Side-Channel Analysis Intro: Acquisition (with ChipWhisperer)

PA192

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November 2025

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Outline

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Plan for Today

1. Introduction

1. ChipWhisperer Installation
2. Setups
3. Analysis of some captured by you traces
4. Even if we have enough devices: please work in pairs! Discuss you solutions.

Disclaimers

- Frist some super-brief introduction to SCA
- The the main goal is to show you how simple power analysis work and
  - building a setup for SCA looks like...
- This seminar is for you and there is no homework. We can look at what you want, so please let me know when you have questions...
- Since there are many technical components, things might get shaky...

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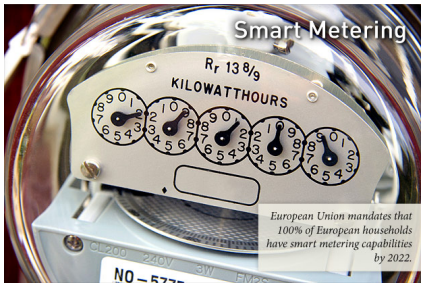
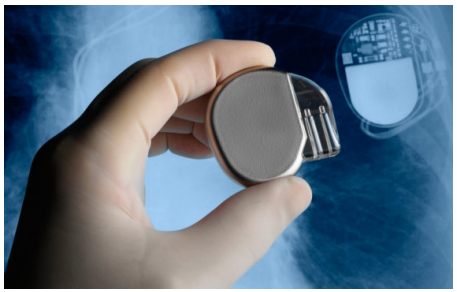
Side-Channel Analysis Introduction

Side-Channel Analysis Introduction

Known challenge: embedded crypto devices





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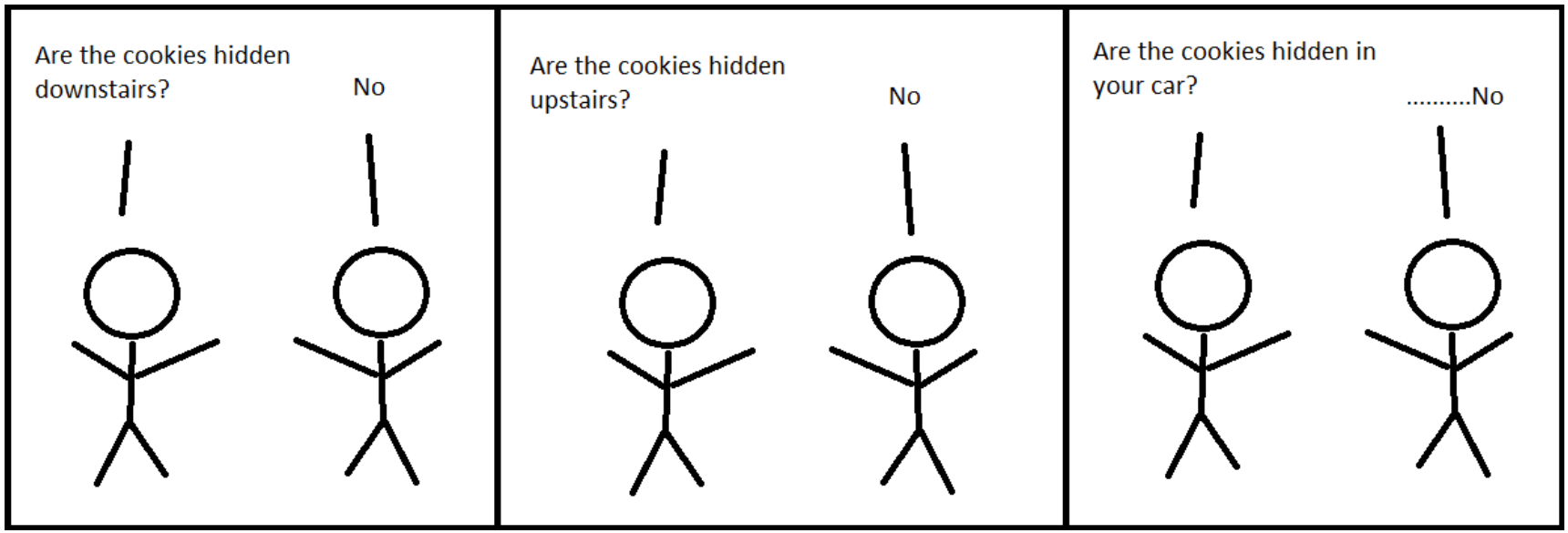
Snow Example: what do you think it is?

Snow Example: what do you think it is? answer.

https://www.independent.co.uk/news/world/europe/melting-snow-being-used-by-police-to-find-cannabis-farms-in-the-netherlands-10036057.html

Cookies Example



https://www.simplethread.com/great-scott-timing-attack-demo/

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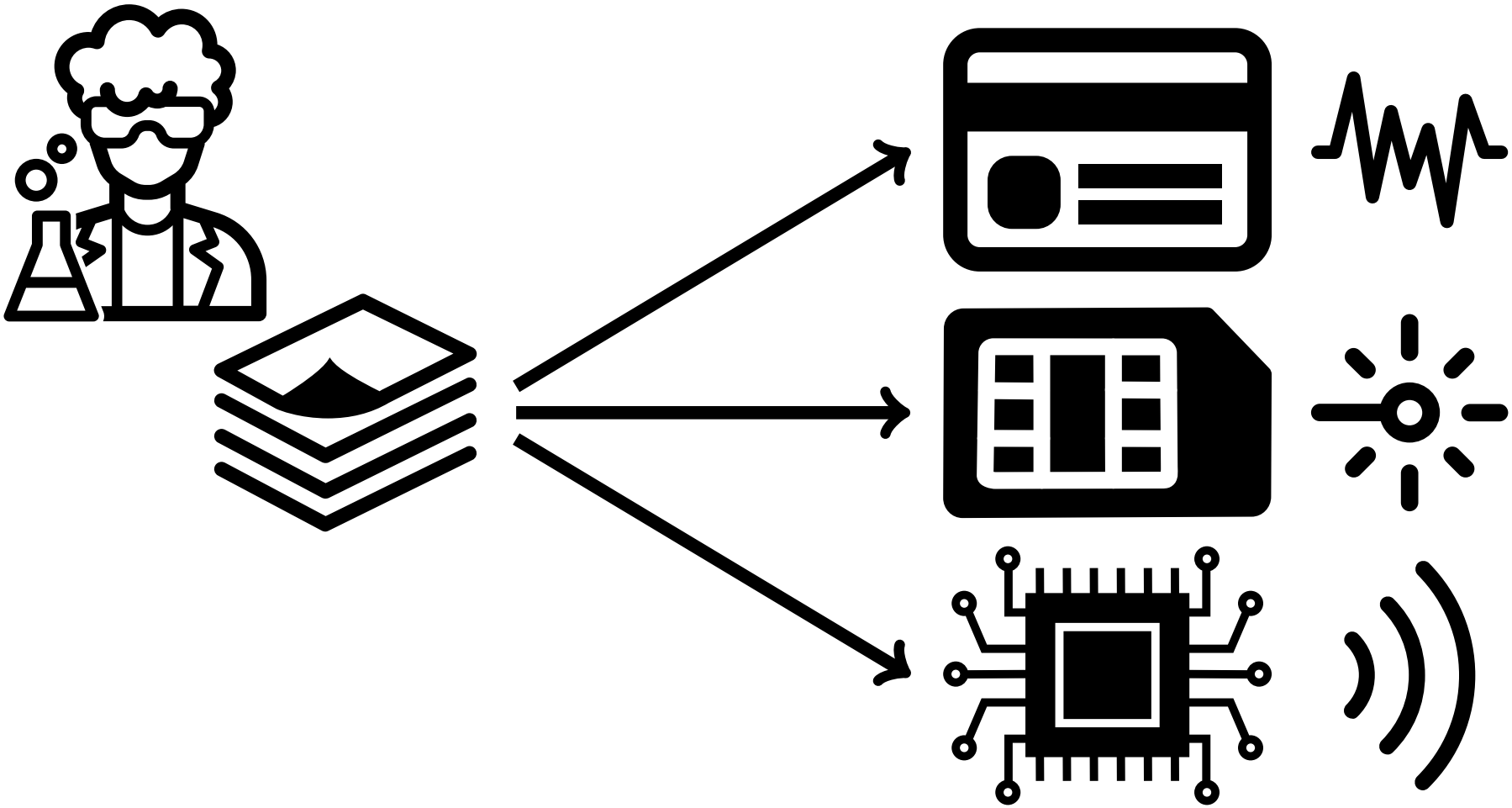
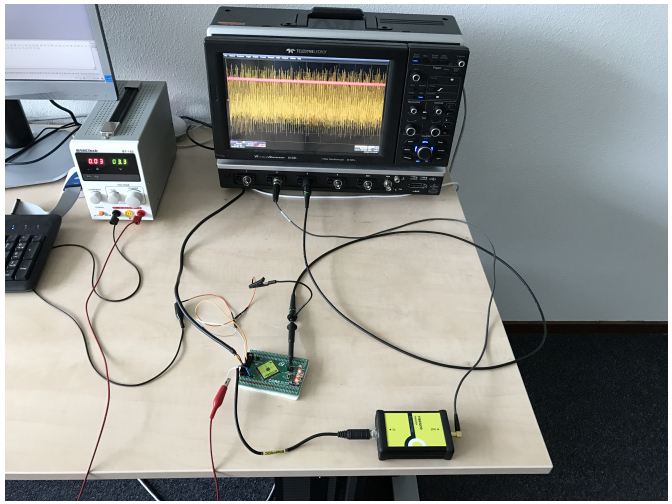
Types of Side Channels



Implementation attacks



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Relevance

TPM-FAIL, November 13, 2019

LadderLeak, May 28, 2020

SCA Titan: January 7, 2021

Minerva, October 3, 2019

TPMScan, March 12, 2024

EUCLEAK, August 30, 2025

A bit older **ROCA** for RSA (2017): `https://crocs.fi.muni.cz/public/papers/rsa_ccs17`

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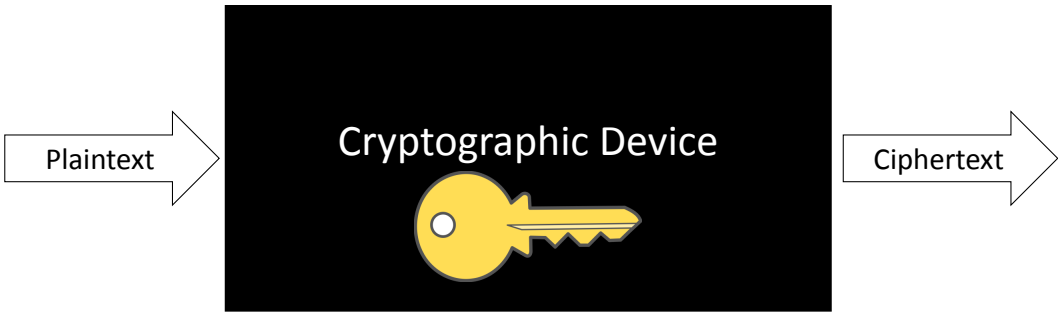
Blackbox scenario



- Cryptographic function is a black box, parameterized with key, that maps plaintext into ciphertext
- Analyzing the security in the blackbox scenario relates to classical cryptanalysis
- Adversary's goal: secret key or plaintext recovery by observing plaintext/ciphertext pairs

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Greybox scenario

- Crypto is **implemented on a real device** such as a microcontroller, FPGA, ASIC etc.
- We can measure and process certain *physical quantities* in the device's vicinity
- Adversary's goal: secret key or plaintext recovery by observing plaintext/ciphertext pairs **and a side channel**
- *Side channel* is any unintentional signal that can offer us a blurry view of the algorithm's internal computations
- Examples: execution/reaction time, power consumption, electromagnetic emission, sound

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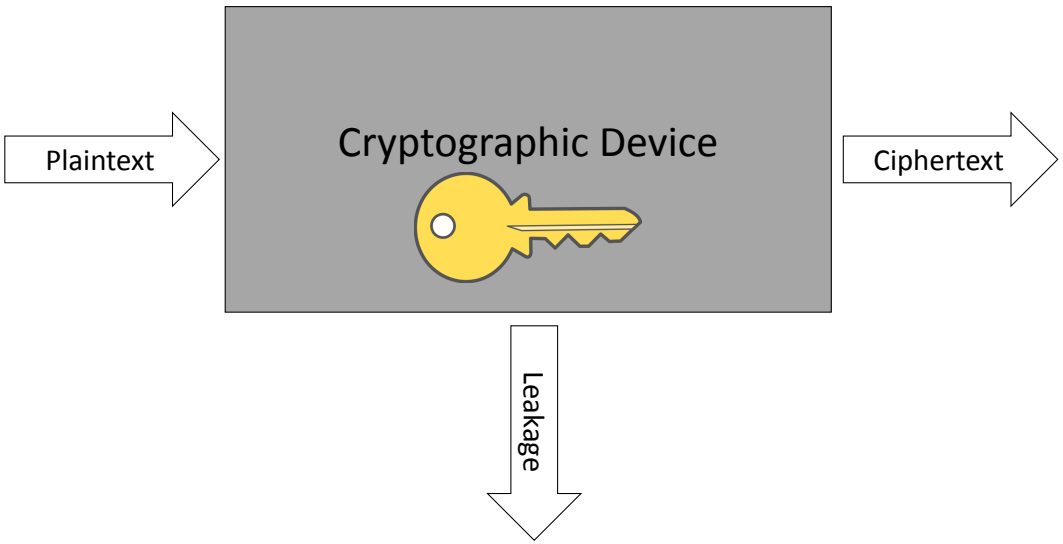
Greybox scenario



- Assuming limited access to the internal computations through this side channel window → greybox scenario
- Security in the blackbox scenario does not imply security under the greybox scenario

Timing side-channel

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Timing side-channel: PIN verification

- Software for PIN code verification

```
Input: 4-digit PIN code
Output: PIN verified or rejected
Process CheckPIN (pin[4])
int pin_ok=0;
if (pin[0]==5)
   if (pin[1]==9)
      if (pin[2]==0)
         if (pin[3]==2)
            pin_ok=1;
         end
      end
   end
end
return pin_ok;
EndProcess
```

We will look at power consumption of a similar function :-)

- What are the execution times of the process for PIN inputs `[0,1,2,3]`, `[5,3,0,2]`, `[5,9,0,0]`
- The execution time increases as we get closer to `[5,9,0,2]`

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Simple Power Analysis (SPA)

- Based on one or a few measurements
- Mostly discovery of data-(in)dependent but instruction-dependent properties e.g.
  - Symmetric:
    - Number of rounds (resp. key length)
    - Memory accesses (usually higher power consumption)
  - Asymmetric:
    - The key (if badly implemented, e.g. RSA / ECC)
    - Key length
    - Implementation details: for example RSA w/wo CRT

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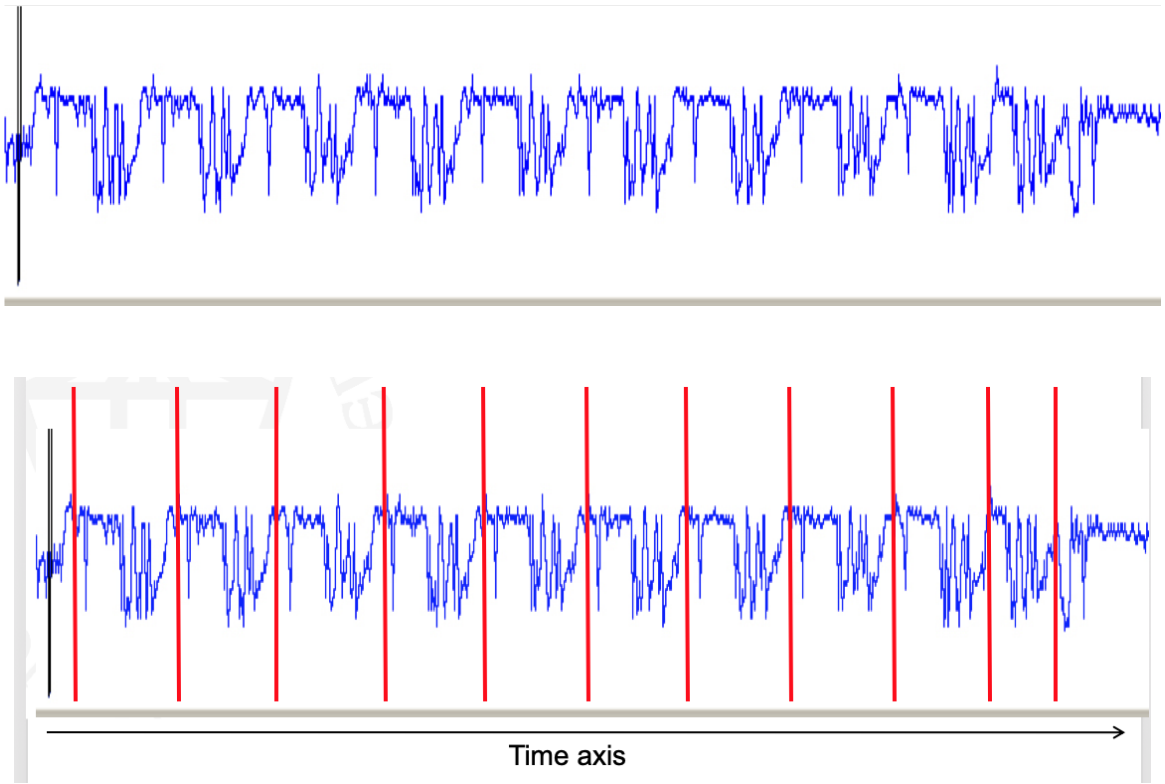
SPA example 1



SPA on RSA (Square-and-Multiply)

- RSA modular exponentiation

```
Input: integers x, e, n, length l of e
Output: x^e mod n

Process ModularExponentiation(x, e, n, l)

r=1;
for j=l-1 down to 0
   r=r^2 mod n //square
   if (bit j of e) == 1
      r= r*x mod n //multiply
end
return r;
EndProcess
```

- Do you already see a timing attack?
- The exponent-dependent branch is causing it!
- Do you see another side-channel attack?

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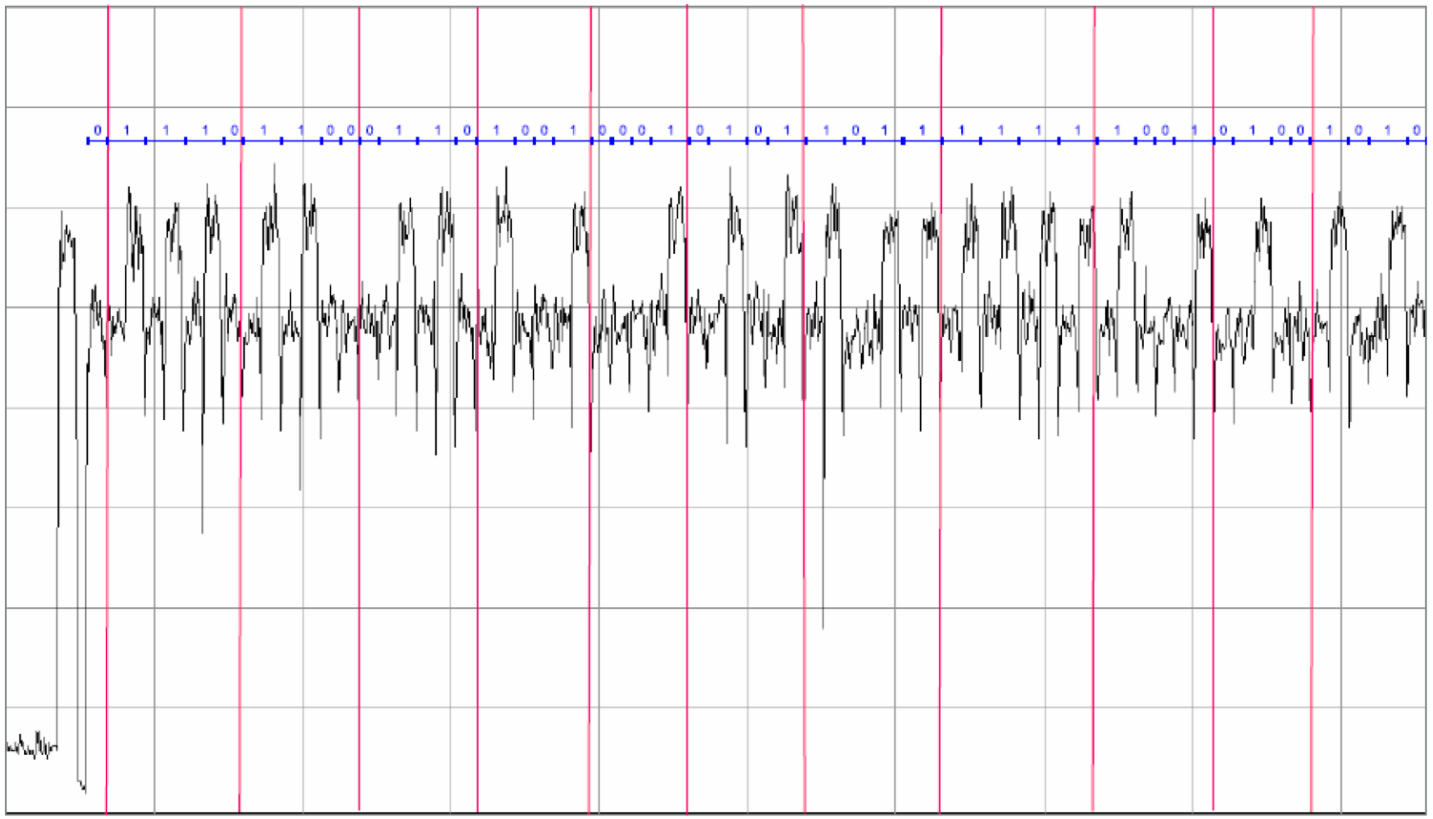
SPA example 2: RSA exponentiation



- Differential Power Analysis (DPA)

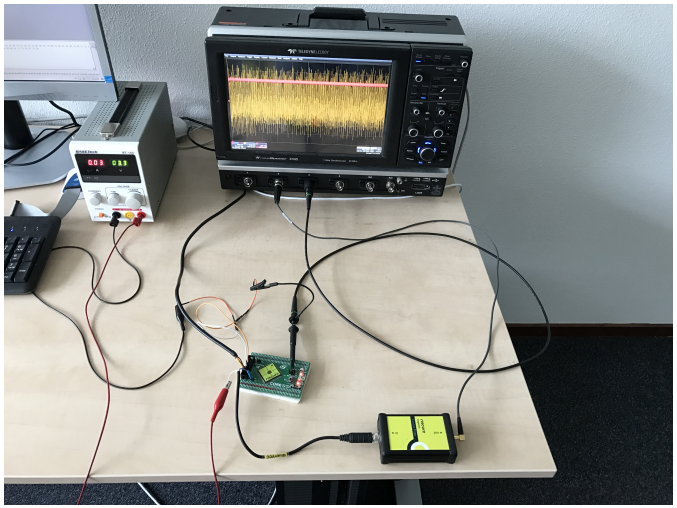
ChipWhisperer

ChipWhisperer

What is chipwhisperer?

To perform a side channel attack, two things is needed,

1. A capture hardware:
   oscilloscope: captures small signals with a precisely synchronized clock.
2. A target board:
   processor: is programmed to perform secure operation.



Setting up the hardware for side channel attacks is not easy!
CW1101 ChipWhisperer-Nano resolves difficulties, but hard to be customized!

CW1101 ChipWhisperer-Nano:

- comes with the capture hardware and the target together on a single board.
- has ARM Cortex-M0 processor.
- we have 20 of them in the lab (and 2 CW1173 ChipWhisperer-Lite based on ARM Cortex-M4F)

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CW1101 ChipWhisperer Nano

The ChipWhisperer Nano comes with two main parts:

1. a multi-purpose power analysis capture hardware, and
2. a microcontroller (target board) which you can implement algorithms onto.

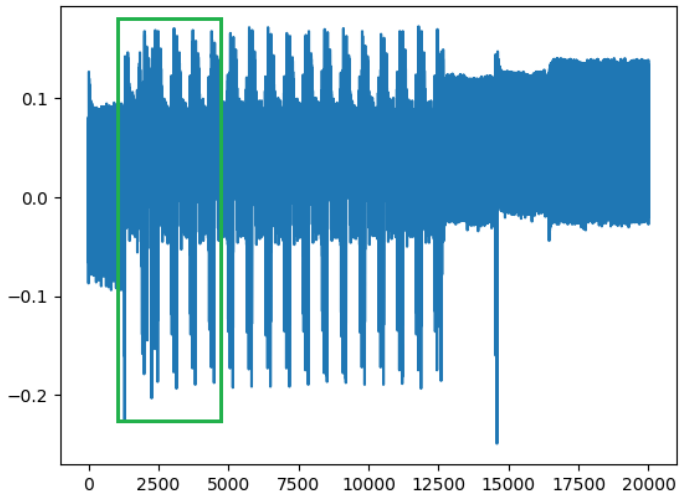

Figure: Figure from: https://myrelabs.com/breaking-rsa-with-chipwhisperer/

Documentation can be found at:

- https://www.newae.com/products/NAE-CW1101
- https://chipwhisperer.readthedocs.io/en/latest/
- https://wiki.newae.com/Main_Page.

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CW1101 ChipWhisperer Nano (Cont'd)

Open-source toolchain for hardware security research and education

Hardware: The ChipWhisperer uses a capture hardware and a target board.

- Schematics and PCB layouts for capture hardware & target board

Firmware: Three separate pieces of firmware are used on the hardware.

- The capture hardware:
  a USB controller (in C) & an FPGA for high-speed captures (in Verilog)
  In "hardware/capture" of the ChipWhisperer Github Repo.
- The target device has its own firmware (mostly in C)
  In "hardware/victims/firmware" of the ChipWhisperer Github Repo.

Software: The ChipWhisperer software includes

- a Python API for talking to hardware (Capture), and
- a Python API for processing power traces from hardware (Analyzer).

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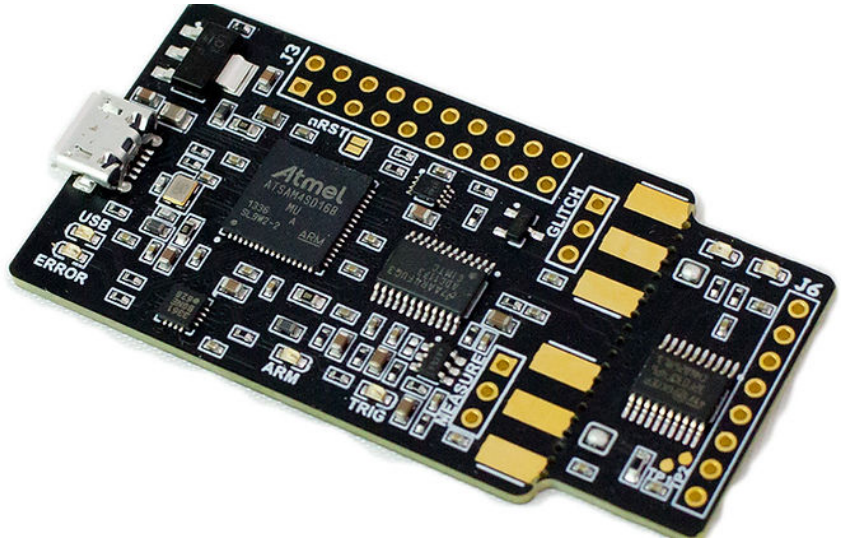
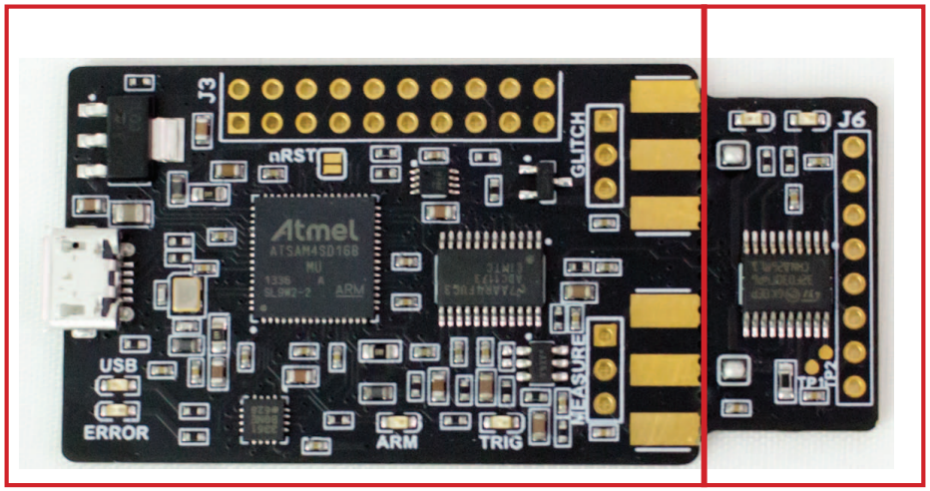
Hardware Specification

- Hardware documentation can be found at: https://rtfm.newae.com
- More specifically look to: https://media.newae.com/datasheets/NAE-CW1101_datasheet.pdf



Hardware Specification



Feature	Notes/Range
ADC Specifications	8-bit ADC, 20 MS/s maximum sample rate.
ADC Sample Clock Source	Selectable between internal generator or external input.
Analog Input	AC-Coupled, fixed gain.
GPIO Types	Serial, clock, logic line (i.e., for reset pin). Fixed pin functions.
GPIO Voltage	3.3V.
Clock Options	3.75 MHz, 7.5 MHz, 15 MHz, 30 MHz , 60 MHz
Clock Output Type	Generated by microcontroller, clock only (no clock glitching support).
Trigger Type (ADC + Glitch)	Rising edge only.
Glitch Width (min)	~20nS (depends on cabling used for routing glitch output).
Glitch Offset	~200nS jitter, adjustable in 10nS increments.
Voltage glitch type	Low-power crowbar circuitry.
Crowbar pulse current	4A.
USB Interface	Custom USB firmware (full-speed USB 2.0 device).
Sample Buffer Size	50 000.
Target Device	STM32F030F4P6 or STM32F070
Programming Protocols	STM32Fx Bootloader

Figure: from https://media.newae.com/datasheets/NAE-CW1101_datasheet.pdf

- **REMARK:** there are different versions of ChipWhisperer, see https://rtfm.newae.com/Capture/

Hardware set up

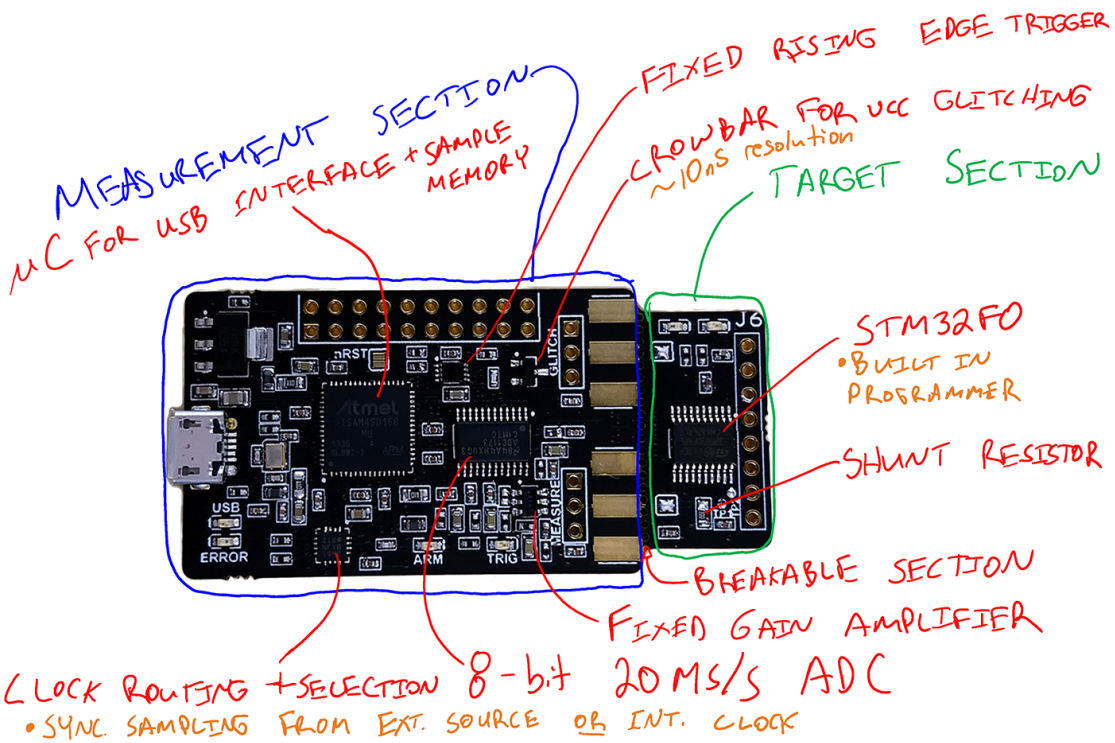


Figure: from https://rtfm.newae.com/Capture/ChipWhisperer-Nano/

Use a micro USB cable to connect the ChipWhisperer to a computer
Done? Then,

follow software guide at https://chipwhisperer.readthedocs.io/en/latest/

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Software installation

Chipwhisperer has an open-source Python library for

controlling the capture hardware and
communicating with the target.

There are two modes (basic & advanced) for chipwhisperer installation.

There are two ways for basic installation

- Windows Installer
- Virtual Machine (VirtualBox)

There are different choices for advanced installation and prerequisites

- GNU/Linux (preferred)
- Windows
- Mac OS X
- Virtual machine (Virtual Box)

Detailed documentation can be found at:
https://chipwhisperer.readthedocs.io/en/latest/index.html.

In this seminar we use the Virtual Box method:
https://chipwhisperer.readthedocs.io/en/latest/virtual-box-inst.html.

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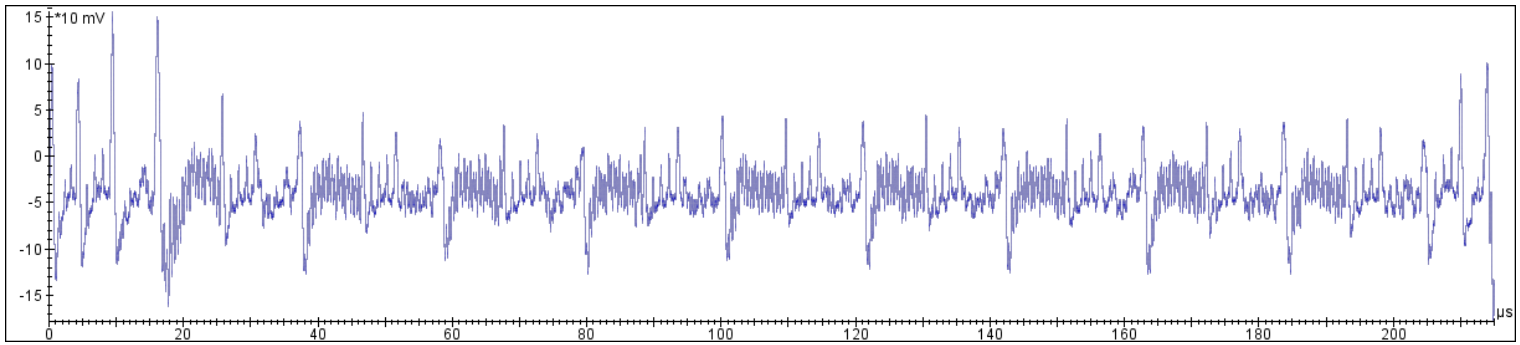
Practical Side-channel Analysis

Practical Side-channel Analysis:
Acquisition of traces and SPA

Side-channel Traces



- What it is? AES
- What are typical side-channels? power, EM, time, sound, temeperature, light...
- smartcards vs. embedded devices
- What to do first? Build the setup :-)

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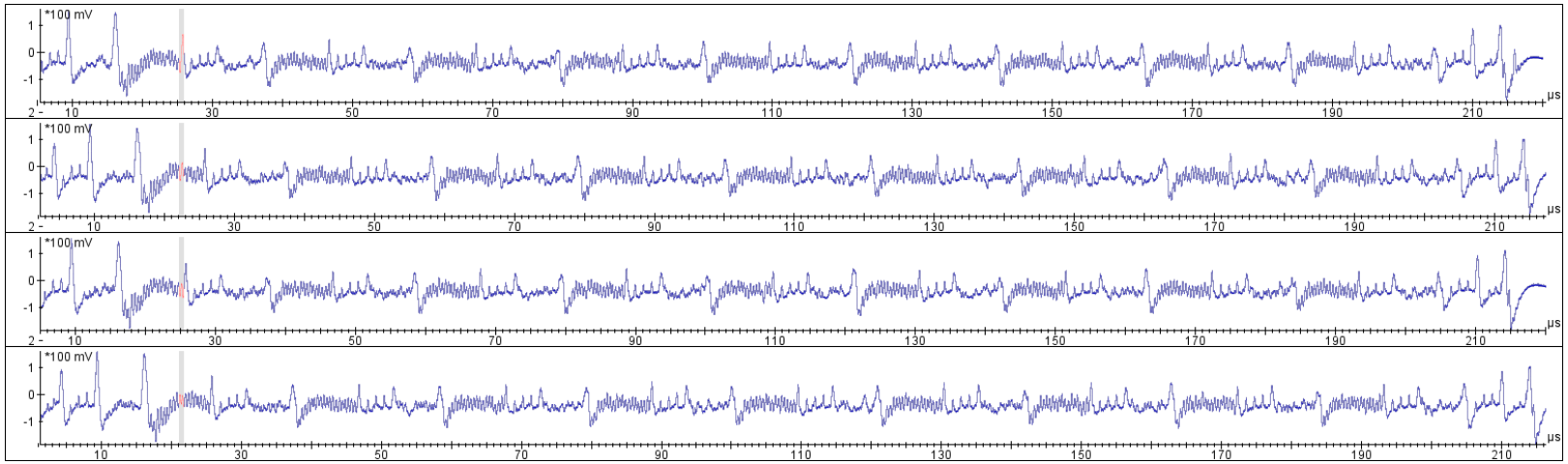
Problems with Side-channel Traces

- Misalignment:



- Noise
- How to minimize these problems?
- (1) Build a good “enough” setup.
- (2) Do processing of the traces (e.g., alignment, compression, etc.).
- (3) Attack and profit.

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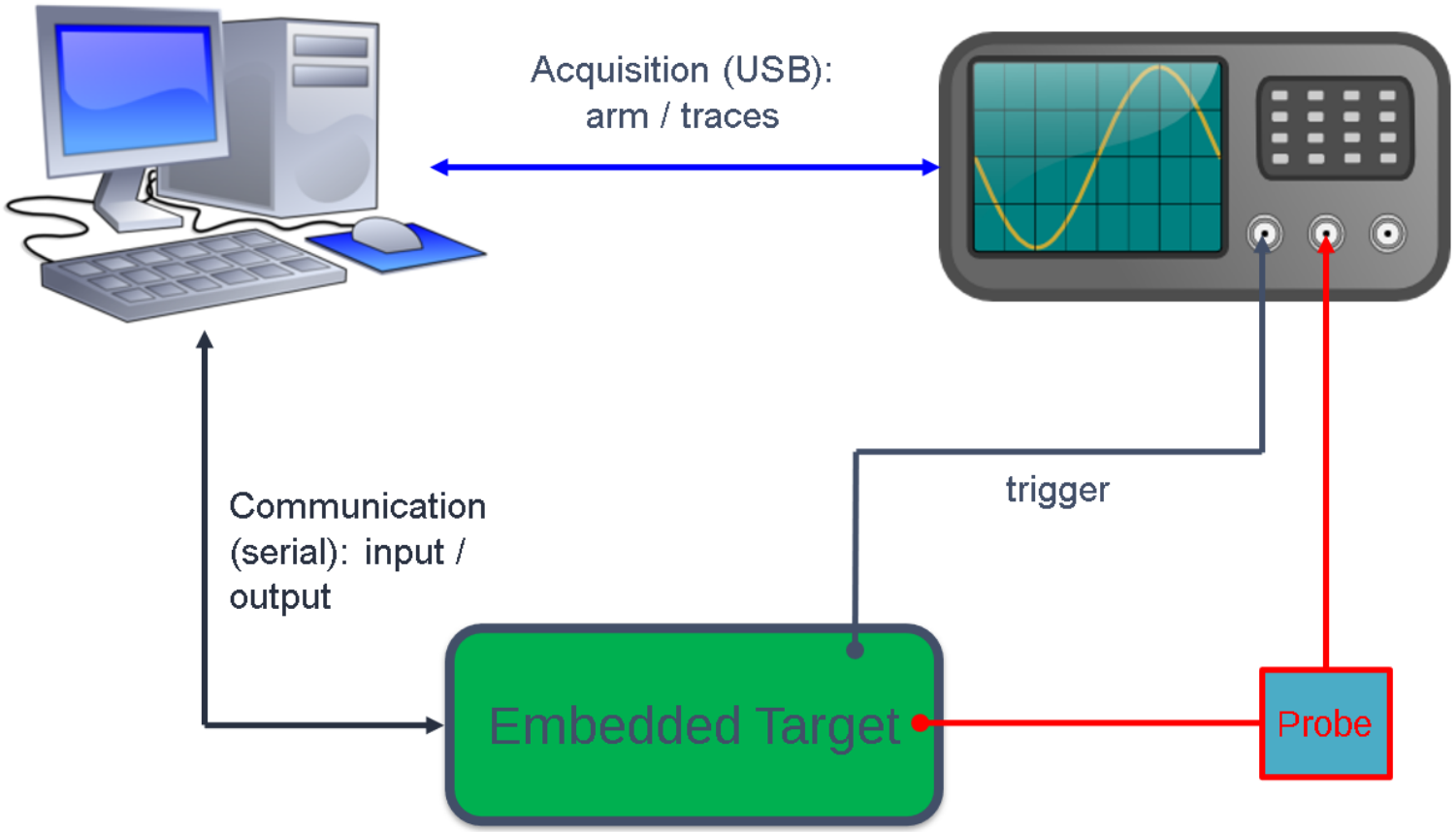
Typical Setup Components



Test Excersise: Capturing AES traces with ChipWhisperer

- Even if your setup works please work in pairs.
- If you installed everything then upload `Excercise_Acquisition_CPA.ipynb` in `http://localhost:8888/notebooks/jupyter/courses/sca101/` and run it.
- Try to capture a few traces and plot them. what do you see?
- What do you think is happening?

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Main Excersise: PIN

- Even if your setup works please work in pairs.
- If you installed everything then upload `Power Analysis for Password Bypass-SPA.ipynb` in `http://localhost:8888/notebooks/jupyter/courses/sca101/` and run it.
- Password-checking is implemented letter by letter.
- What do you see?
- What do you think is happening?

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Conclusions

- The main goal of this seminar is to introduce Side-Channel Analysis by experimenting with ChipWhisperer.
- Simple Power Analysis.
- Thank you for the attendance :-)

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Questions

?