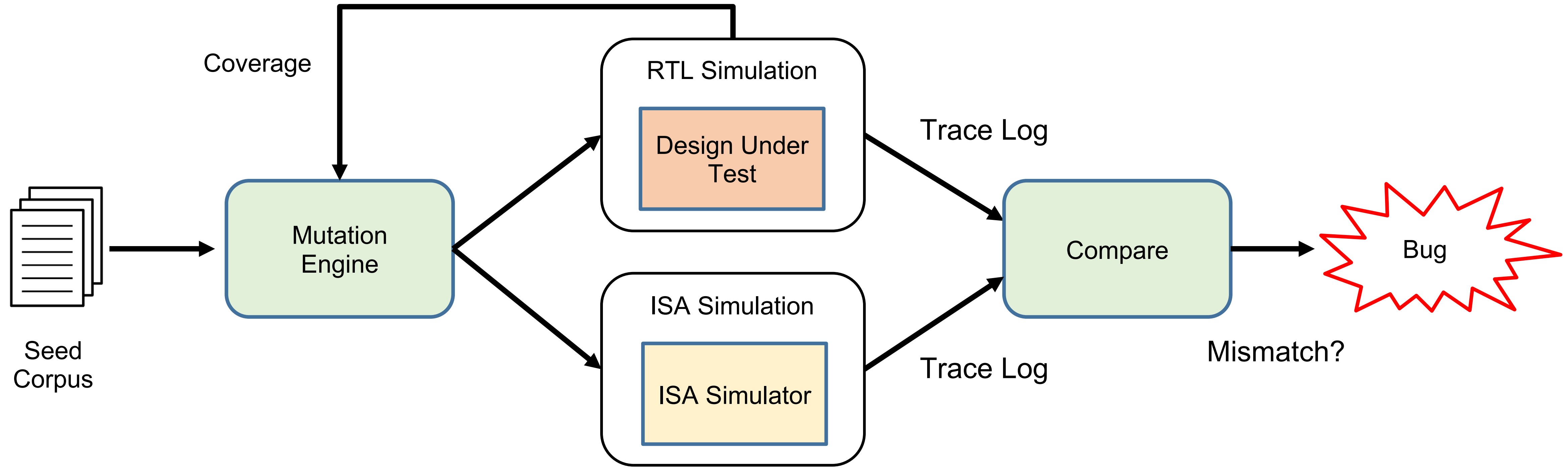


Adapting Fuzzing for Hardware Testing

- What is the input format and how to mutate the inputs?
  - Driving RTL signals Vs assembly test programs
  - Mutations
- What is the coverage feedback metric?
  - Standard RTL coverage metrics Vs new coverage metrics for fuzzing
- How to detect when the **bugs** get triggered?
  - Golden models
  - Hardware equivalent of a software crash?

Fuzzing for Hardware Testing

- Fuzzing has been ‘recently’ adapted for hardware testing.
- Hardware fuzzing research is rapidly growing [5-7].

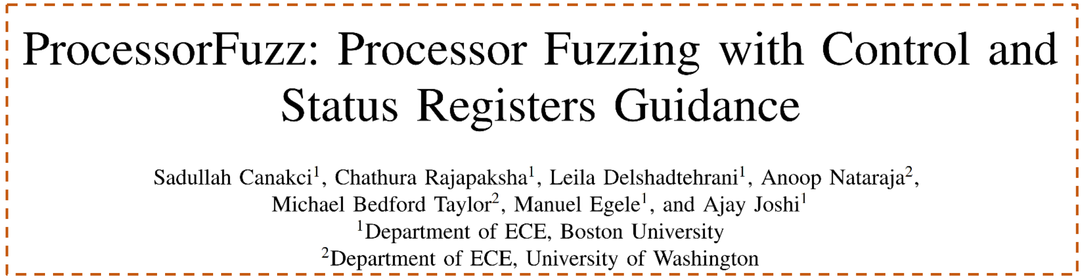


Our Contributions

- What is the input format and how to mutate it?
  - Driving RTL signals Vs assembly test programs
  - Mutations

- What is the coverage feedback metric?
  - Standard RTL coverage metrics Vs. New coverage metrics for fuzzing

- How to detect when the **bugs** get triggered?
  - Golden models
  - Hardware equivalent of a software crash?



ProcessorFuzz: Processor Fuzzing with Control and Status Registers Guidance

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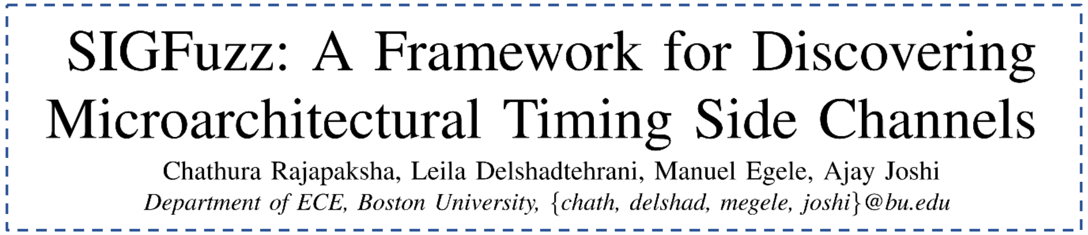

SIGFuzz: A Framework for Discovering Microarchitectural Timing Side Channels

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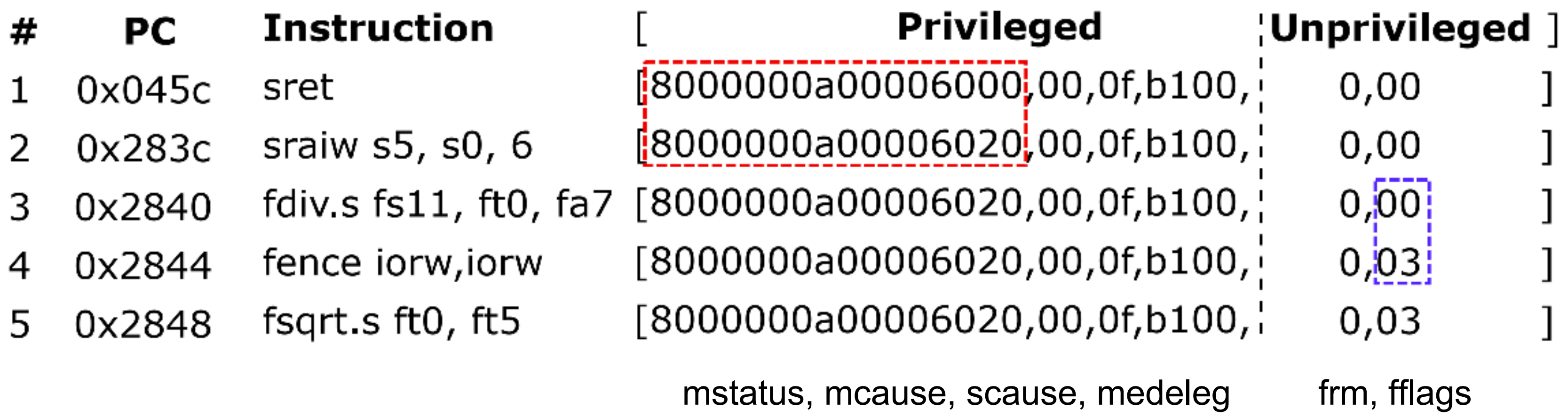
ProcessorFuzz: Processor Fuzzing with Control and Status Registers Guidance

- Problem: Existing coverage metrics for processor fuzzing is limited by
  - Lack of support for widely used Hardware Description Languages (HDLs)
  - Misleading coverage feedback
- Introduces a new coverage metric for processor fuzzing.
  - New transition in CSR values -> coverage increase



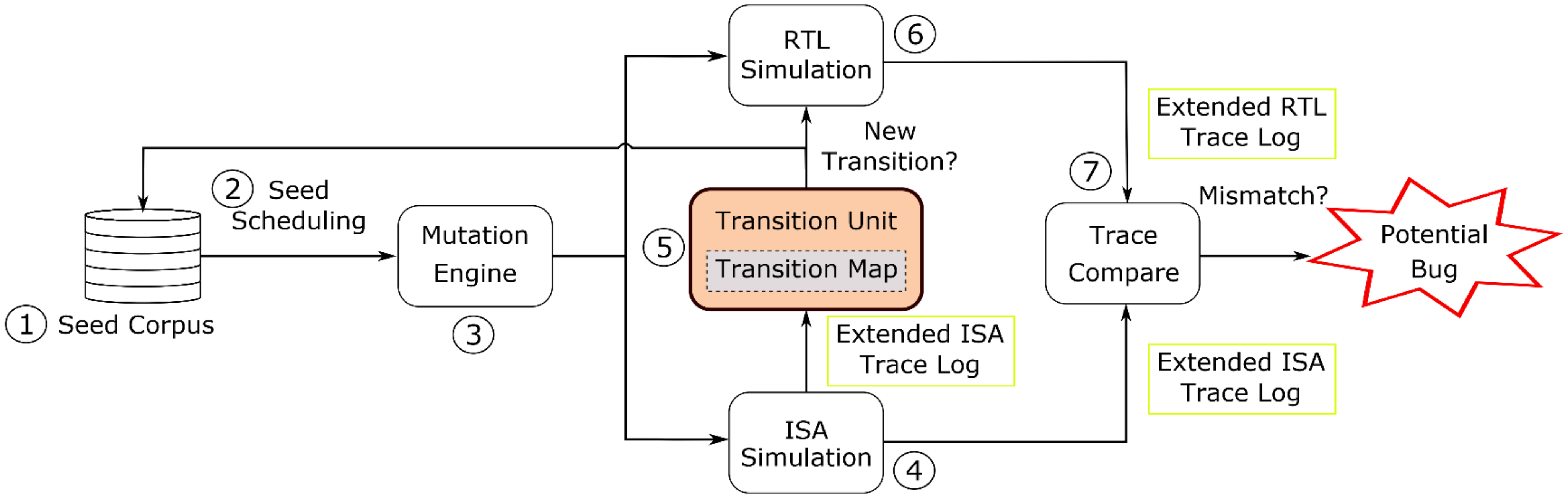
#	PC	Instruction	[Privileged	Unprivileged]
1	0x045c	sret	[8000000a00006000,00,0f,b100,	0,00]
2	0x283c	sraiw s5, s0, 6	[8000000a00006020,00,0f,b100,	0,00]
3	0x2840	fdiv.s fs11, ft0, fa7	[8000000a00006020,00,0f,b100,	0,00]
4	0x2844	fence iorw,iorw	[8000000a00006020,00,0f,b100,	0,03]
5	0x2848	fsqrt.s ft0, ft5	[8000000a00006020,00,0f,b100,	0,03]

mstatus, mcause, scause, medeleg

frm, fflags

ProcessorFuzz: Design Overview

- ProcessorFuzz uses an ISA simulator to collect CSR transition coverage, making the coverage collection more efficient and HDL agnostic.



ProcessorFuzz: Evaluation

- Evaluated on Rocket [8], BOOM [9], and BlackParrot [10] RISC-V processors.
- Detect known bugs 23% faster than the state-of-the-art DifuzzRTL [7].
- Discovered 9 new bugs
  - 6 in BlackParrot processor
  - 2 in Rocket and BOOM processors
  - 1 in Dromajo ISA simulator

SIGFuzz: A Framework for Discovering Microarchitectural Timing Side Channels

- Problem: Existing methods are limited in
  - Scalability
  - Scope of side channels they can discover
- SIGFuzz introduces a generic method for discovering microarchitectural timing side channels.

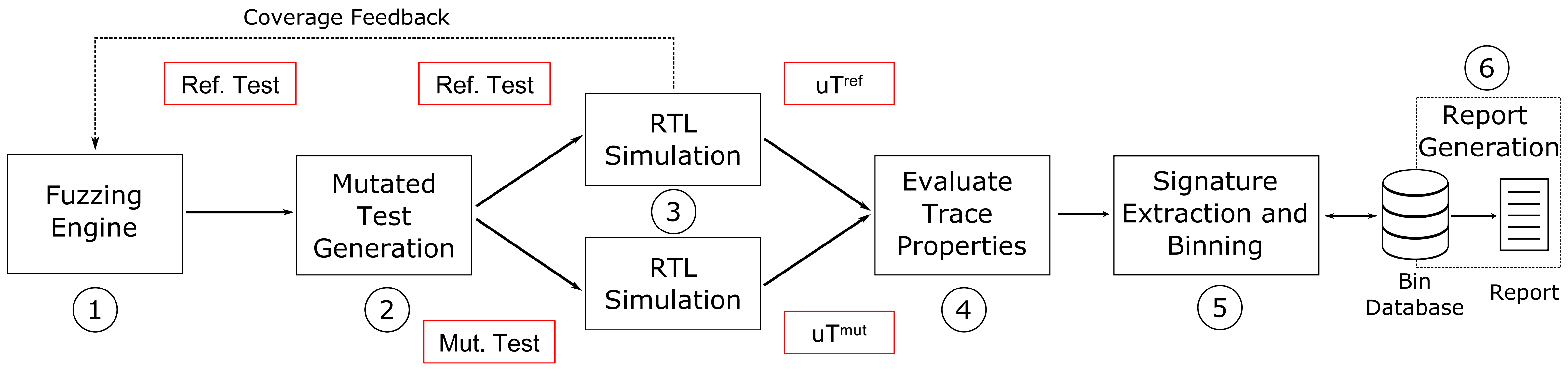
	Reference Test	Mutated Test	
t^{ref}_1	1: …	1: …	t^{mut}_1
t^{ref}_2	2: div x1, x5, x6	2: div x1, x5, x6	t^{mut}_2
t^{ref}_3	3: **mul x8, x15, x21**	3: ***nop***	t^{mut}_3
t^{ref}_4	4: …	4: …	t^{mut}_4

$t^{ref}_2 \neq t^{mut}_2 \Rightarrow$ Potential Side Channel

Trace Property 1

SIGFuzz: Design Overview

- SIGFuzz flags potential timing side channels using trace properties evaluated on cycle-accurate commit traces.



SIGFuzz: Evaluation

- Evaluated on Rocket and BOOM RISC-V processors.
- Discovered both known and new timing side channels.
  - 3 new side channels
  - 2 known side channels
- Spectre-style attack based on a newly discovered side channel on BOOM

Summary

- Fuzzing is a proven software testing technique that is recently adapted for hardware testing.

- **ProcessorFuzz** introduces a new coverage metric based on CSRs, which improves the overall efficiency of processor fuzzing.
  - ProcessorFuzz discovered 8 new bugs in Rocket, BOOM, and BlackParrot processors.
  - ProcessorFuzz will be open-sourced soon: https://github.com/bu-icsg/ProcessorFuzz

- **SIGFuzz** introduces a generic method for discovering a broader scope of microarchitectural timing side channels in processors.
  - SIGFuzz discovered 3 new side channels in Rocket and BOOM processors.
  - SIGFuzz is open-sourced: https://github.com/bu-icsg/SIGFuzz

References

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