6.S983
Secure Hardware Design

v0.3

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Spring 2023

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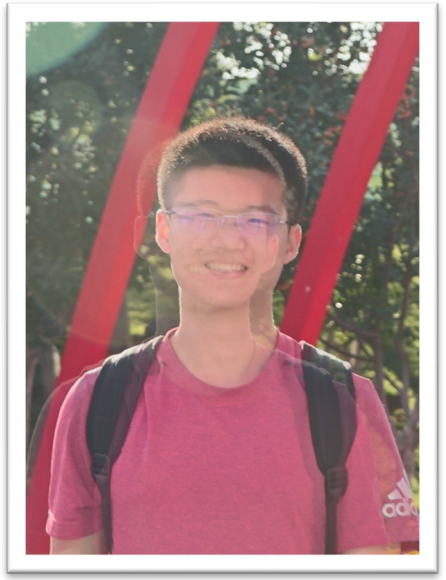

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Mengyuan Li

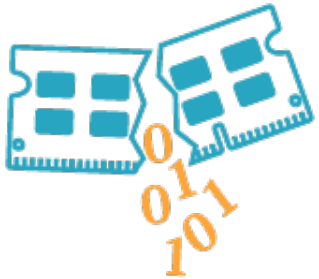
Today’s Agenda

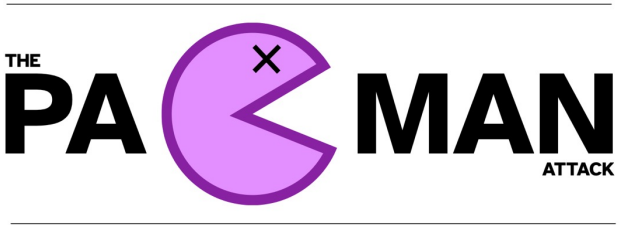
1. Course Overview

2. Course Logistics: assignments, labs, grading, etc.

Course Overview

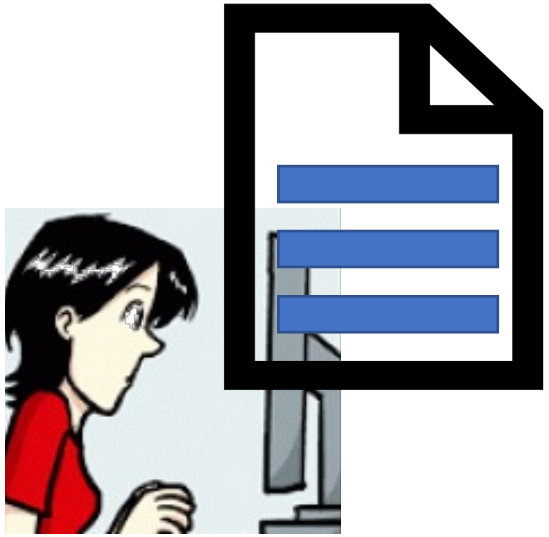
Hardware Attacks on The Spotlight

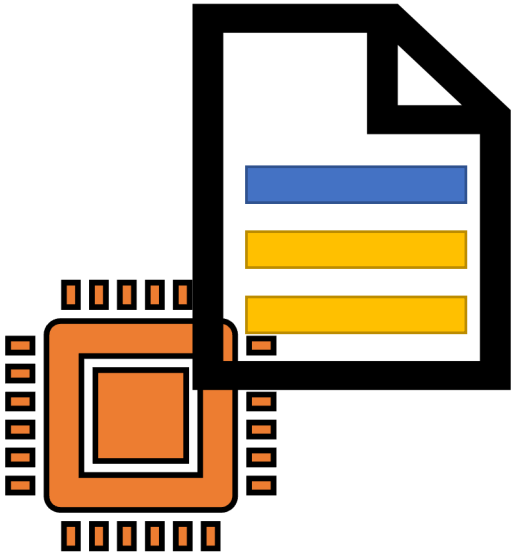




It is not a bug!

The attacks target the key micro-architecture mechanism of processors: speculative execution.





Hardware Security Defenses

Software Security Guidance

This information is designed for developers and systems experts looking to understand potential vulnerabilities and assess risk, with resources and recommendations for building more secure solutions.

Overview | Advisory Guidance | Best Practices | Disclosure Documentation | Feature Documentation | More Information

Advisory Guidance

Overviews and one-page descriptions of security advisories along with recommended mitigations for affected environments.

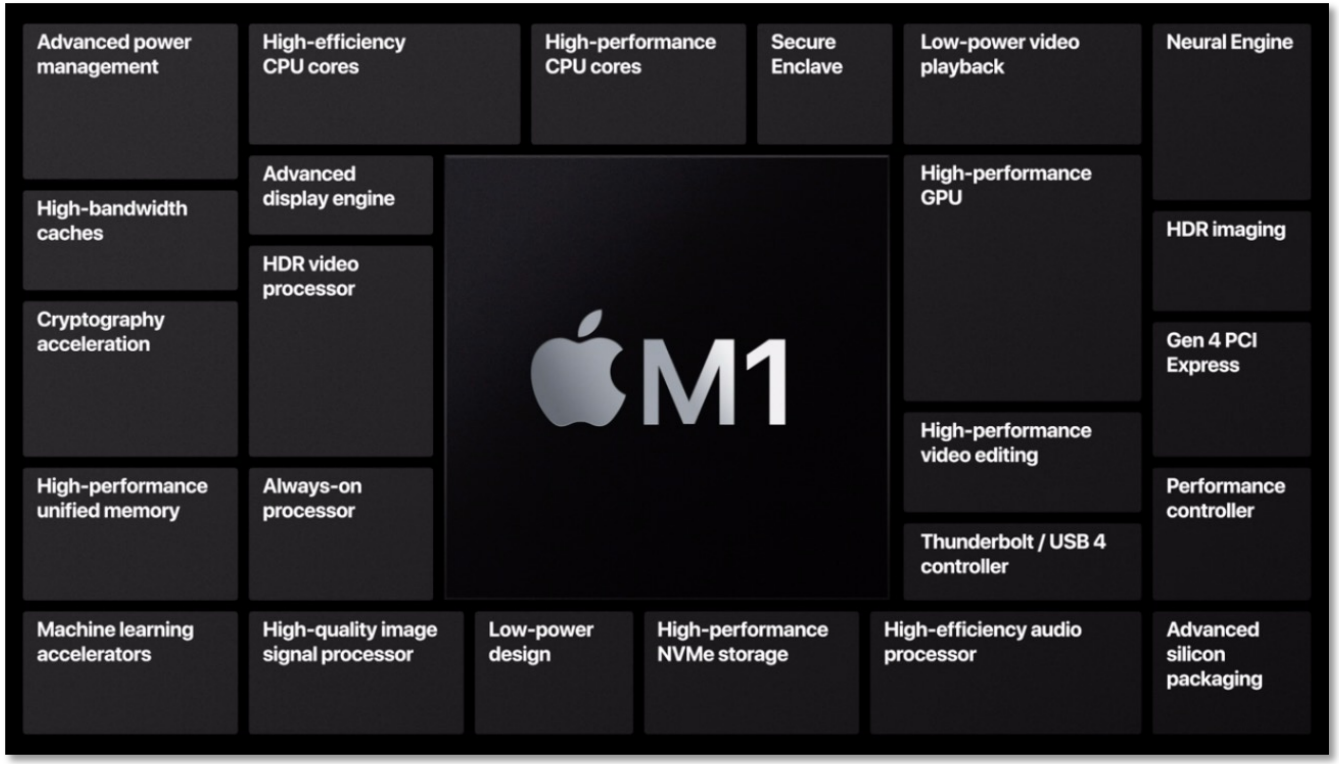
Find industry-wide severity ratings in the National Vulnerability Database.

Critical | High | Medium | Low

CVSS	Title	CVE	SA	Severity	Disclosure Date
6.0	Stale Data Read from Legacy xAPIC	CVE-2022-21233	INTEL-SA-00657	Medium	2022-08-09
5.5	Post-Barrier Return Stack Buffer Predictions	CVE-2022-26373	INTEL-SA-00706	Medium	2022-08-09

https://www.intel.com/content/www/us/en/developer/topic-technology/software-security-guidance/advisory-guidance.html

Hardware Security Features



- What do hardware security features offer?
- Better performance?
- More secure due to physical shields?
- Easy to use?

Why take this course?

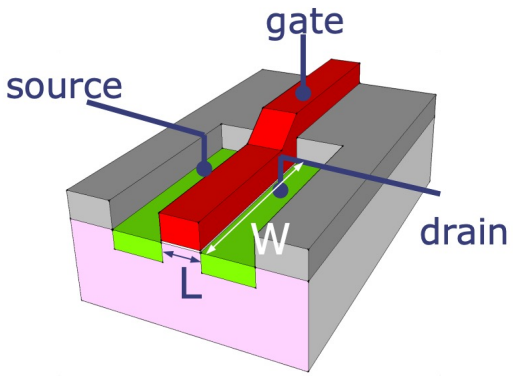
- The topic: Study security attacks and defenses primarily focusing on the hardware

1. Real-world hardware attacks
   - Not bugs. a) affect broadly; b) difficult to fix.
2. Defenses
   - What is good? Tradeoff between security and performance/cost
3. Hardware security features
   - Move SW features to HW. a) better performance, b) physical shield
4. Cross system abstractions

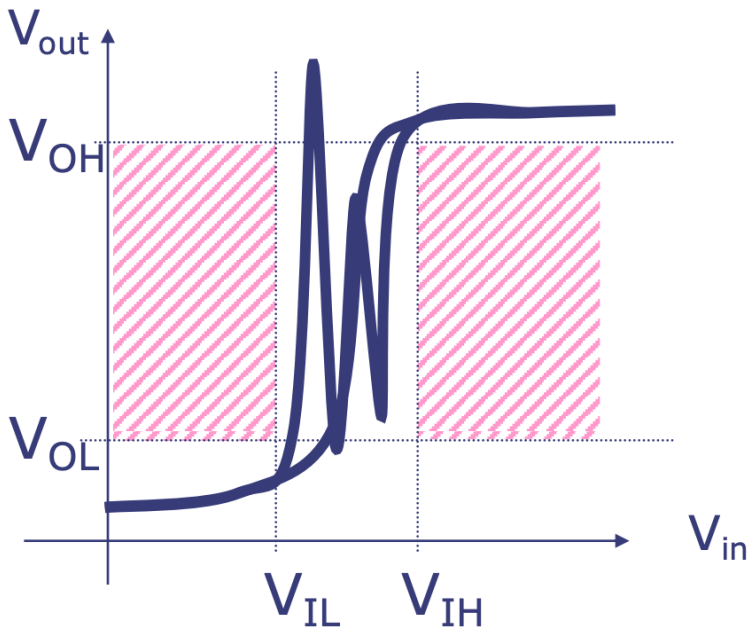
System Abstractions

Programs

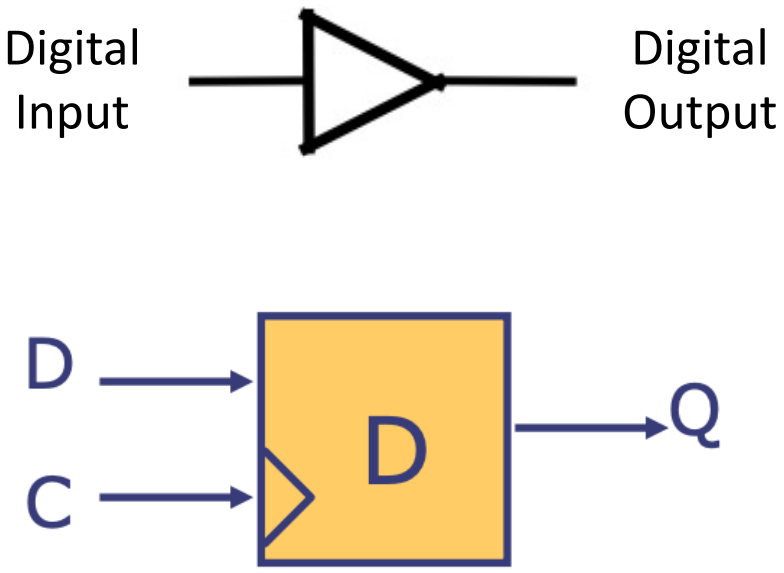
Analog Circuits; Devices (transistors)



The Digital Abstraction



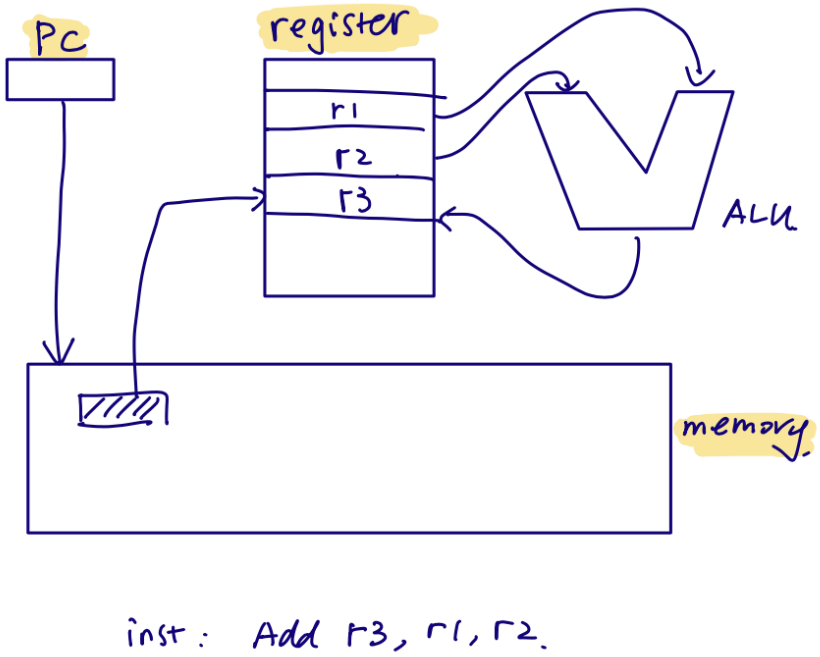
Voltage Transfer Characteristics



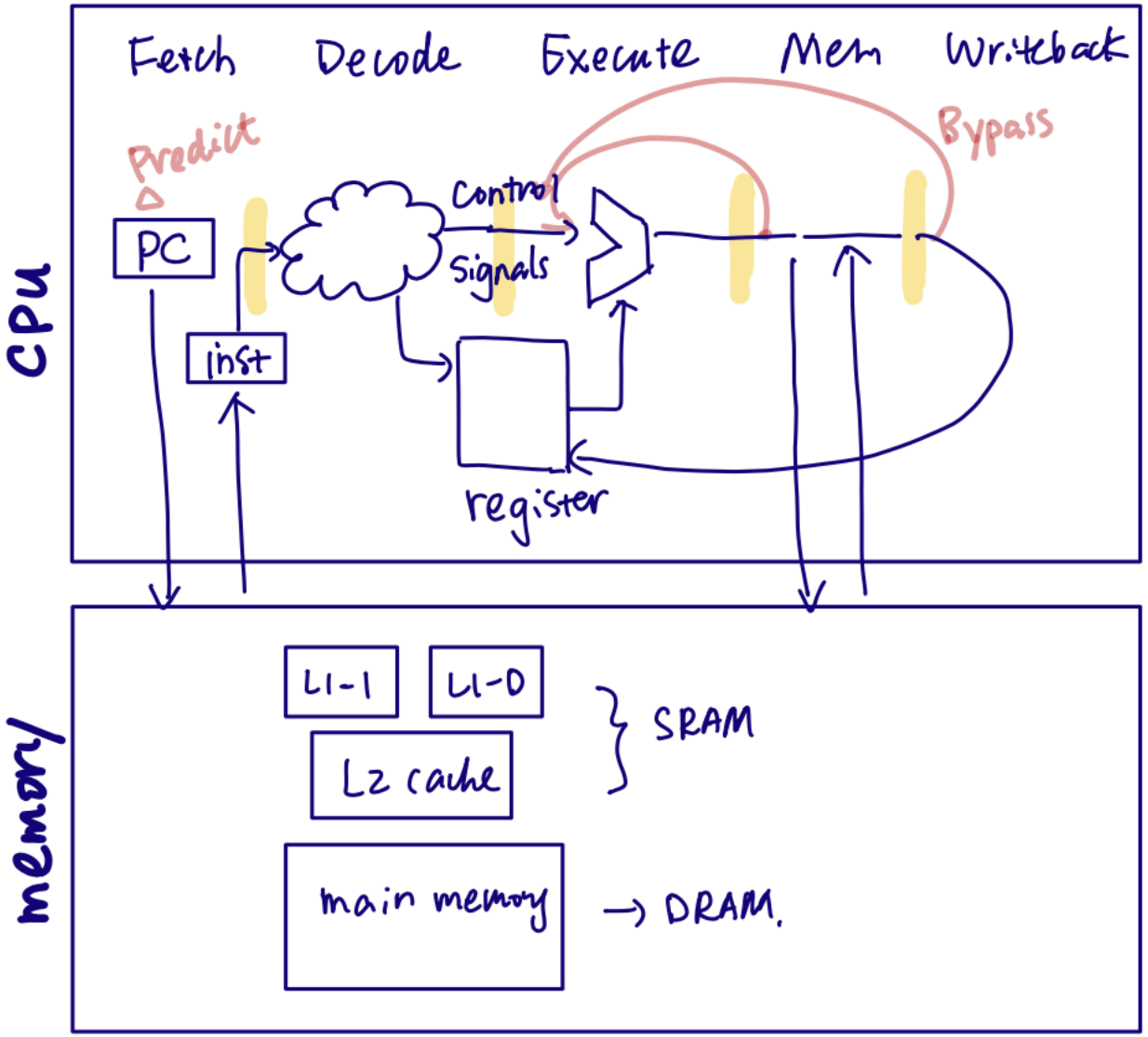
-> Build combinational and sequential circuits

-> Build general-purpose processors

The ISA Abstraction

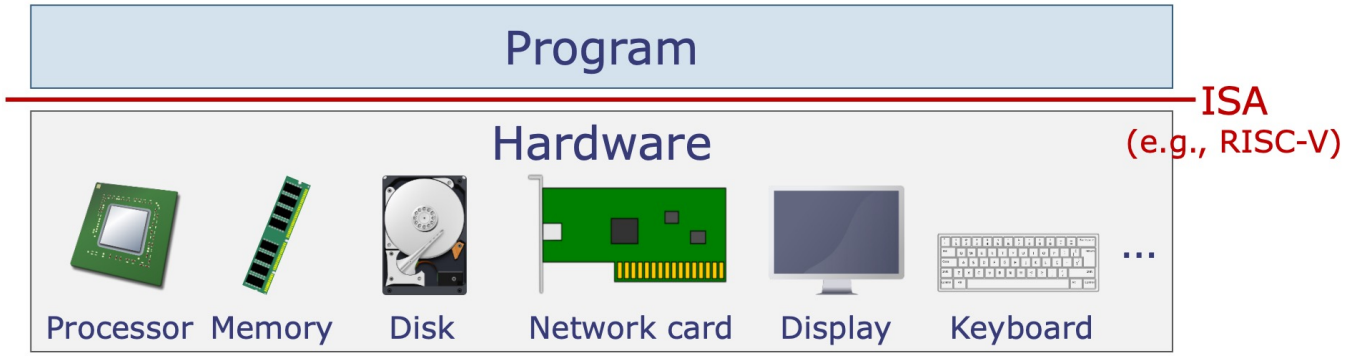


Software's View of the Processor



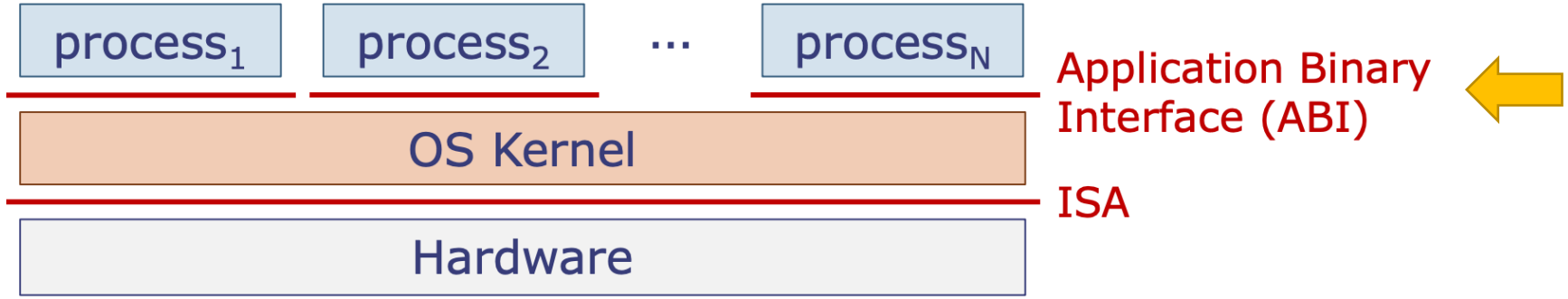
A 5-stage Pipelined Processor

The Virtual Machine Abstraction



Motivation:

- Cumbersome to use hardware resources
- Security issues when running multiple programs
- Need coordination between programs



The Virtual Machine Abstraction

Application's View

Memory Space from
0x00…00 to 0xFF…FF (48bits)

Virtual memory
(Address translation)

Physical memory sized
from 2GB to 32GB

>100 processes
run together

Process scheduling
(Interrupts)

4-8 physical cores

Use hardware devices via
APIs, such as
`print, read, write`

System calls

Talk to the devices following
protocols, tediously
read/write device registers

Physical HW

System Abstractions

Programs

Virtual Machine

System Software (virtual memory, process, I/O) *<- 6.1810[6.828]*

Instruction Set Architecture (ISA)

Computer Architecture (caches, core, pipelining) *<- 6.5900[6.823]*

Digital Circuits (combinational and sequential circuits)

Digital Abstraction

Analog Circuits; Devices (transistors) *<- 6.6010 [6.374]*

Abstractions

- A well-understood interface that hides the details within a subsystem

- Why use abstractions?
  - Good abstraction let us reason about the behaviors of a system while shielding us from the details of implementations
  - Implementation technologies can evolve while preserving the engineering investment at other levels

- Hardware security attacks usually **break abstractions**

Hardware Attack Examples

- Example #1: Rowhammer breaks the digital abstraction
- Examples #2: Side Channel breaks the ISA abstraction
- *Note covered:* hardware trojan, supply chain attacks, cryptographic accelerators, etc.

Course Assignments: Lectures, Paper Discussion, Grading

Navigate through the course website

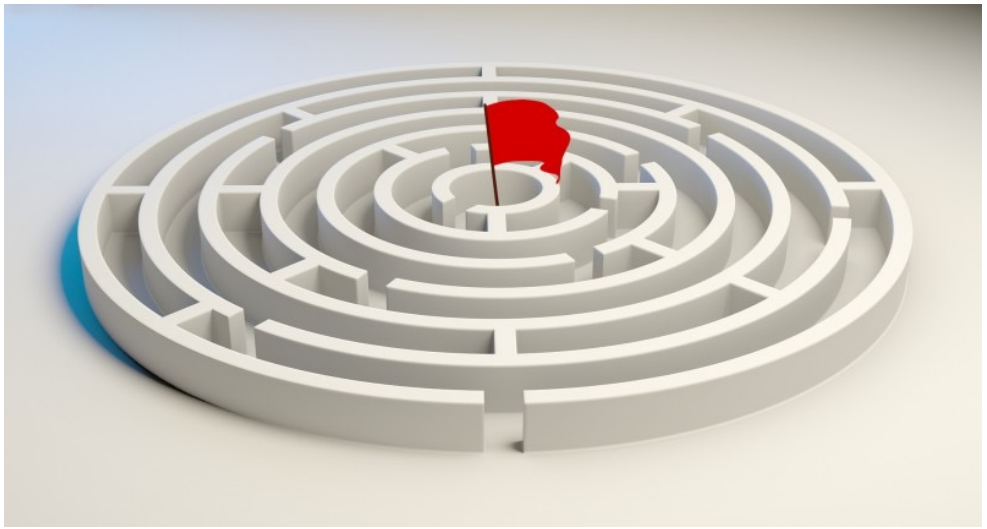
Hardware Security: The Evil and The Good

- Attack modern processors

- Know how to design defenses better

Preview on Lab Assignments

1. Website Fingerprinting Attack
2. Cache Attack
3. Speculative Execution Attack
4. Rowhammer
5. ASLR Bypassing
6. Hardware Fuzzing and Verification



Final Project

- Original research project to substitute Labs 4-6

- Deliverables
  - Proposal (schedule pre-proposal meetings with me)
  - Weekly report (short and informal)
  - Final report + Final presentation

- Open-ended topics
  - Must have some hardware security angle

Preview of In-class CTF

1. Learn C/C++

2. Physical attacks on embedded systems/microprocessors

3. Tool chain for fuzzing and formal verification

Next: Side Chanel Overview