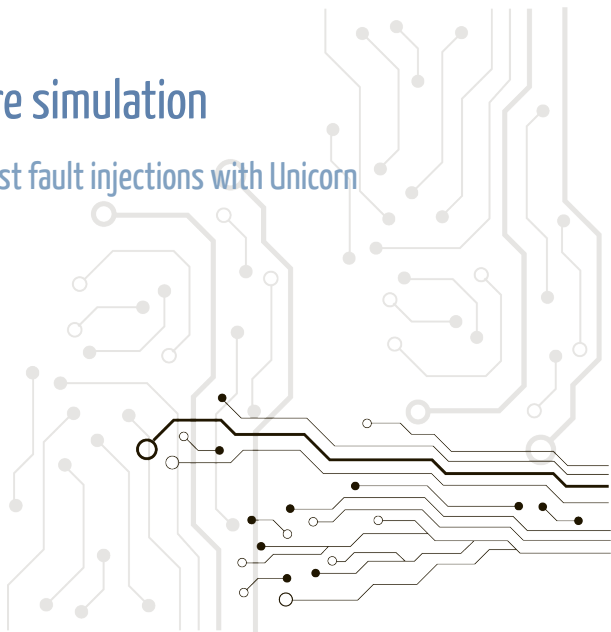




Fault injection through hardware simulation

How to evaluate your countermeasures against fault injections with Unicorn

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Fault Injection

Unicorn Engine

Simulation Environment

Conclusion





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» Context

Sources of faults in a system:

- * Harsh environment
- * Adversary

Risks?

- * Undesired change in a program control flow
- * System crash

Solution?

1. Implement countermeasures
2. Test them in practice (expertise is required)
3. Identify new vulnerabilities
4. Repeat

» Fault Injection Simulation

Why would hardware simulation be useful?

- * Does not require expensive equipment
- * No risk to damage important components
- * Allows precise actions on instructions and registers
- * Environment is easy to setup
- * Simulations are fast to perform and reproducible

Ideal to test countermeasures against fault injections.

» Project Description

Objectives:

- * set up simulation environment
- * perform firmware vulnerability analysis
 - **automatic fault injection simulation**
 - SCA feature: cycle count annotation

Setup:

- * ARM GNU Toolchain: C code compilation
- * Unicorn: CPU emulation
- * Python: simulation tool implementation



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» Methods

Several methods exist to inject faults in a system:

- * Clock fault injection
- * Voltage fault injection
- * Electromagnetic fault injection
- * Optical fault injection
- * ...

» Fault Model Characteristics

Two main categories of fault injections:

- * Global: affects global parameters (voltage, clock)
- * Local: precise fault location (expensive equipment)

Fault models are essentially characterized by:

- * Location
 - Spatial: point or area in the system
 - Temporal: instant during the execution
 - Precision level: bit, byte, variable, ...
- * Impact: skip, stuck-at, bit-flip, random byte, ...

» Countermeasures: Examples

- * Double check important functions execution
- * Double check branching conditions
- * Verify that loops have not been aborted
- * Avoid boolean values to access critical functions

M. Witteman. *Secure application programming in the presence of side channel attacks*. Aug. 2017. URL: <https://www.riscure.com/publication/secure-application-programming-presence-side-channel-attacks/>.



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» Unicorn Engine

Overview

- * QEMU-based open-source project
- * CPU emulator
- * Multiple target architectures (ARM, ARM64, MIPS, RISC-V, ...)
- * Implemented in C, and many bindings exist
- * No requirement regarding emulation context
- * Easy to instrument (hooks on specific events)

» Unicorn Engine

Emulation

1. Create Unicorn instance
2. Read binary
3. Map program segments into instance memory
4. Prepare initial state/context (optional)
5. Define start and end addresses
6. Add hooks (syscalls, tracing)
7. Run the simulation

» Unicorn Engine

Fault Injection

Inject fault using method **(1)** or **(2)**:

1. → 6. Prepare Unicorn instance (see previous slide)
7. Add fault injection hooks **(1)**
8. Start the simulation
9. Perform fault injection **(2)**:
 - * halt simulation
 - * inject fault
 - * resume



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» Description

- * Based on Unicorn and dedicated to 32-bit ARM architectures
- * Using Python binding: easy to adapt to your needs
- * Two command line scripts:
 - one to explore possible fault attacks
 - one to perform/reproduce a specific fault attack
- * User may define external functions:
 - to set emulation context
 - to perform fault injection
 - to extract fault detection flags

» Fault Models

- * Skip instruction fault model
- * Register-based fault models:
 - “on instruction” fault (transient)
 - stuck-at fault (permanent)
 - bit flip fault (transient)
- * Memory-based fault models:
 - “on write access” fault (permanent)
 - “on read access” fault (transient)

Fault models are implemented using method **(1)**, i.e. hooks.

» Simulated Execution States

State Set of values extracted from registers and memory regions at a given point of the emulation

Initial state State before the emulation has been started

Final state State after the emulation has been completed

Reference state Final state of a “sane” emulation

» Status of Fault Attacks

- * If fault detection flags are extracted through external functions:
 - fault is ignored if detection flag was raised,
 - otherwise, fault injection may be logged.

- * Logging of fault injections works as follows:
 - fault injection is logged if a delta appears between the final state and the reference state,
 - otherwise, fault injection is ignored.

» Exploration of Fault Attacks Space

1. Select desired fault models
2. Try to perform a fault injection attack:
 - for each fault model,
 - for each instruction,
 - depending on written/read registers (if register-based),
 - for each value of the fault model parameters.
3. Identify the status of the fault attack
4. Log it if necessary

Note: limited set of values for each parameter of the different fault models

Demo.



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» Conclusion

- * Allows to inject faults in program running on specific architectures
- * Should be useful to check if countermeasures work as expected
- * Should allow to detect unknown vulnerabilities
- * Does not allow to test all specific countermeasures (e.g. delay-based)
- * Emulation of peripherals on a high level should be possible