#RSAC

RSAConference2018

San Francisco | April 16 – 20 | Moscone Center

MATTERS NOW

SESSION ID: MBS-W02

CHEAPSCATE: ATTACKING IOT WITH LESS THAN $60

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RSAConference2018

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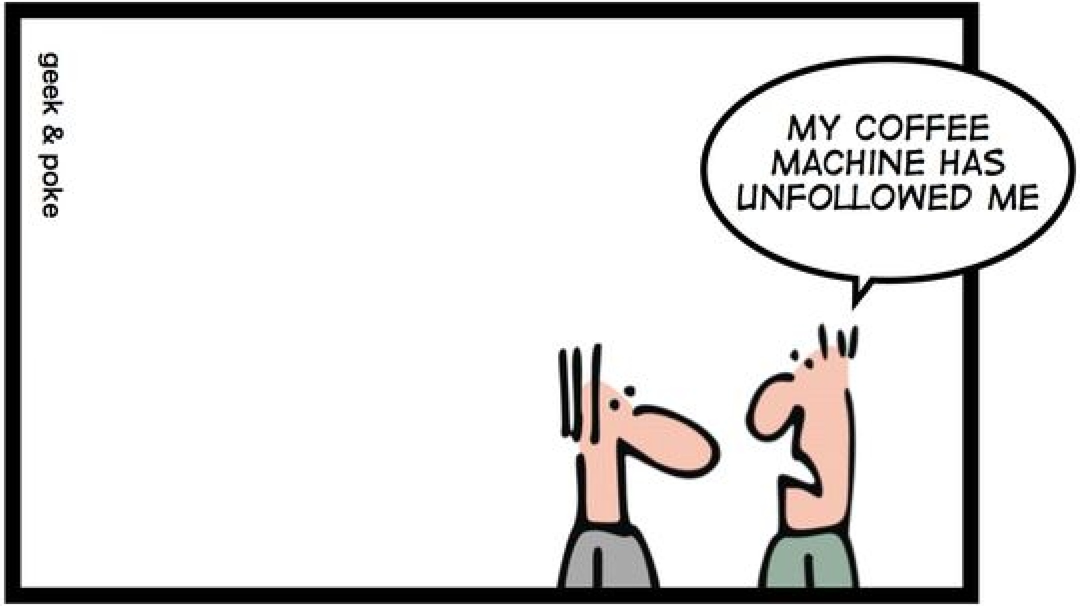
A BRIEF STORY ABOUT A HARDWARE CTF AND IOT

A brief story about a hardware CTF

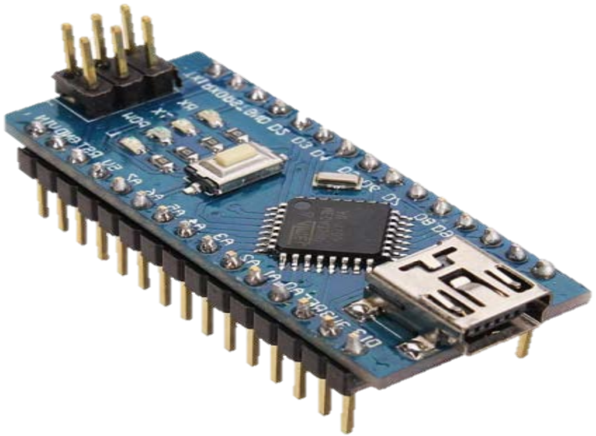


2017: 8.4 BILLION "THINGS" CONNECTED TO INTERNET

A brief story about a hardware CTF

The typical IoT device is quite cheap but does a lot of stuff

- Heart of the device: general purpose microcontroller (MCU)
- TON of features for extremely low $$$
  - WiFi / Bluetooth / memory / USB / …
  - Lots of interfaces & sensors
  - Devkit packed with peripherals typically < 20$



A brief stor

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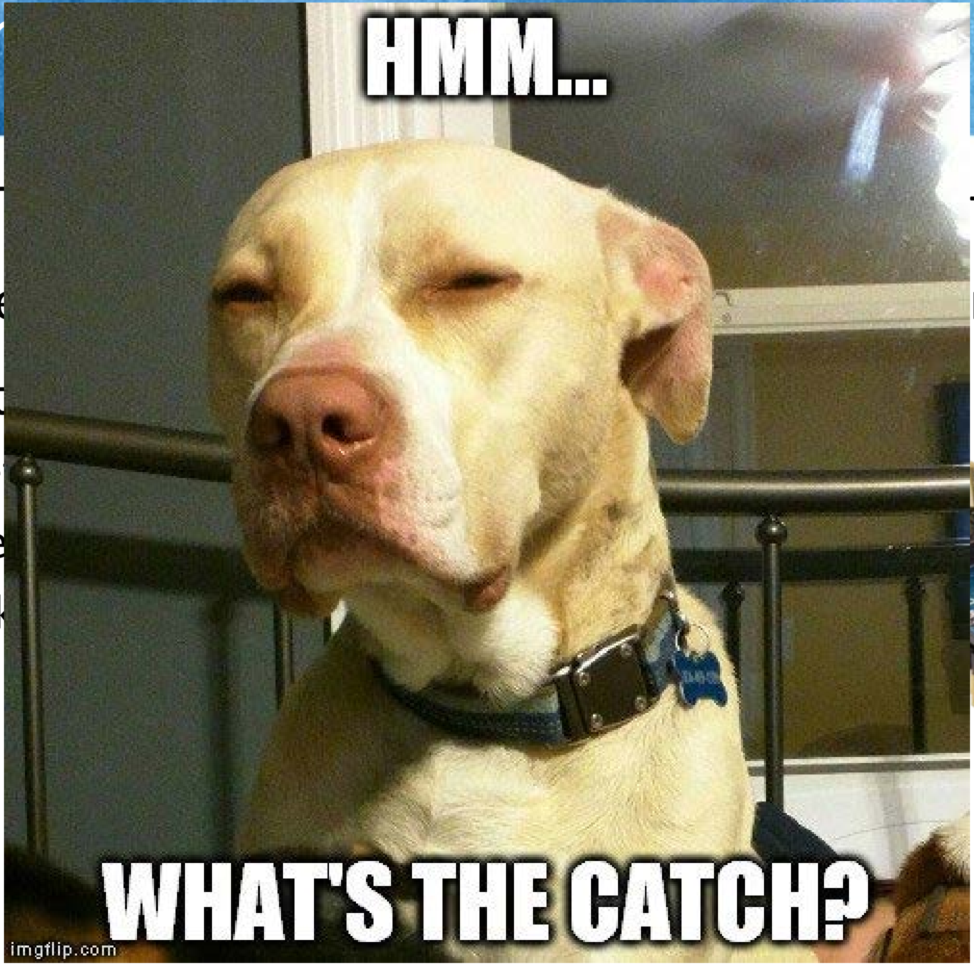
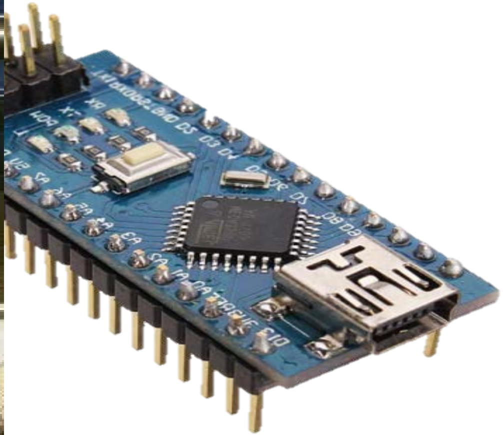




GENERAL PURPOSE MCUs ARE NOT SECURE AGAINST SCA AND FI ATTACKS

GENERAL PURPOSE MCUs ARE NOT SECURE AGAINST SCA AND FI ATTACKS


the Faulty Islands
Finetuning
Revenge
Fiesta
Fiasco
Emergency Transmitter
Sergei's Secret Source
the State of Crypto
AVR keyserver
AVR Secure Filesystem v1.92r1.
AVR Secure Filesystem
Whac-a-mole
Piece of SCAke
Still not scary
Escalate
Animals
Casino
Weird machine
Photo manager
United Exploitation
Jumpy
FridgeJIT
impostor
Hide and Seek
Bootloader Territory
Desert of Reversing
Republic of Sidechannel Analysis

A brief story about a hardware CTF

Lots of people solved the software challenges

But very few attempted the SCA and FI challenges ☹

Typical reasons given:

- "The SCA equipment is very expensive"
- "SCA and FI are too difficult"
- "These attacks are only for evaluation labs"
- "I'm allergic to mathematics"
- "I will destroy my device"

A brief story about a hardware CTF

My goals today

- You will learn that SCA is affordable for everyone
- You will learn that FI is affordable for everyone
- If you are an IoT developer, and:
  - you handle sensitive info
  - you believe these attacks don't apply to you
  - you don't try these attacks
  - you don't learn how to defend

THEN you WILL get hacked: please do something!!

Rules of the game

In order to prove the point, I will use the following rules:

- Cheapest tooling I could find
- Generic for (almost any) target
- Using Open Source Software only
- Result reproducible by a script-kiddie profile

SIDE-CHANNEL ANALYSIS: THEORY AND APPLICATION

Let's break an AES implementation!

SCA: theory and application

Challenge: Piece of SCAke (available on riscure.com/Github)

Goal

- Get the AES key from the device

Info

- The device performs AES encryption of a message
- Then replies the encrypted message

SCA: theory and application

The attack works with any crypto implementation

You just need to have the device at reach

SCA in a nutshell

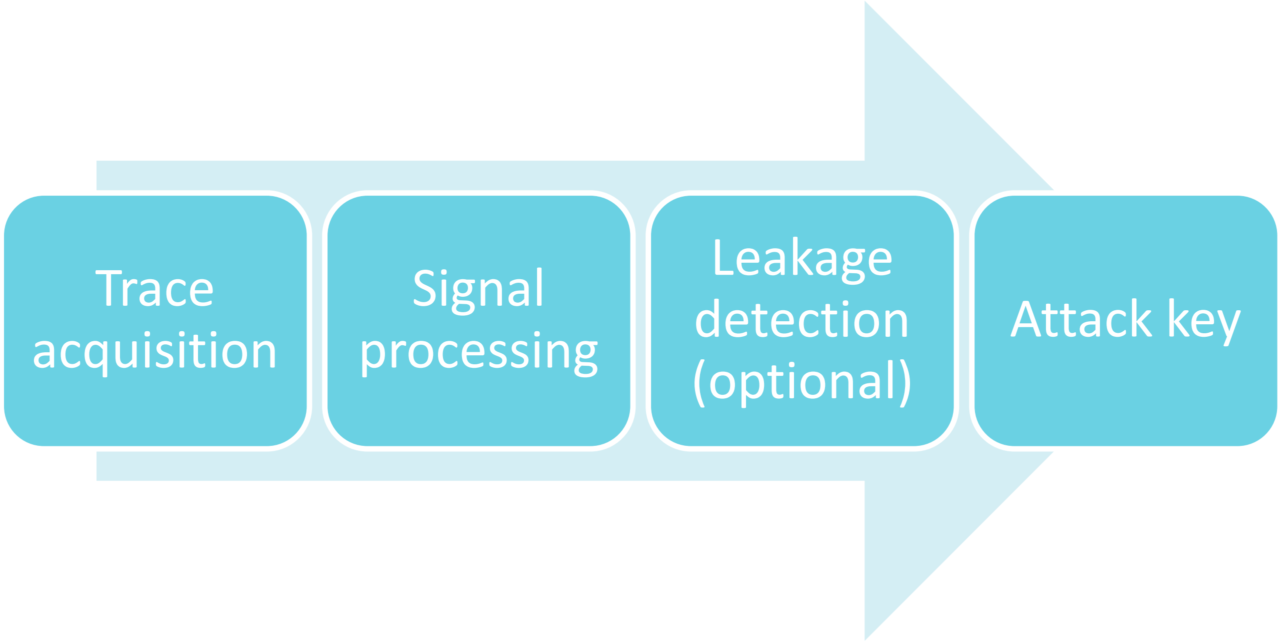
1 – Talk or listen to a device doing crypto (e.g. AES)

2 – Measure power consumption of device doing crypto

3 – SCA program computes math with collected data

4 – You get the crypto key

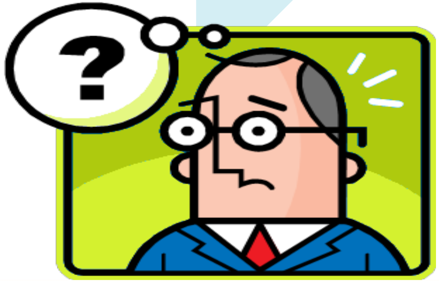
SCA steps in practice(attacker)



SCA steps in practice(attacker)

- Trace acquisition
- Signal processing
- Leakage detection (optional)
- Attack key: CPA

How do I get traces?



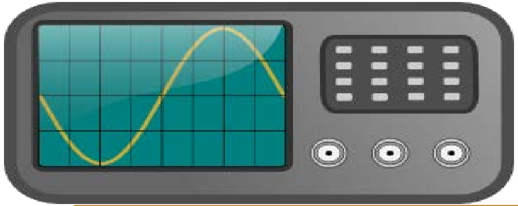
Measuring power from an embedded device

Computer

sampled power

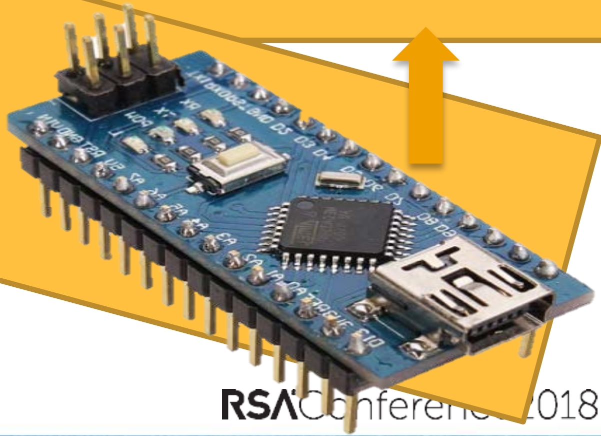
command

response

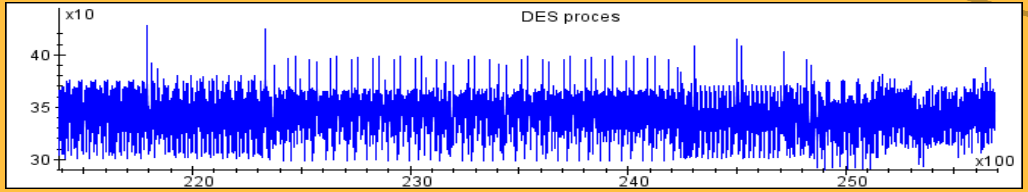


Resistor or Current Probe

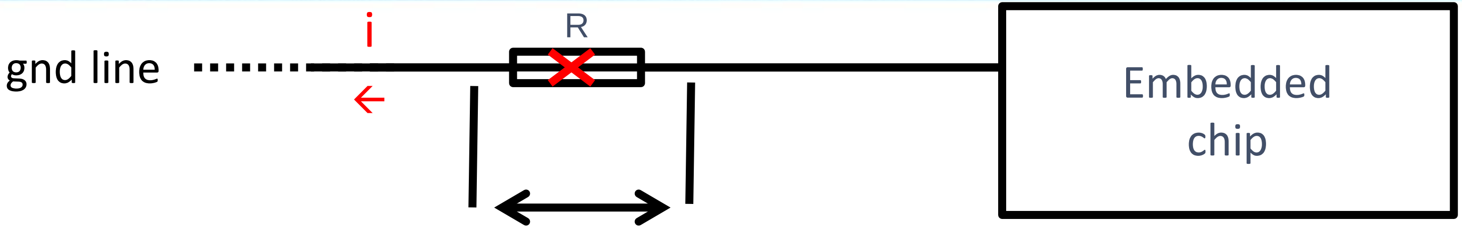
Power measurement



Power trace:
- Measured power
- I/O data



Measuring power in an embedded device

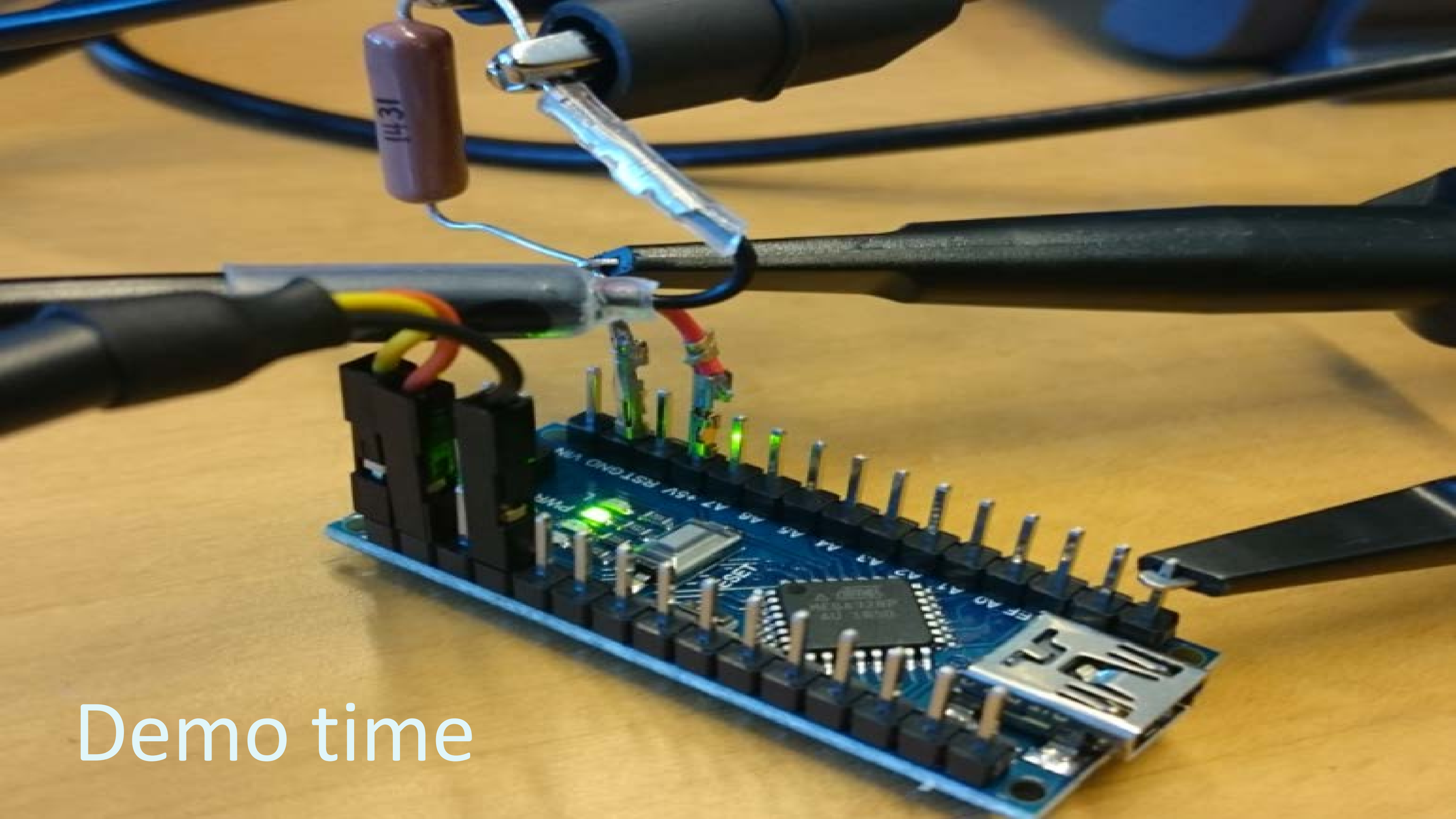


- This approach has some issues
- There are other “more efficient” ways to measure power (current probe, EM, …) but we will not see them today…

Because a resistor is CHEAP!! (<$0.01)

Cost of the SCA setup

- Resistor
  - US$ 0.01
- Scavenged USB cable
  - Free
- USB soldering iron
  - US$ 4.64, free shipping!
  - Comes with tin!
  - It actually works! AMAZING!
- Hantek 6022BE “oscilloscope”
  - US$ 53.32, free shipping!
  - Comes with probes and cables!
- USB to serial cable
  - US$ 1.10, free shipping!
- **Total new hardware cost: US$ 59.07**

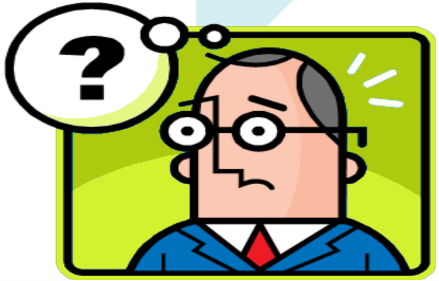


Demo time

General steps for SCA

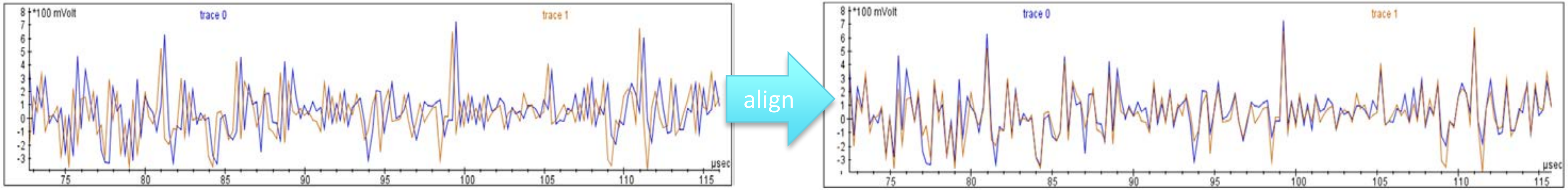
Trace acquisition → **Signal processing** → Leakage detection (optional) → Attack key

Improve signal?



Signal processing: alignment

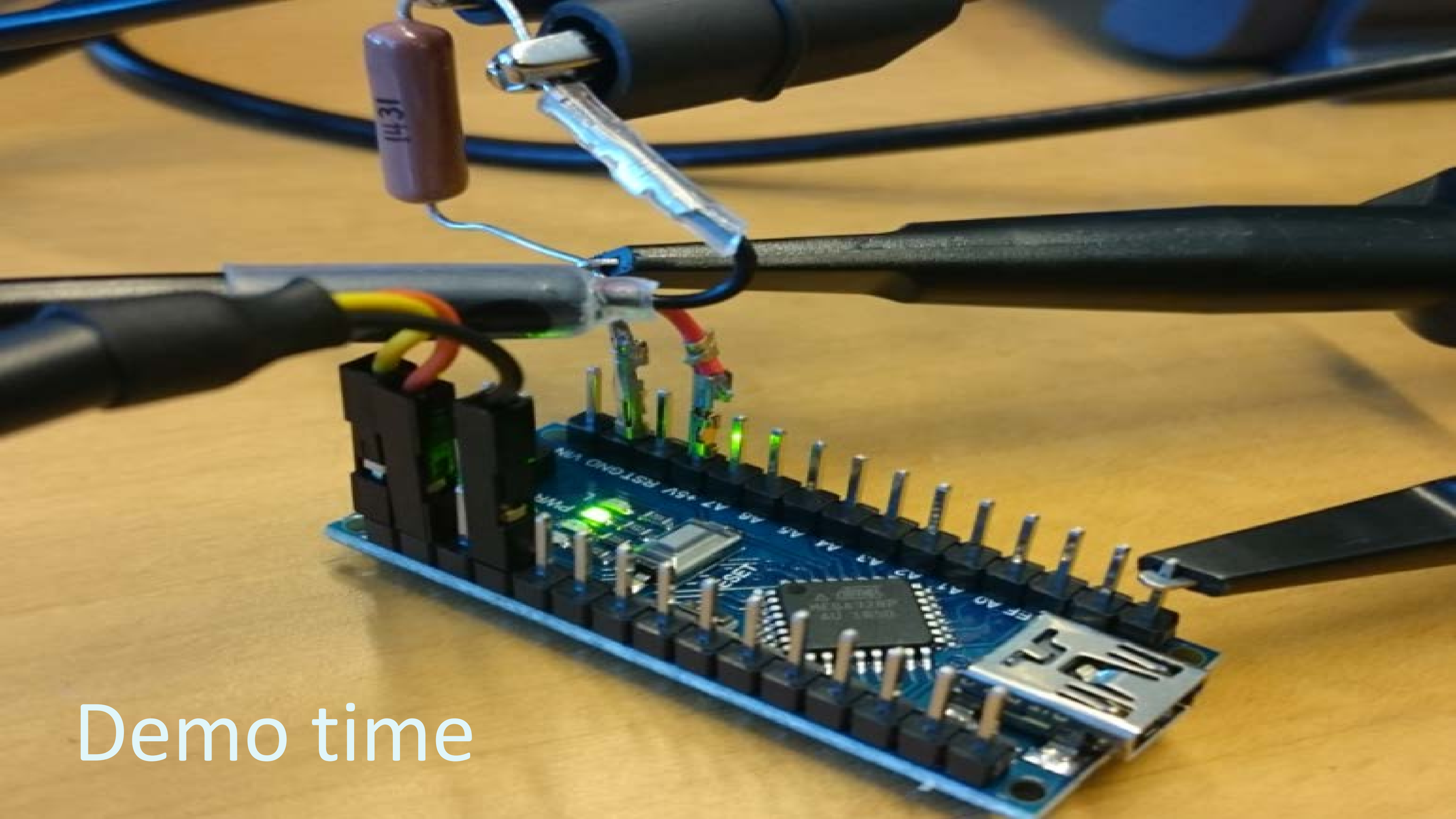
In order to do math, we need to compare “apples to apples”



IoT things typically have LEDs that blink when busy

The RHMe board has a blinky LED that is ON when busy

- **Let’s align measurements with the LED activity**

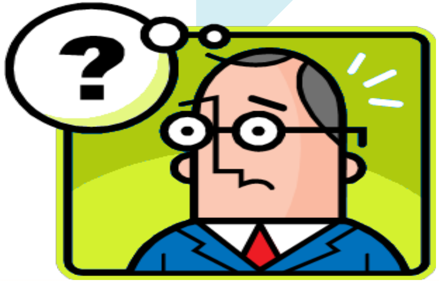


Demo time

General steps for SCA

Trace acquisition → Signal processing → **Leakage detection (optional)** → Attack key: CPA

Does it leak?

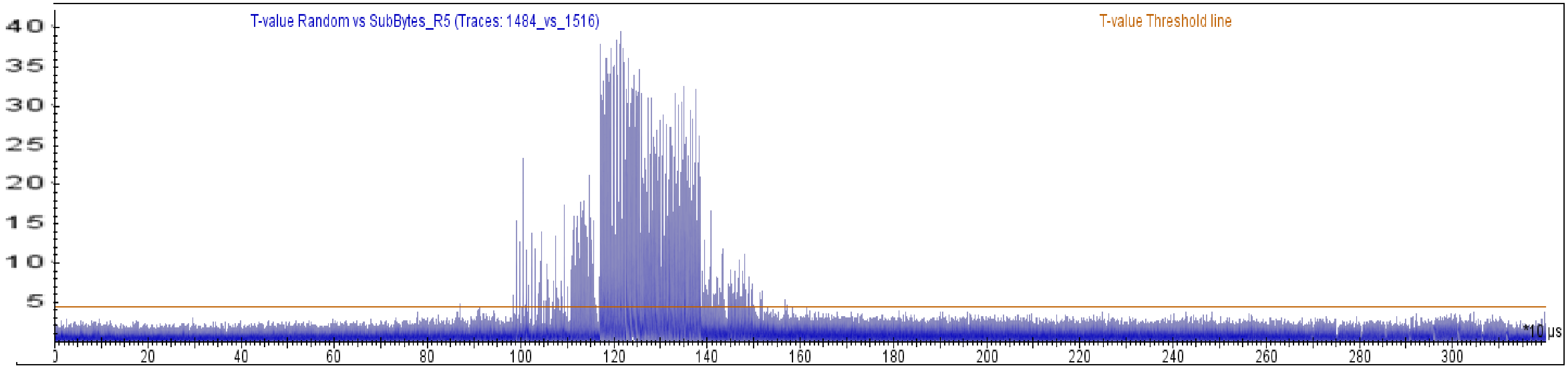


Does it leak?

You can use any tool (e.g R, SciPy, Octave, …) to compute statistics

Useful statistic to find info leakage: Welch T-test

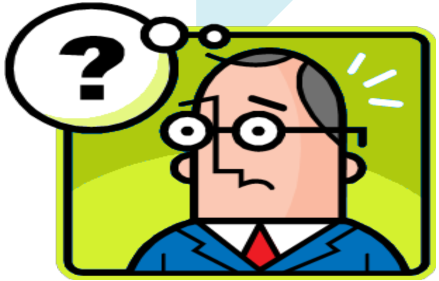
- This test shows if I can tell apart random messages from a fixed one



General steps for SCA

Trace acquisition → Signal processing → Leakage detection (optional) → **Attack key**

Profit?



Warning: math ahead!

I will explain the attack a bit in depth

If you don’t get it now, **don’t worry**:

- SCA programs have everything implemented
- run the scripts and check results
- check later the presentation until it becomes clear

CPA attack: divide and conquer!

Sub-keys in AES

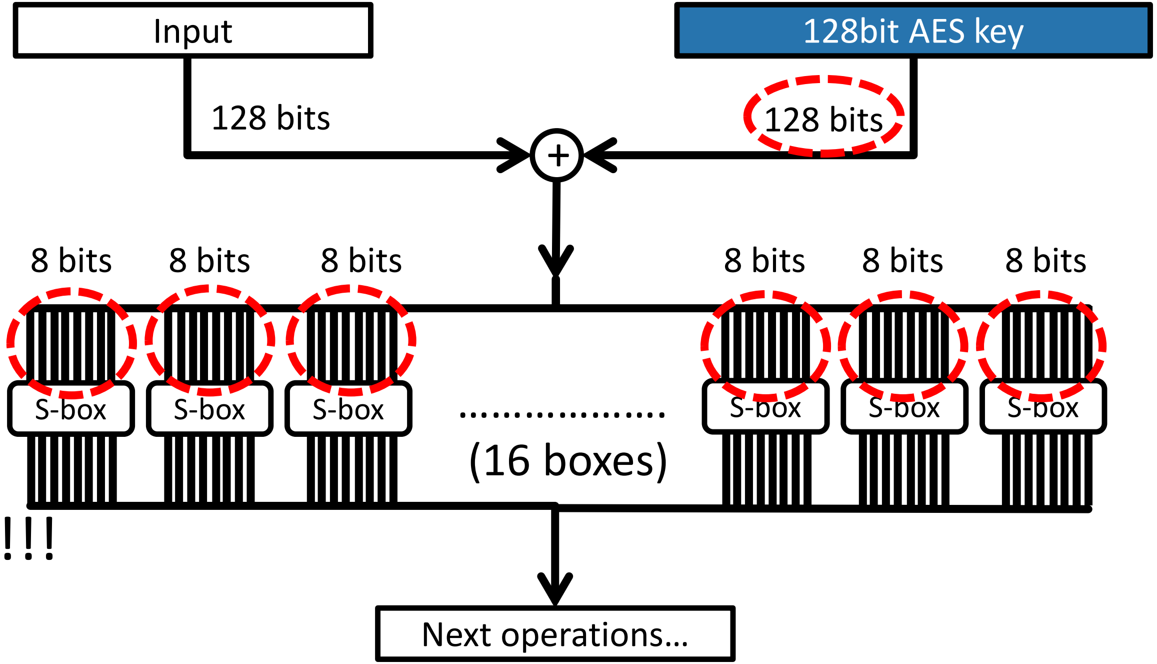
- are used independently
- can be attacked separately

Bruteforce key: 2^{128} tries

Divide and conquer

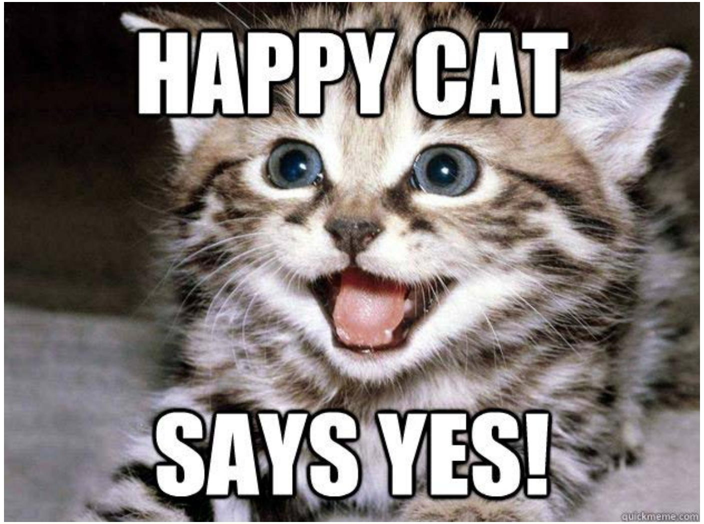
$16*2^8 = 2^{12} = 4096$ tries

We reduce from 2^{128} to 4096!!!



CPA attack: divide and conquer!

- Modern ciphers are fully public
- If we guess part of the key, we can rebuild part of the internals
- Can we check if the values we rebuild match device behavior?

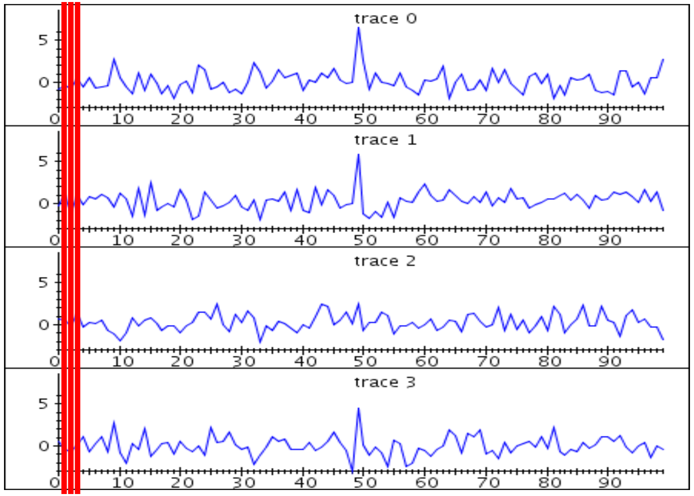


The CPA attack

#RSAC

Data	Bits	HW
FF	11111111	8
C7	11000111	5
09	00001001	2
8B	10001011	4

Power



Correlation trace

Demo time

Side-Channel Analysis takeaways

SCA Takeaway 1: homebrew SCA is dirt-cheap and allows scalable attacks

- ***Total cost for presented setup: <US$60***
- Q: What about time? *2 full days for first attack **
  - 1.8 days fighting the "scope" & drivers & OSS
  - 0.1 days to build the physical setup (removing caps)
  - 0.1 days to build an OSS SCA setup & measure
  - **Note: if you spend US$150 in a decent scope, time is ~2 hours. With professional tools: <2 minutes*
- Q: What about repeating the attack with same setup?*2 minutes!!*
- Result: full key retrieval & scalable attack

SCA Takeaway 2:

Open-Source Software SCA setup complexity for IoT-like devices is minimal

FAULT INJECTION: THEORY AND APPLICATION

Let’s break a security check implementation!

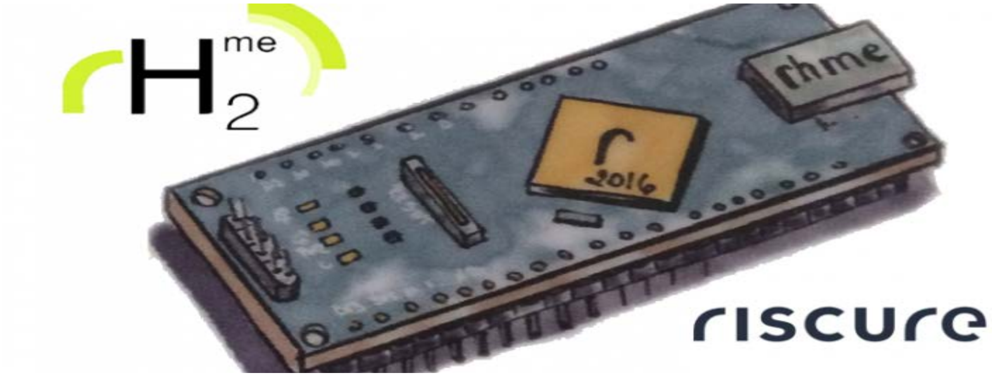
Challenge: FIesta

Goal

- Unlock the device

Info

- The device boots
- And then keeps saying “Lock” forever



Lock
Lock
Lock
Lock
…

Hypothesis

Guess is that the code in the board is similar to this:

```
boolean unlocked=false;
boot_CPU_and_IO();
while(1){
	unlocked=do_some_check();
	if(unlocked){
		print(secret);
	}
	else{
		print(“Lock”);
	}
}
```

Hypothesis

What would you glitch here?

```
boolean unlocked=false;
boot_CPU_and_IO();
while(1){
      unlocked=do_some_check();
      if(unlocked){
            print(secret);
      }
      else{
            print(“Lock”);
      }
}
```

Attack plan

What did I glitch:

```
boolean unlocked=false;
boot_CPU_and_IO();
while(1){
    unlocked=do_some_check();
    if(unlocked){
        print(secret);
    }
    else{
        print(“Lock”);
    }
}
```

How to generate a glitch 101

Simplest FI attack I can think of: VCC glitching

Clock of the MCU in the RHMe2 board is 16MHz

- 1clk = 62.5ns
- Hopefully timing won't be an issue

Brainstorm for FI setup

- MCU, a transistor and two PSUs
- MCU with DAC attached a buffer
- MCU with multiplexer chip and a buffer
- ….

CheapoGlitcher

Free development board I got with ARM MCU@ 180MHz

- If you want to buy a similar board, it is ~US$ 15

GPIO pins can be driven @ 90MHz max →11ns glitch → fast enough

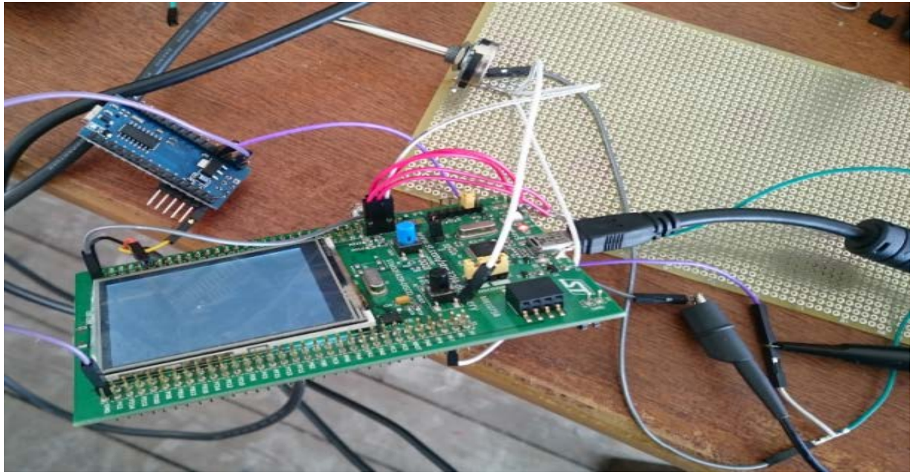
GPIO supplies enough current to power up the IoT board

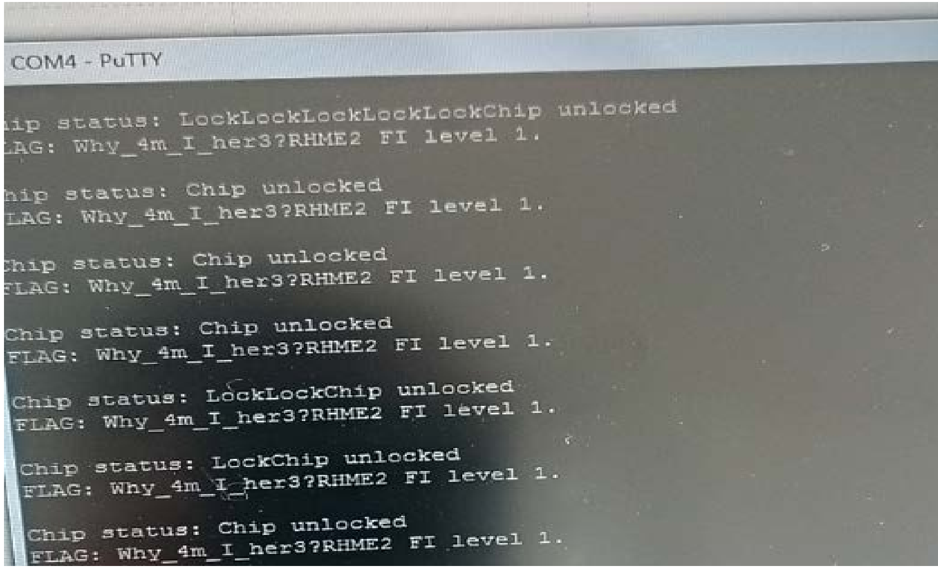
I’m just going to toggle the GPIO at different instants

Will it even work?

CheapoGlitcher: will it work?

5 hours of high-caffeine drinks in the SHA2017 Amsterdam conference:





100% success rate

CheapoGlitcher unexpected result

Fault Injection (FI) takeaways

FI Takeaway 1:you can glitch general purpose MCUs with almost anything

- RHMe2: 100% reproducibility, uber-cheap stuff and 5 hours of effort

FI Takeaway 2: countermeasures for FI is a must

- Attack was possible due to the infinite loop: free unlimited retries
- Think about your implementation: do you have such a structure?

```
/* glitch here */
if(mbedtls_pk_verify(..., hash, signature, ...)) {

  /* do not boot up the image */
  while(1);

} else {

  /* boot up the image */
  boot();
}
```

CONCLUSION & TAKEAWAYS

Conclusion

My goals today

- SCA is affordable for everyone ✓
- FI is affordable for everyone ✓

Conclusion

My goals today

- Developer: should you do something?

Do you know the answer for these questions?

- Is my security going to be somehow bypassed with FI?
- Are any of my secrets going to leak with SCA?

Apply: what you should do after this talk

1. **Understand threat**
   - Learn how SCA/FI attacks work (read papers or take a training)
   - Try the attacks yourself!
2. **Develop a solution**
   - Remember: current attacks can be way more advanced than what was presented here
   - Effective countermeasures include multiple levels
     - Software
     - Hardware
     - Protocols
   - Try design patterns as described in documents here: https://www.riscure.com/gocheap/
3. **Verify**
   - Design != Implementation → vulnerabilities are more persistent than you think
   - Independent testing avoids blind spots → security evaluation labs can help

Questions?

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