Side-Channel Attacks and Countermeasures

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Overview

- What are side-channel attacks?
  - Definition, examples
- How to thwart side-channel attacks?
  - Countermeasures
- How to make sure that you did it?
  - Proofs, automatic tools

Side-Channel Attacks

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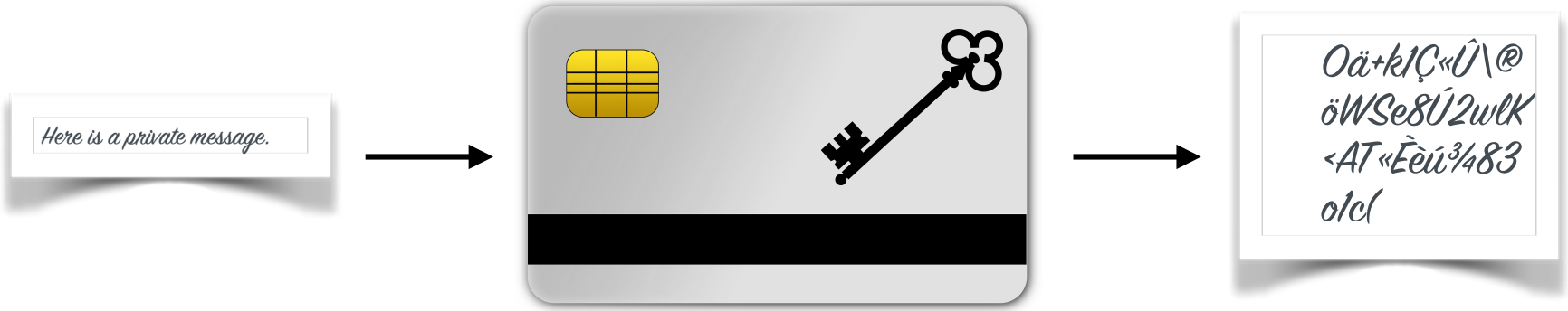

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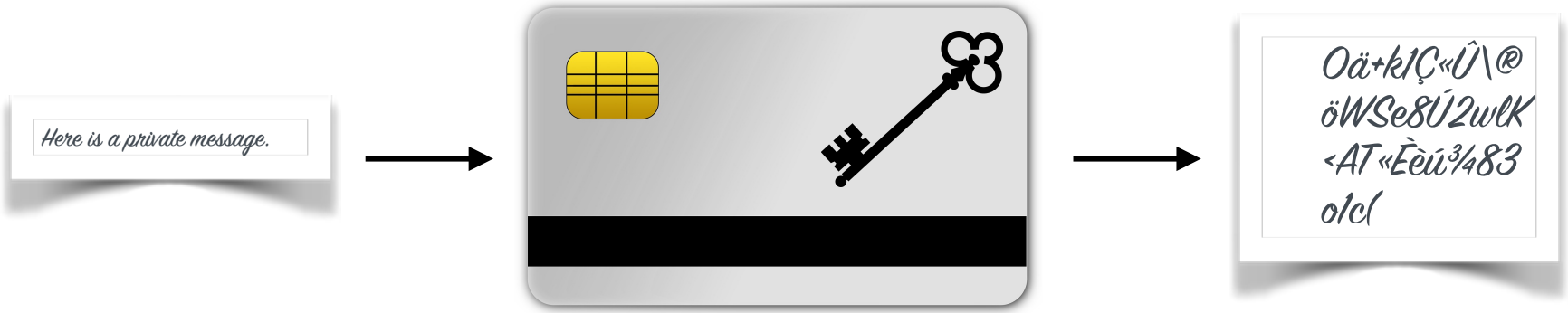

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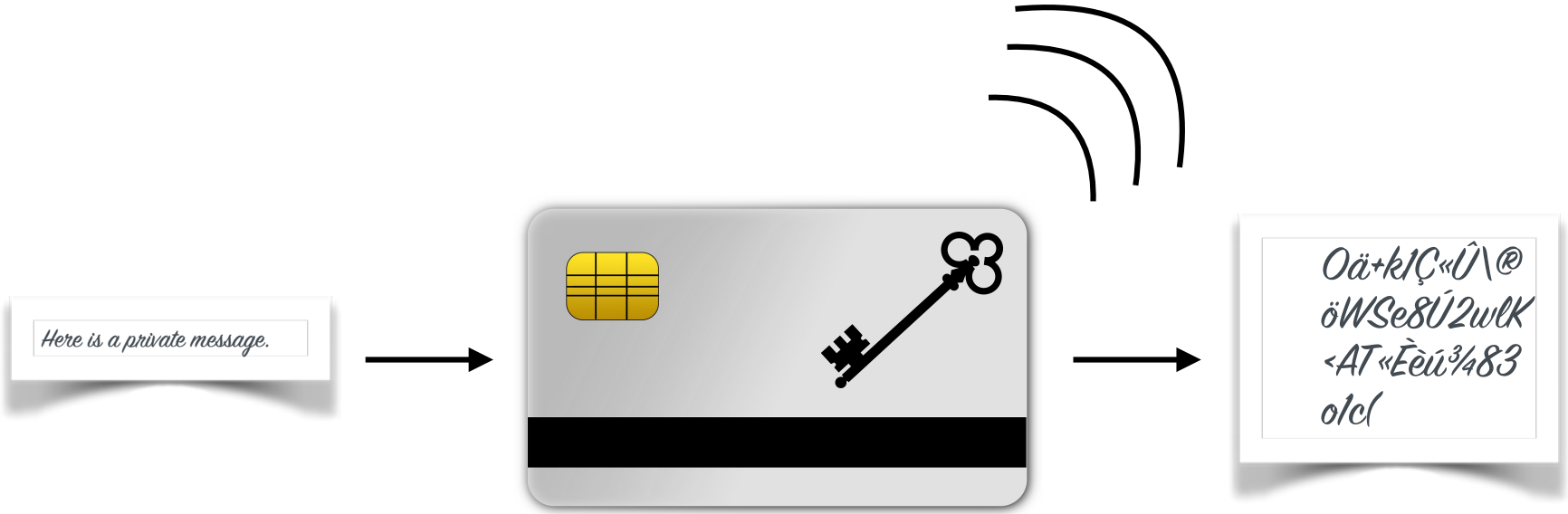

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- Side-channel analysis: $\mathscr{A} \leftarrow (m, c, \mathscr{L})$

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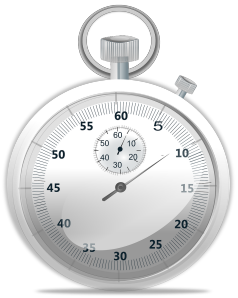

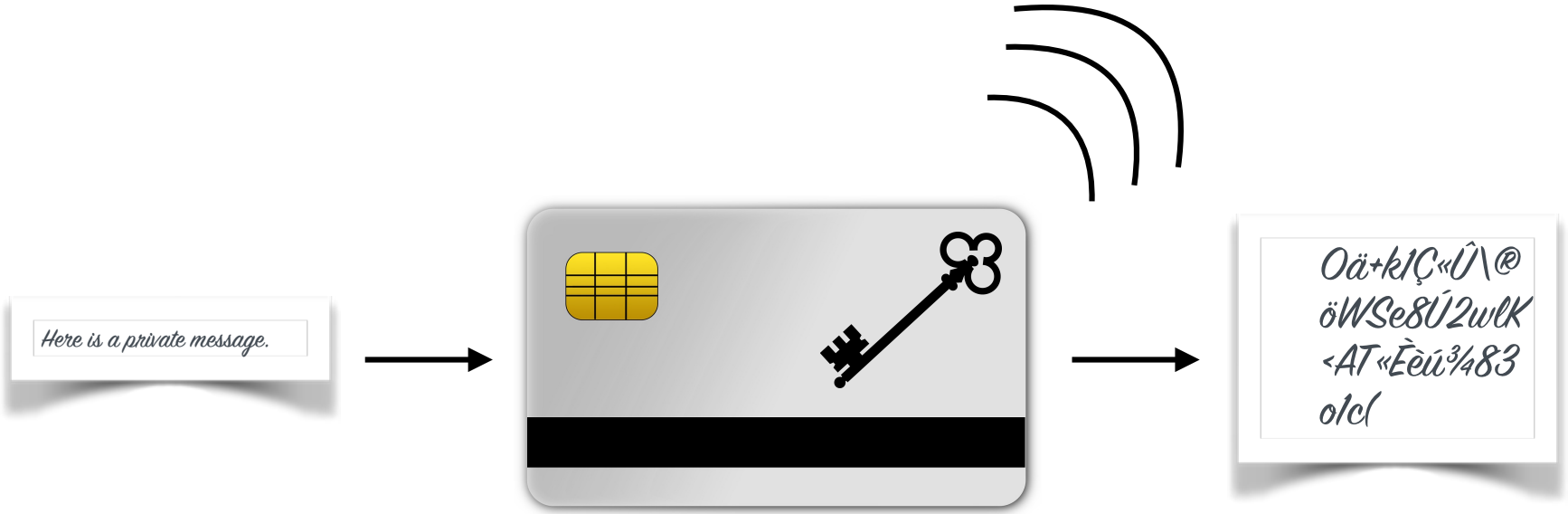

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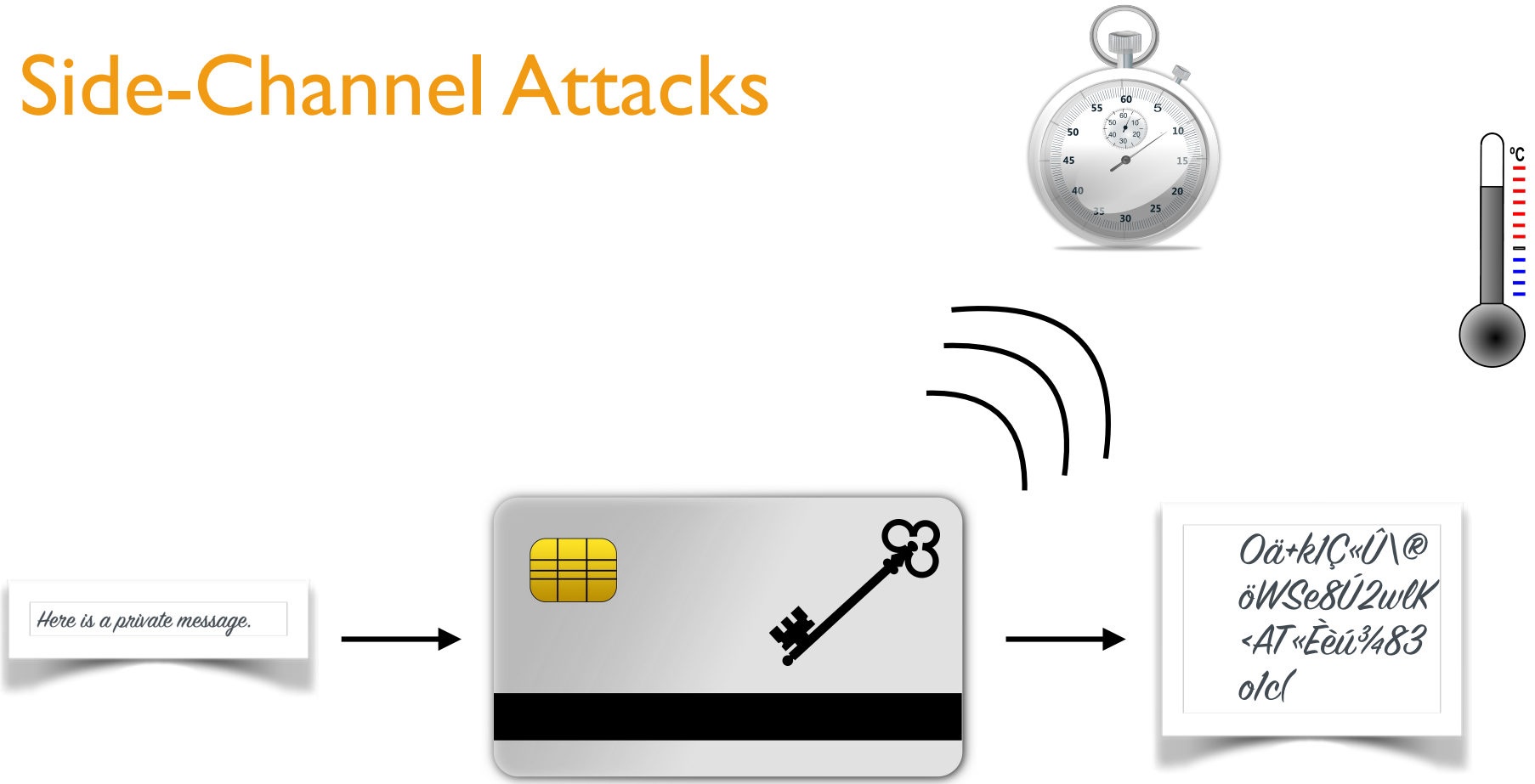

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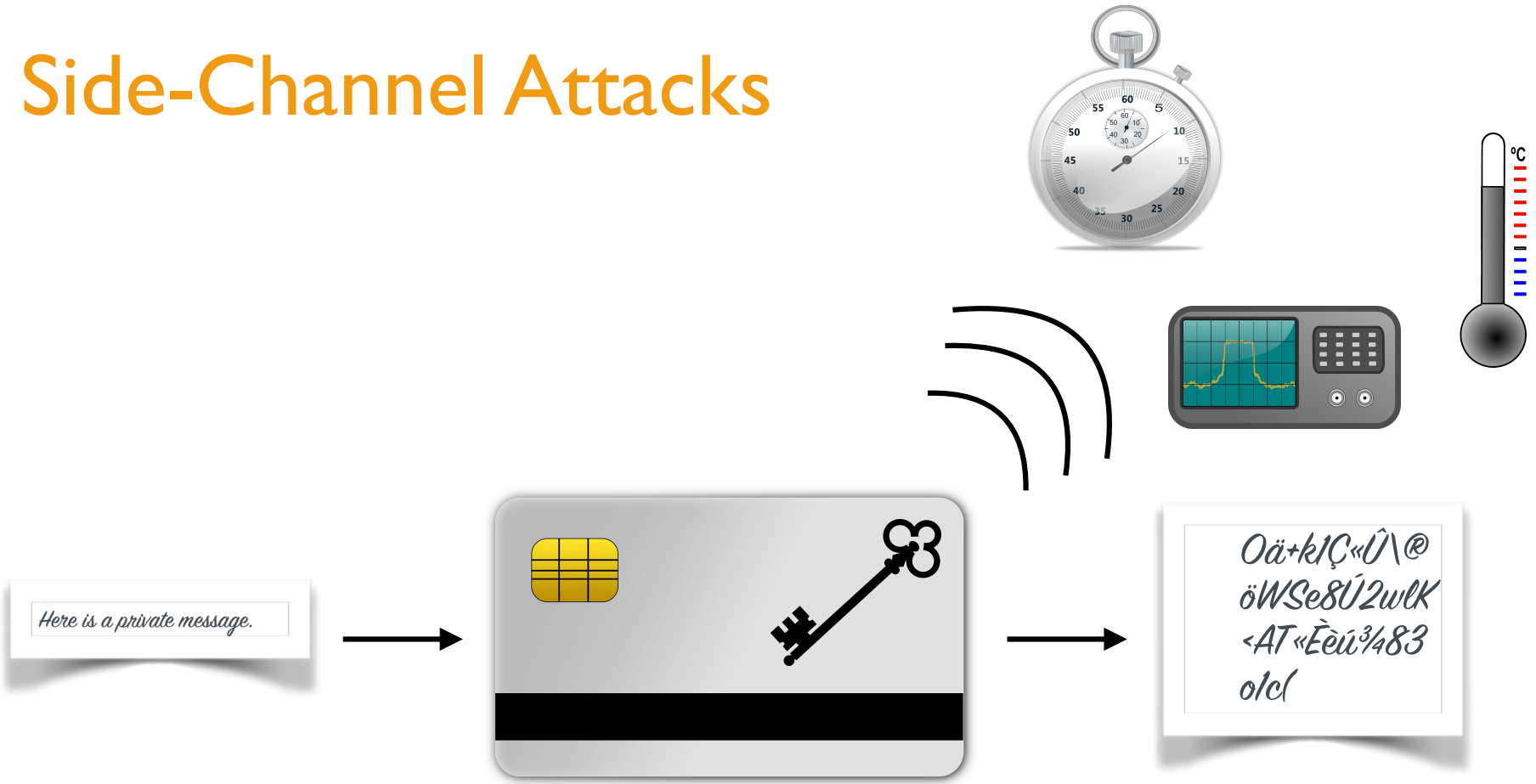

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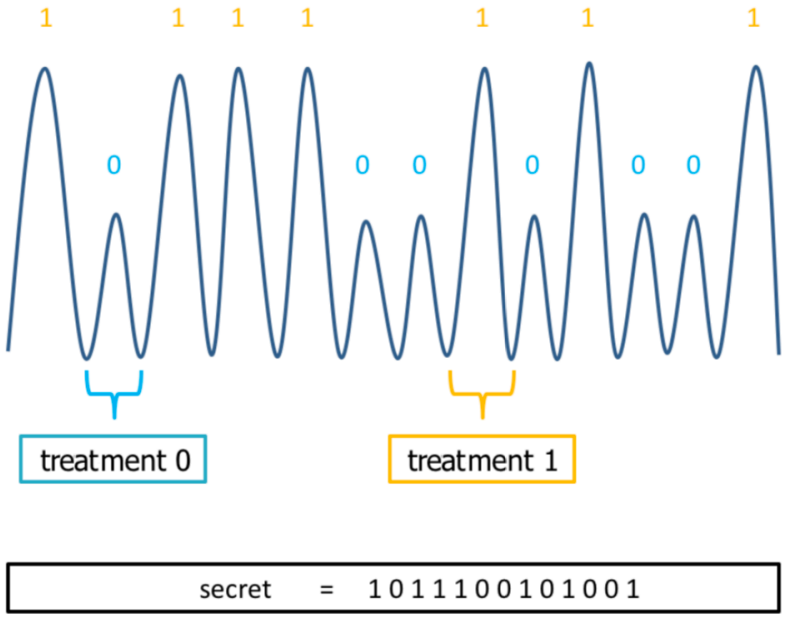
Example of SPA

Algorithm 1 Example

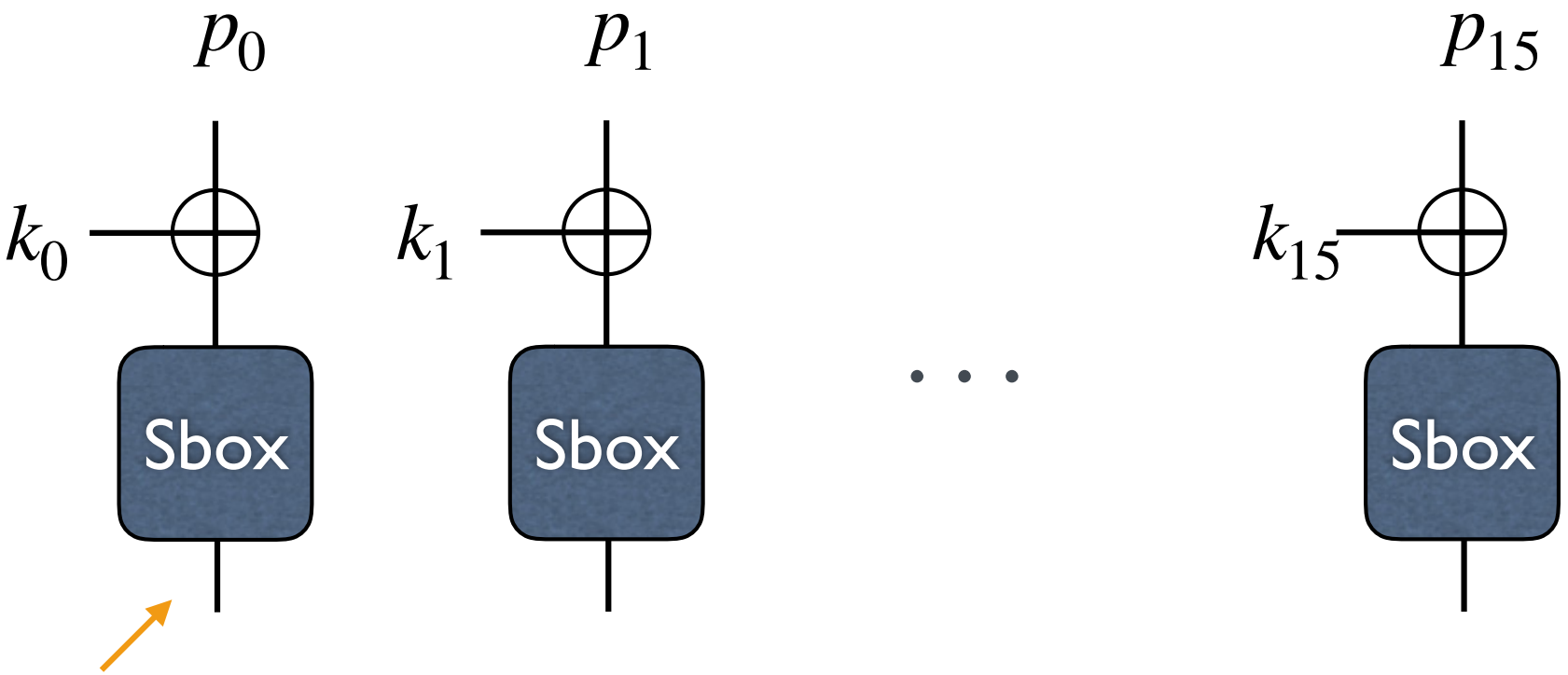
```
for i = 1 to n do
    if key[i] = 0 then
        do treatment 0
    else
        do treatment 1
    end if
end for
```



SPA: one single trace to recover the secret key

Example of DPA

- AES
  - plaintext and key on 16 bytes
  - First round: 16 S-boxes



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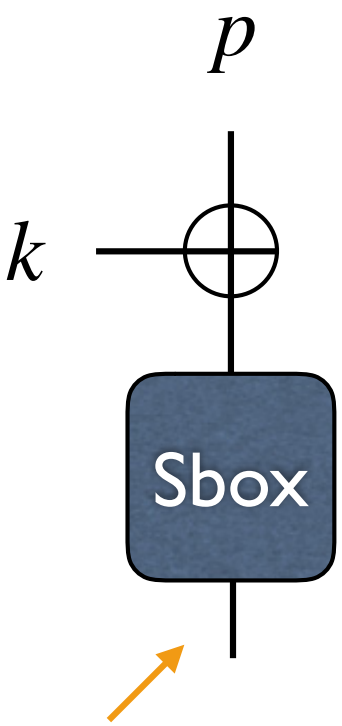

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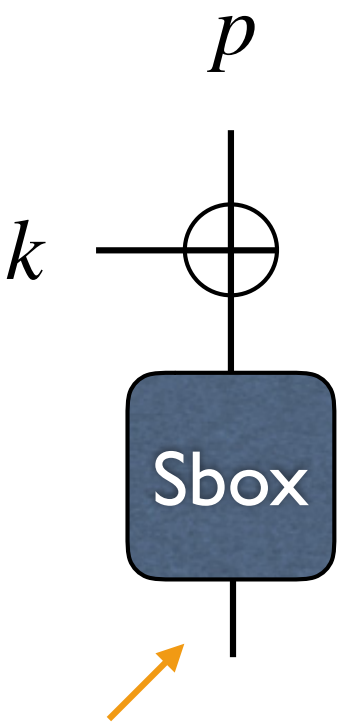

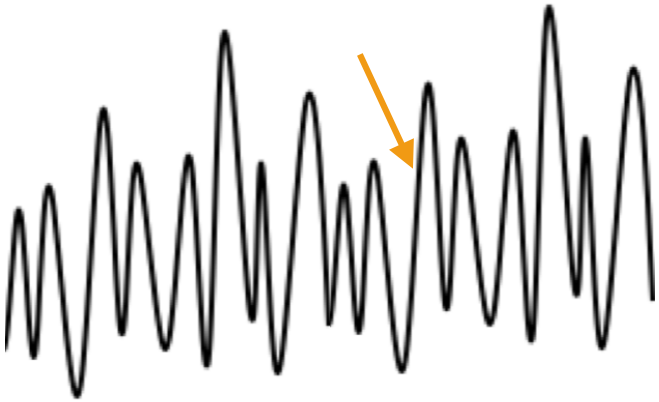

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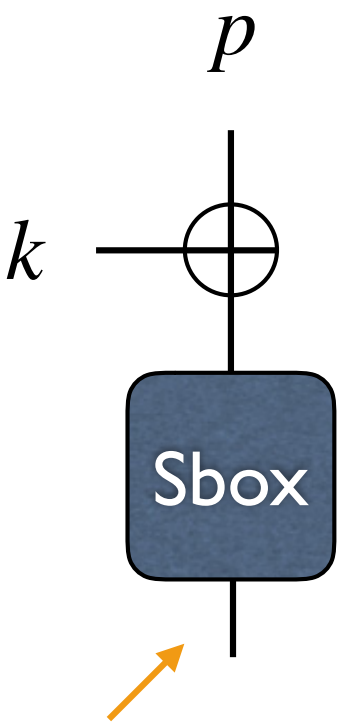

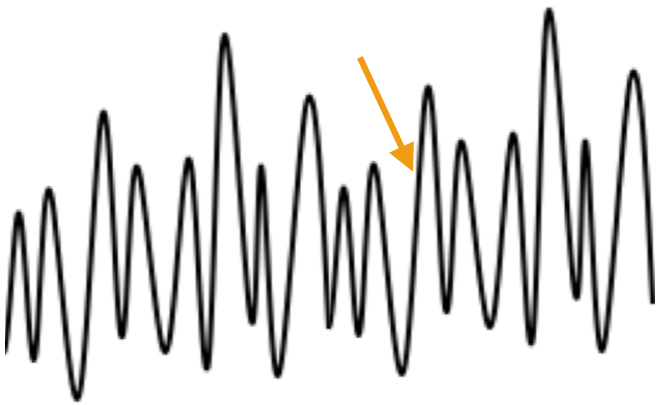

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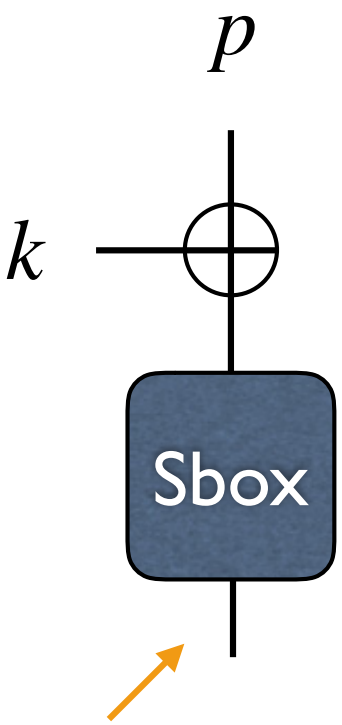

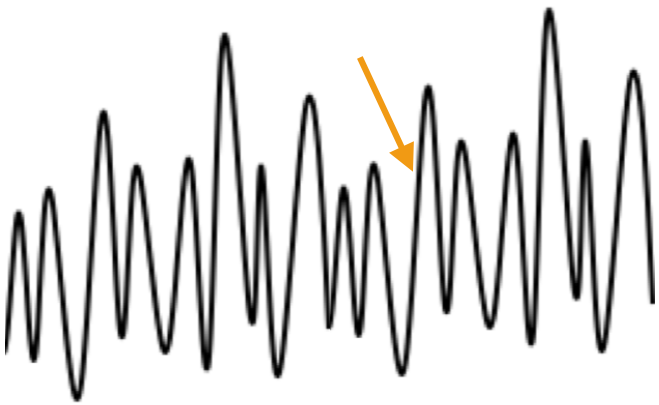

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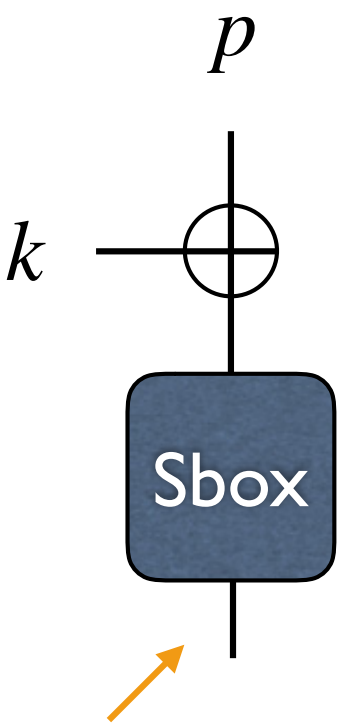

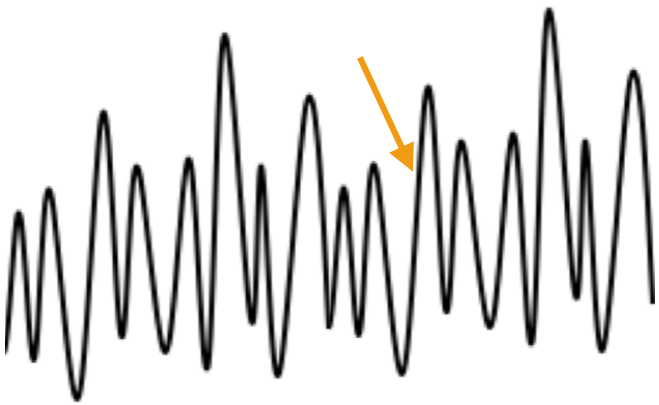

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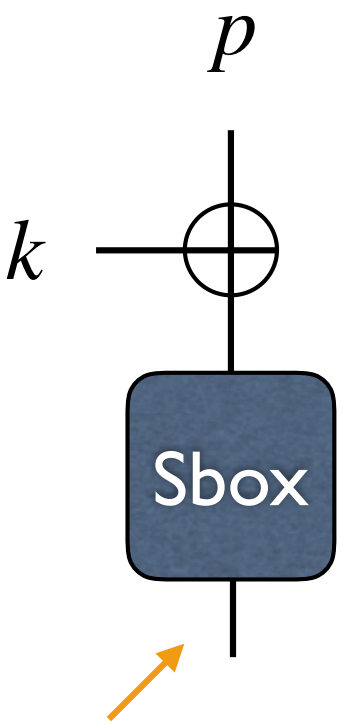

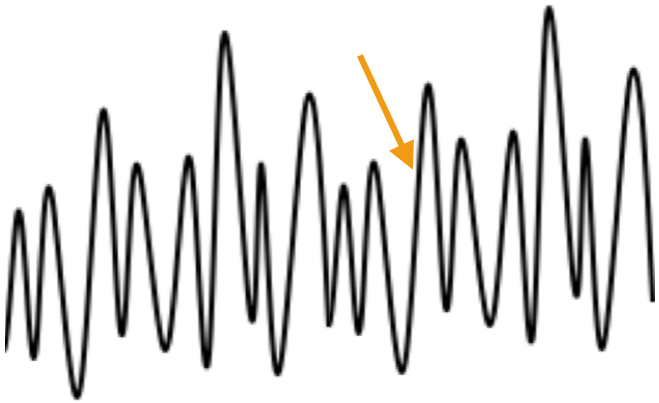

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$\mathscr{C}_0$

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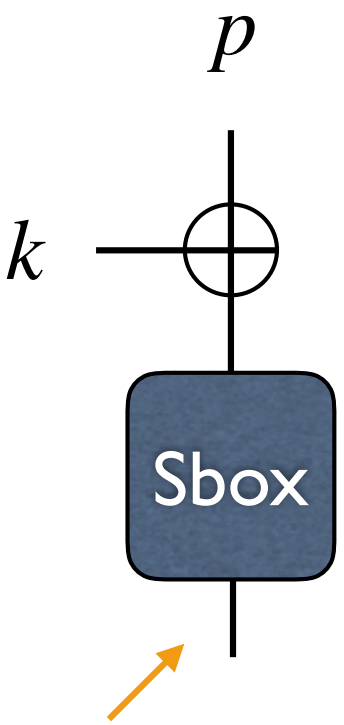

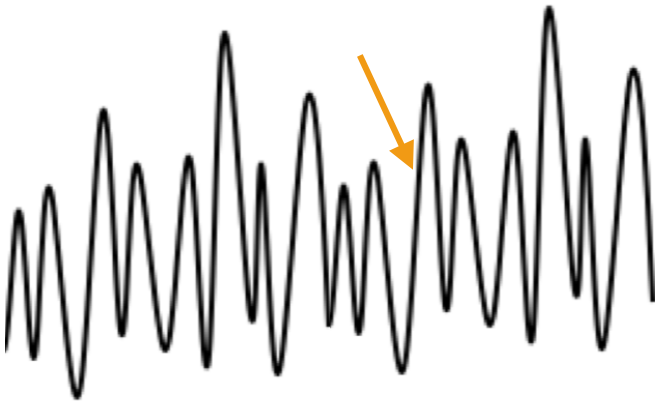

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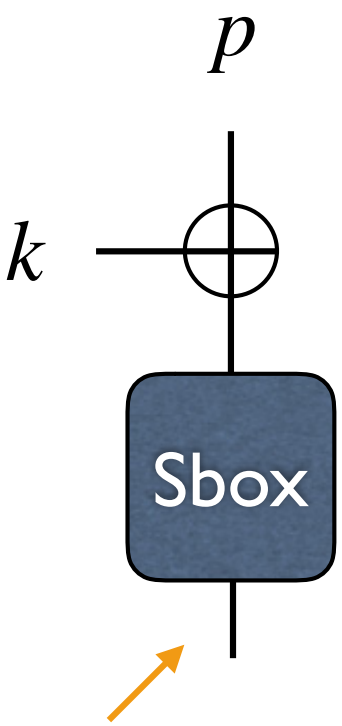

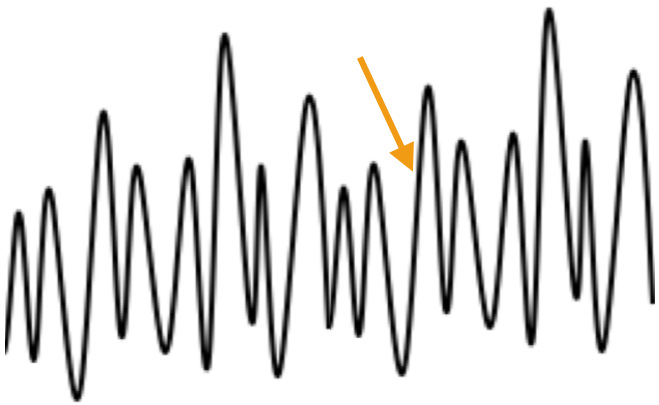

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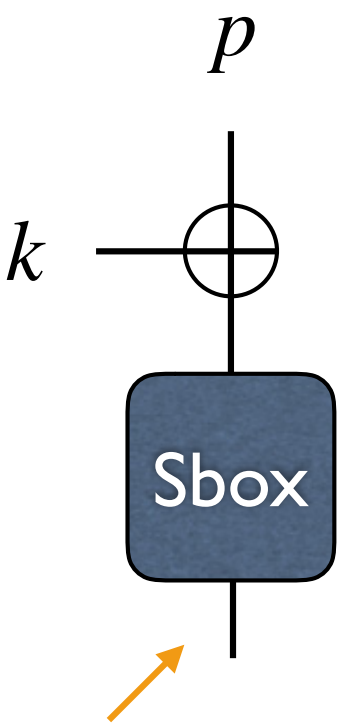

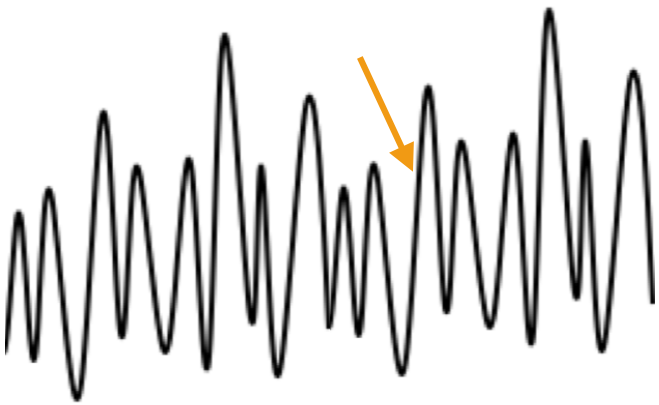

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$$(\mathscr{C}_0, \mathscr{C}_1, \mathscr{C}_2, \ldots, \mathscr{C}_{255})$$

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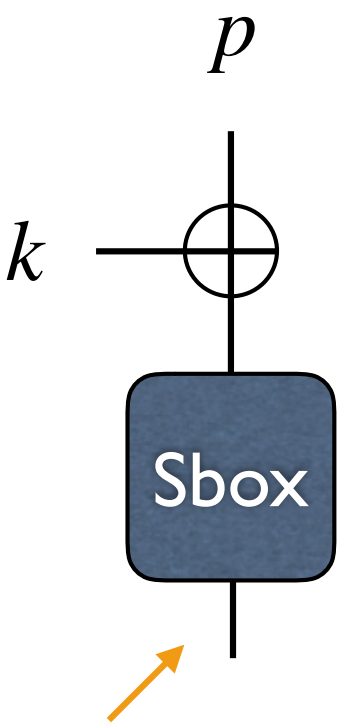

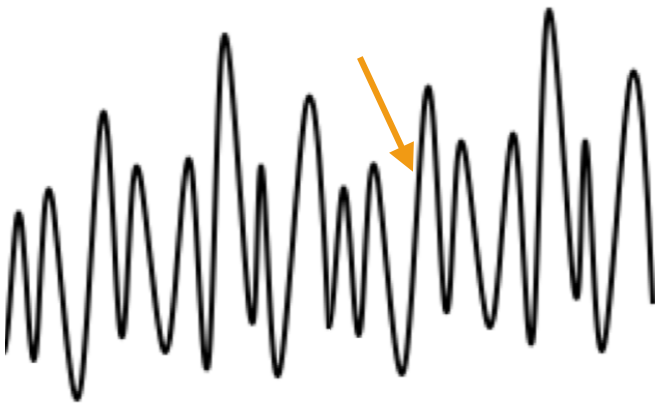

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$$\text{argmax}\ (\mathscr{C}_0, \mathscr{C}_1, \mathscr{C}_2, \ldots, \mathscr{C}_{255})$$

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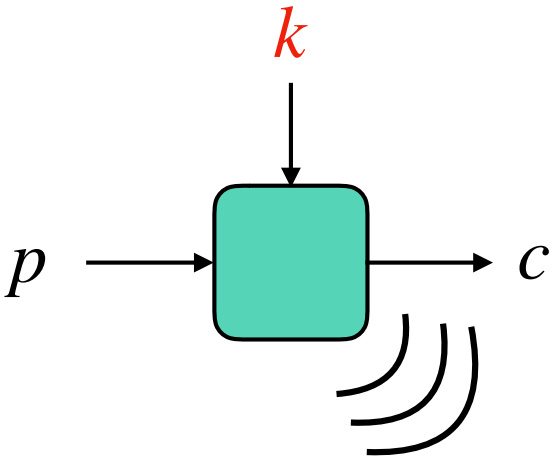
Side-Channel Attacks

- Cheap equipment
  - Basic oscilloscope is enough
- Few traces
  - Less than a hundred traces to recover secrets in software
  - A few hundreds/thousands traces in hardware
- Fast
  - A few minutes to get the traces
  - A few seconds to mount the attack

Countermeasures

How to thwart SCA?



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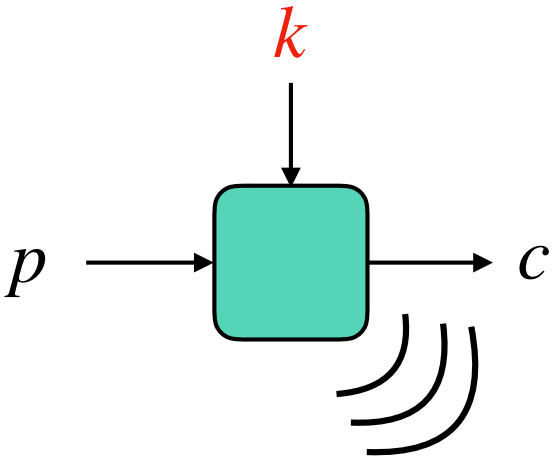

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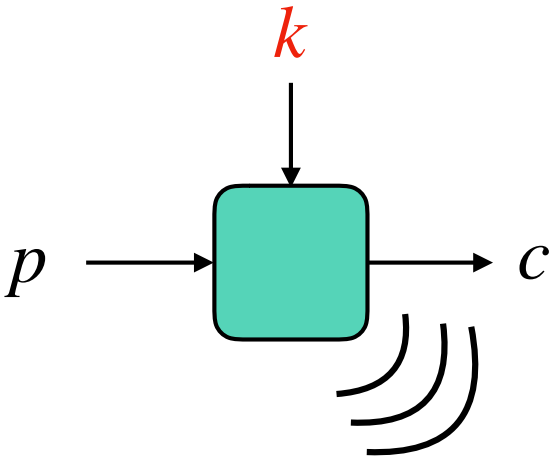

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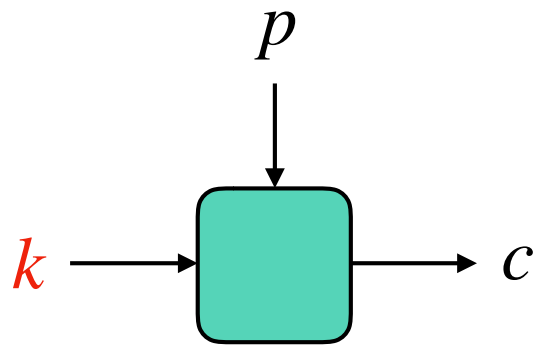

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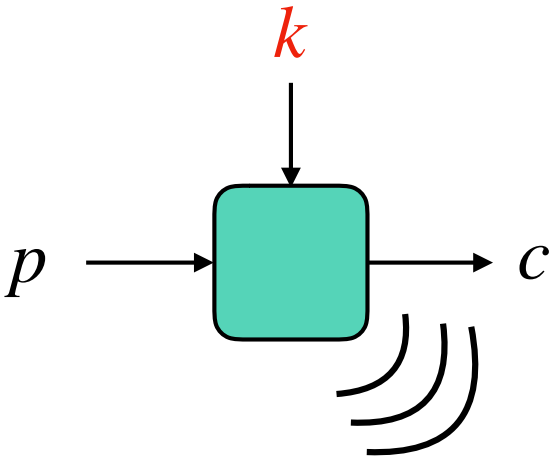

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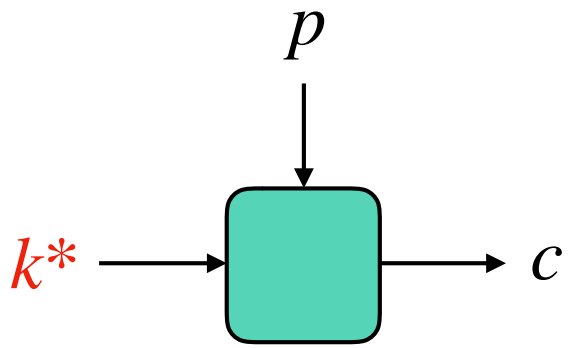

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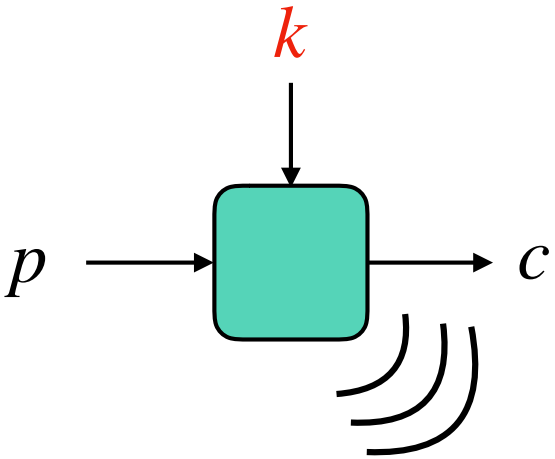

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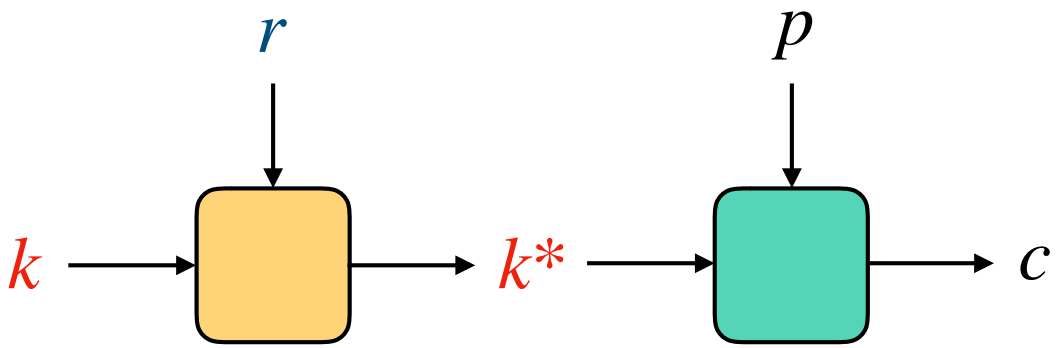

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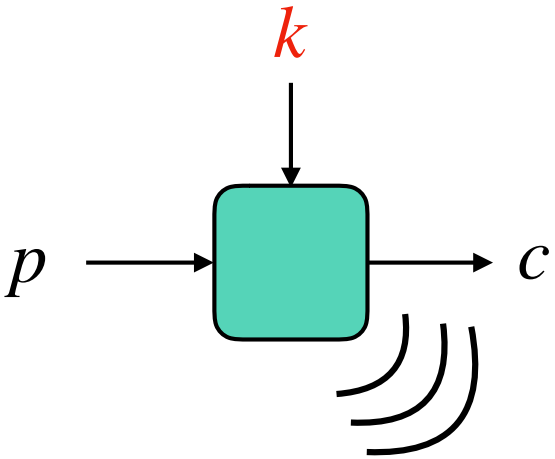

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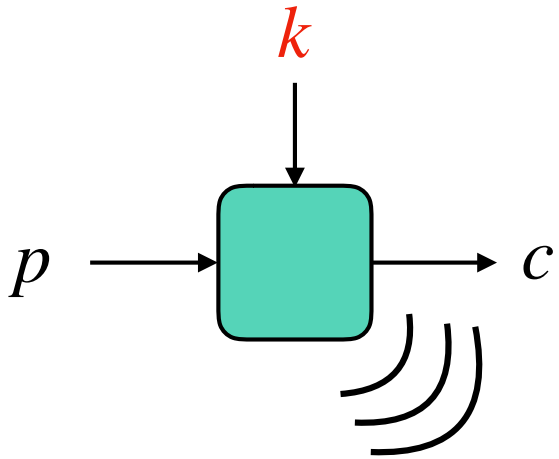

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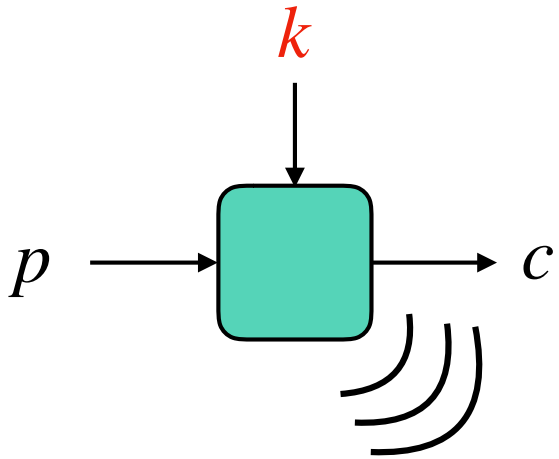

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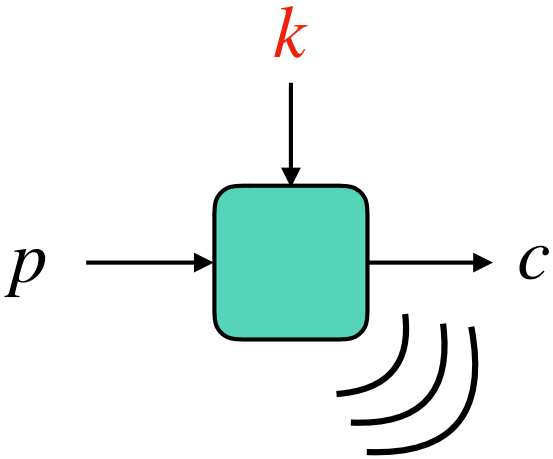

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for each sensitive value $v \leftarrow f(p, k)$

$$v_0 \leftarrow v \oplus \left(\bigoplus_{i=1}^{n-1} v_i \right) \qquad v_1 \leftarrow \$ \qquad v_2 \leftarrow \$ \qquad \cdots \qquad v_{n-1} \leftarrow \$$$

Masking in Practice

- Masking linear operations

$$z \leftarrow x \oplus y$$

$$x = x_0 \oplus x_1 \oplus \ldots \oplus x_{n-1}$$
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Leakage Models

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- How to evaluate the security of an implementation?

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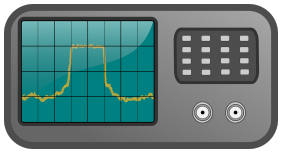

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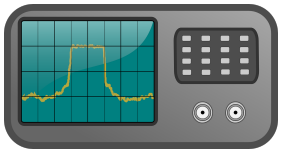

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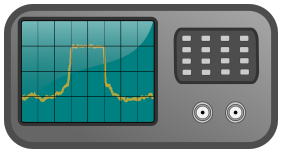

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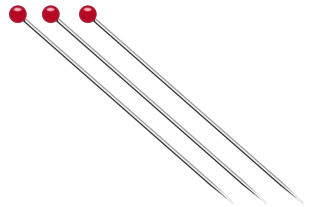
Probing Model



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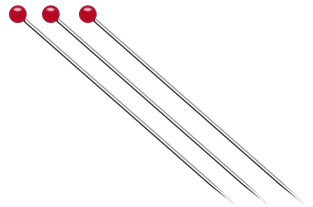

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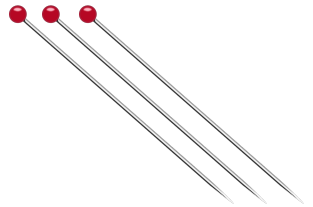

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  - Not that close to the reality…

Random Probing Model

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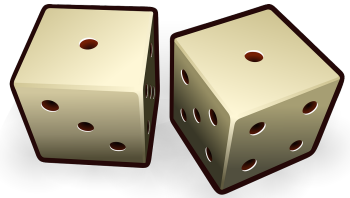

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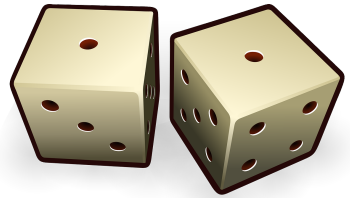

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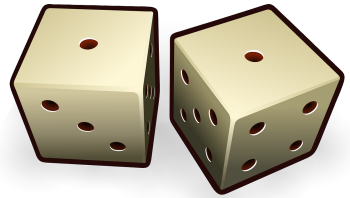

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- Pros and Cons
  - A bit more complicated to make security proofs
  - Closer to the reality

Noisy Leakage Model

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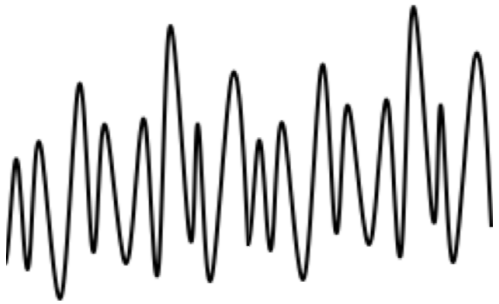

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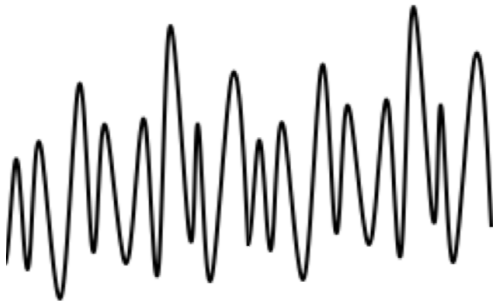

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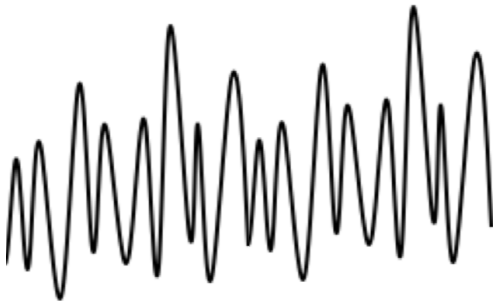

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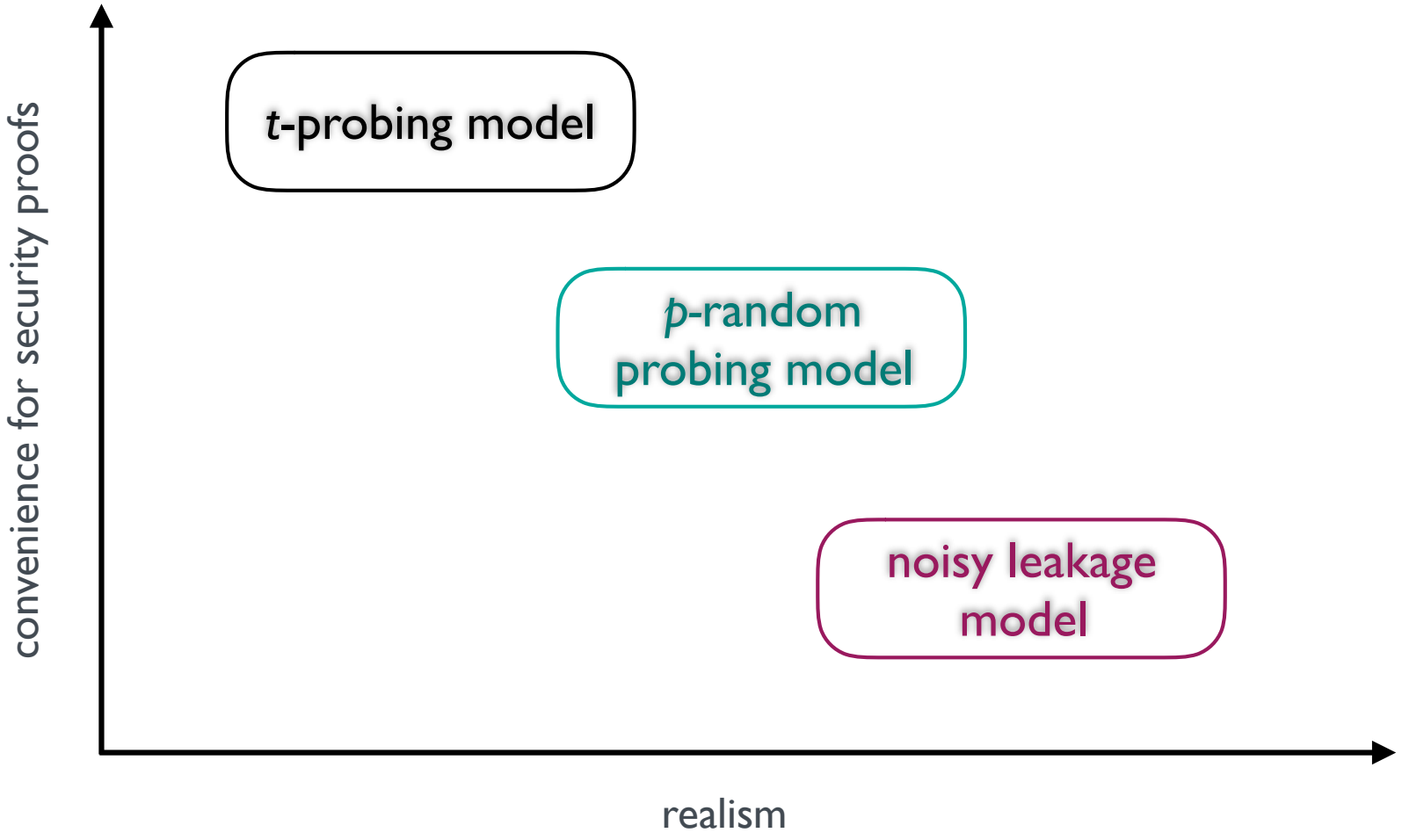
Reductions


convenience for security proofs
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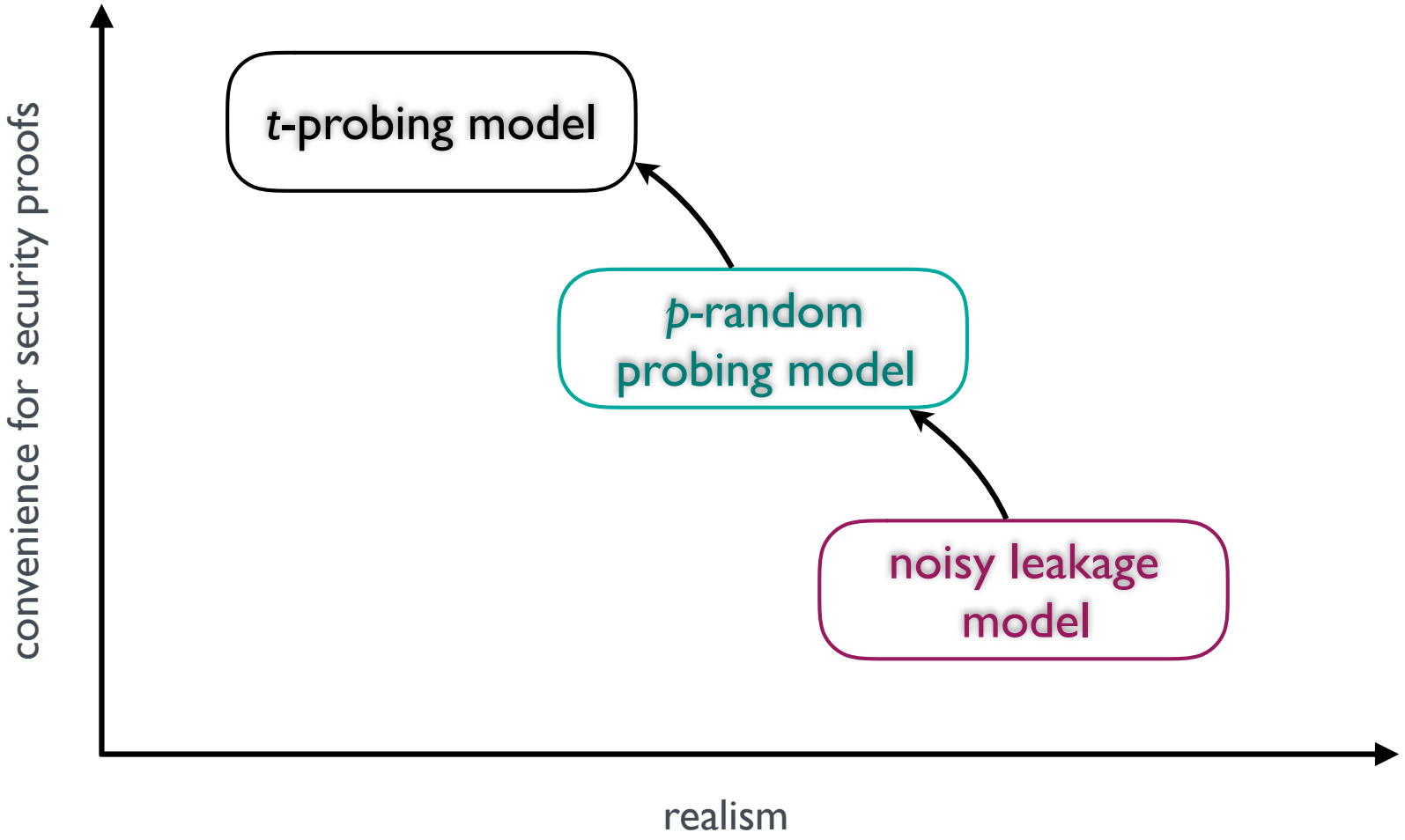
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Security Proofs

Proof in the Probing Model

- Reminder: an implementation is *t*-probing secure iff any set of at most *t* variables is independent from the secret

2 shares

function example(a_0, a_1, b_0, b_1)

$r \leftarrow \$$

$u \leftarrow a_0 \cdot b_0$

$c_0 \leftarrow u \oplus r$

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$x \leftarrow a_0 \cdot b_1$

$w \leftarrow v \oplus x$

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return (c_0, c_1)

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1-probing secure?

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$\binom{33}{2} = 528$ couples to verify

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maskVerif

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Security order t

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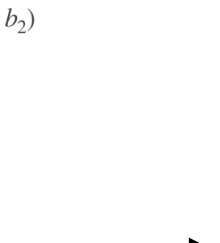

maskVerif

Security proof or potential attacks

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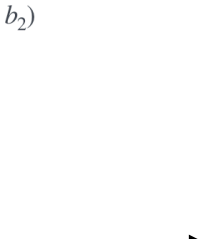

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Security proof or potential attacks

Rules?

Conclusion

Summary

- Side-channel attacks are very powerful
  - Few seconds to recover the key on some software devices
  - Cheap equipments

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- Practical security
  - Security proofs in relevant leakage models
  - Automatic tools

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- Efficiency
  - The least possible randomness
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  - The least possible randomness
  - The least possible operations
- Security
  - Theoretical proofs of existing schemes
  - Automatic tools to verify the security of implementations
- Practicality
  - Security of implementations under leakage models as close as possible to the reality

Thank you

Subsidiary Question

Is probing secure ?