SIFA: Exploiting Ineffective Fault Inductions on Symmetric Cryptography

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Outlook

We present fault attacks that are ...

- Hard to prevent
  - Defy detection, any degree of redundancy
  - Defy infection
  - (Defy masking)
- Versatile
  - Many possible fault locations/effects
  - Applicable to many symmetric schemes
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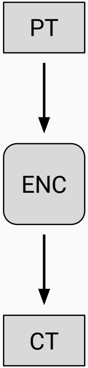
Fault Attacks

- Get device access:
  - Set plaintexts
  - Observe ciphertexts
- Cause (partially) erroneous computation
- Observe faulty and correct ciphertext
- Determine correct sub key guesses by verifying output pairs

⇒ Differential Fault Attack (DFA)



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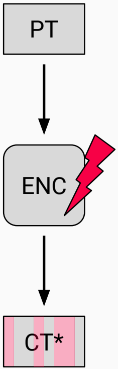

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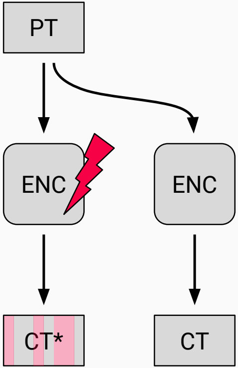

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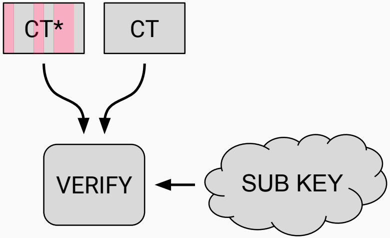

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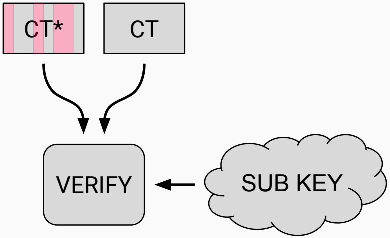
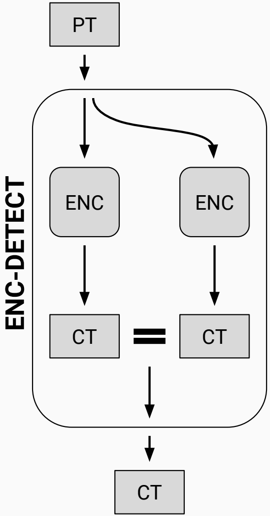


- Use redundancy to detect faults
- Fault detected → No ciphertext
- 2 identical faults necessary for attack

→ More redundancy, Enc-Dec, masking, etc...



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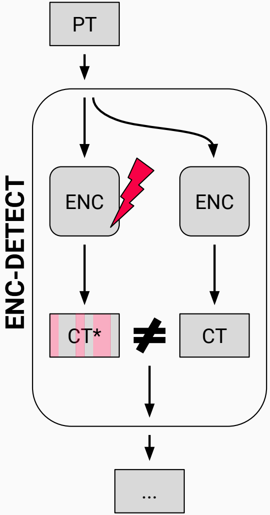

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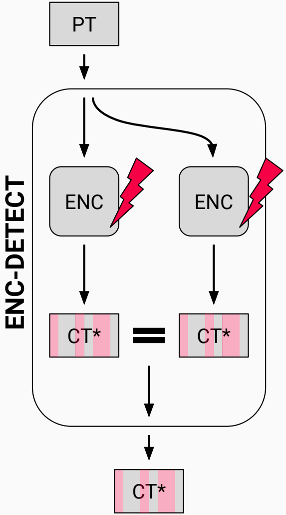

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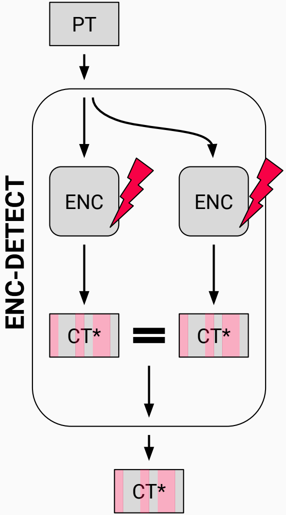

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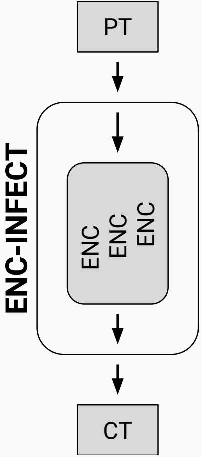

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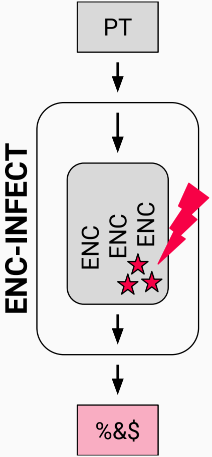

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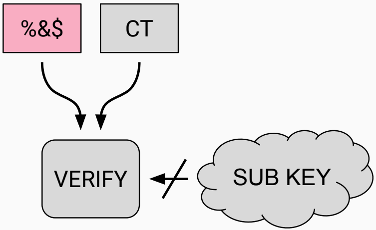

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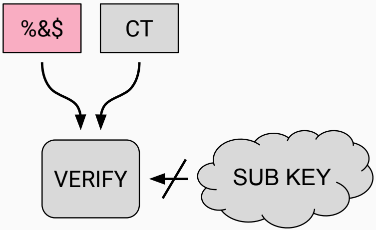

Statistical Ineffective Fault Attacks (SIFA)

Combines ...

- Ineffective Fault Attacks (IFA) by Clavier et al. [Cla07]
  - \+ Exploits only correct ciphertexts (similar to safe error attacks)
  - – Requires precise faults with known effect
- Statistical Fault Analysis (SFA) by Fuhr et al. [FJLT13]
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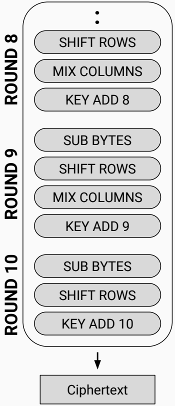
SIFA on AES - Fault Injection Phase

Example for AES...

- Over multiple encryptions, state bytes are uniformly distributed
- Fault somewhere between MC in round 8-9
- Goal is some non-uniform distribution
  - Stuck-at fault, random fault, skips, flips...
  - Fault Granularity: 1 bit → a few bytes
- **Works even for ineffective faults**
  - i.e. a fault was injected but the computation is still correct
  - Attacker gets "access to subset of ciphertexts"



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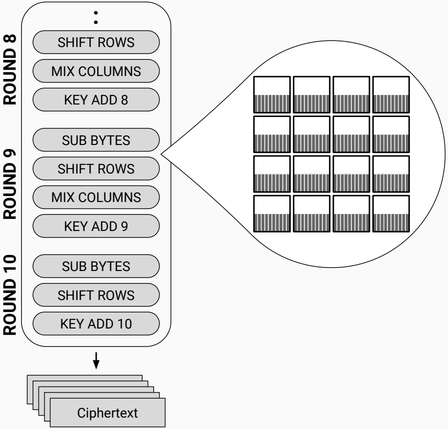

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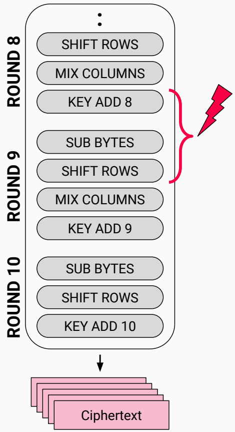

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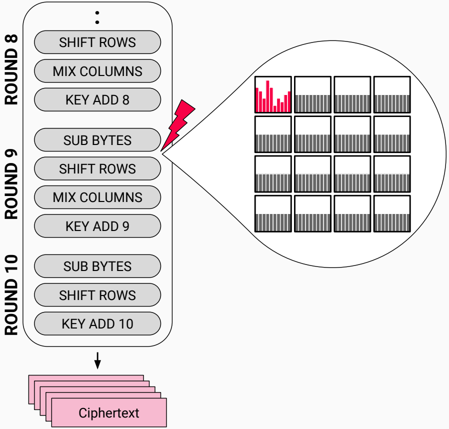

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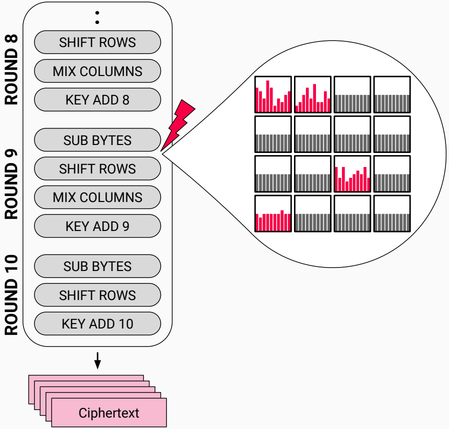

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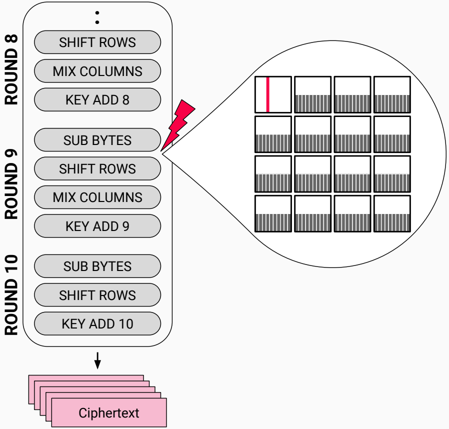

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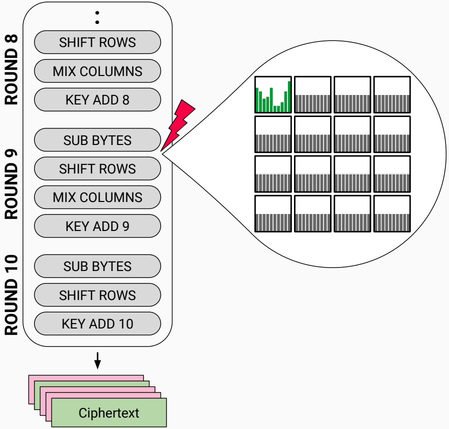

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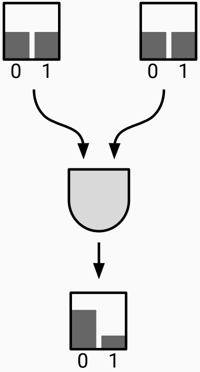

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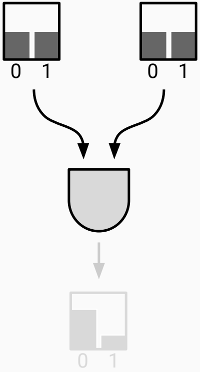

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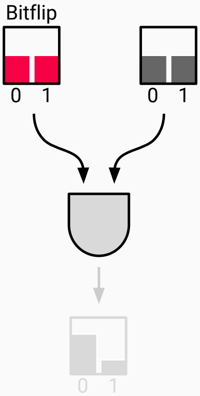

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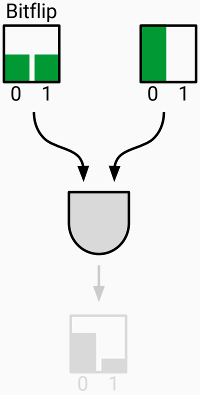

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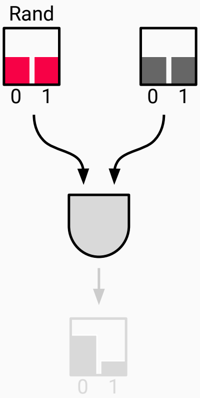

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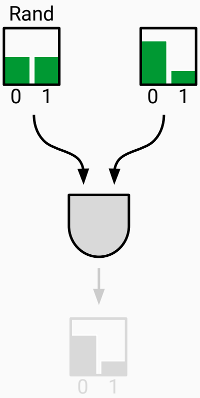

SIFA on AES - Key Recovery Phase

- Collect set of correct ciphertexts $\mathcal{C}_1 \ldots \mathcal{C}_n$ from faulted encryptions
- Guess 32-bit sub key $\mathcal{K}_{10}$ and calculate state $\mathcal{S}_i$ in round 9 ($\mathcal{K}_9$ is not needed):

$$\mathcal{S}_i = \mathsf{MC}^{-1} \circ \mathsf{SB}^{-1} \circ \mathsf{SR}^{-1}(\mathcal{C}_i \oplus \mathcal{K}_{10})$$

- Measure uniformity of $\mathcal{S}_1 \ldots \mathcal{S}_n$ using e.g. the Squared Euclidean Imbalance (SEI)
- Uniform distribuiton expected for wrong key candidate
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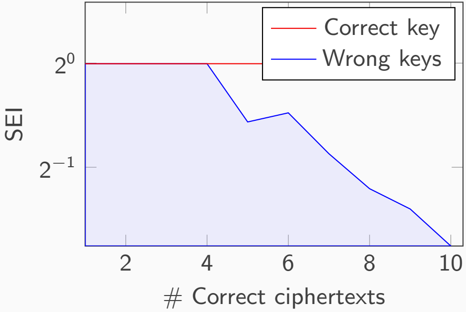

- Clock glitch on ATXmega 128D4
- SW-AES from AVR-crypto-lib
- $\approx$ **5** correct ciphertexts
- $\approx$ **1 300** faulted encryptions

- Clock glitch on ATXmega 256A3
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- $\approx$ **1 000** faulted encryptions

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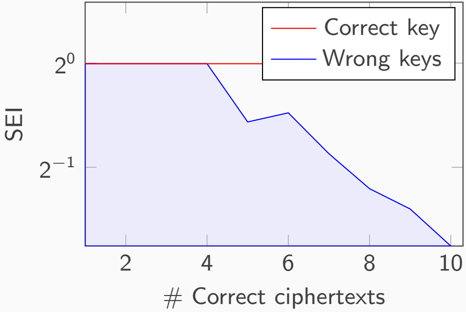

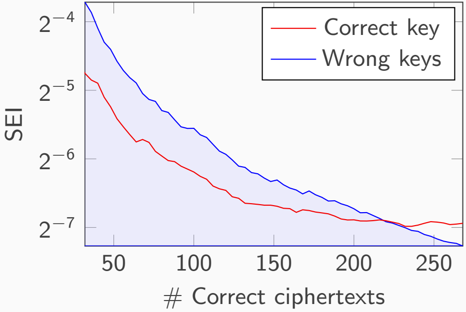

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Results - Infection by Tupsamudre et al. [TBM14]

- Clock glitch: ATXmega128D4
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- 22 real + **11** dummy rounds
- $\approx$ **25** correct ciphertexts
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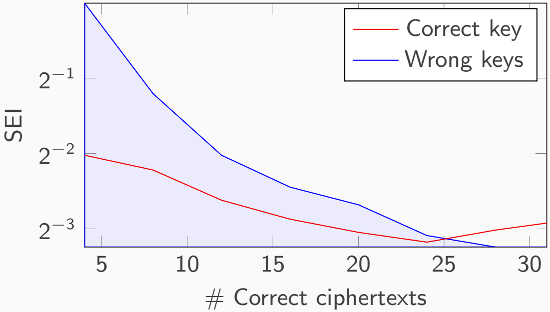

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- 22 real + **22** dummy rounds
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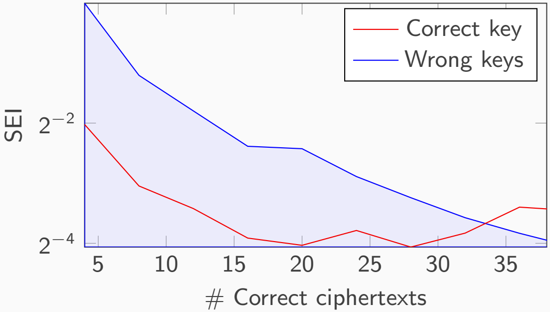
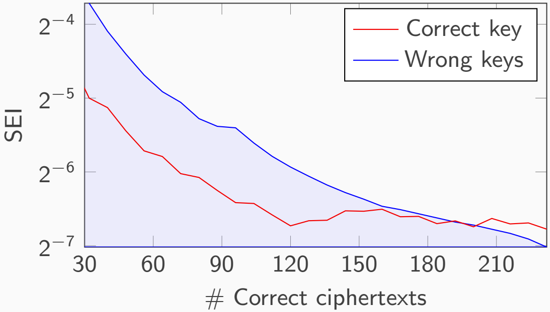
- $\approx$ **9 000** faulted encryptions



Results - Infection by Tupsamudre et al. [TBM14]

- Clock glitch: ATXmega128D4
- SW-AES with infection
- 22 real + **66** dummy rounds
- ≈ **180** ciphertexts needed
- ≈ **46 000** faulted encryptions



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- requires hundreds/thousands faulted computations
- requires only one fault per computation
- does not require precise fault locations
- works with any type of fault, even if effect is unknown ($\rightarrow$ blackbox attacks)

$\Rightarrow$ works for AE schemes (SAC 2018) [DMMP18]

- $\rightarrow$ including stream-cipher, sponge-based schemes
- $\rightarrow$ e.g. all CAESAR finalists

$\Rightarrow$ works for masked implementations (ASIACRYPT 2018) [DEG+18]

- $\rightarrow$ just faulting one share is sufficient
- $\rightarrow$ same performance, no real overhead
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$\rightarrow$ including stream-cipher, sponge-based schemes

$\rightarrow$ e.g. all CAESAR finalists

$\Rightarrow$ works for masked implementations (ASIACRYPT 2018) [DEG$^+$18]

$\rightarrow$ just faulting one share is sufficient

$\rightarrow$ same performance, no real overhead

$\rightarrow$ essentially independent of degree of masking and redundancy

Thank you for your attention!

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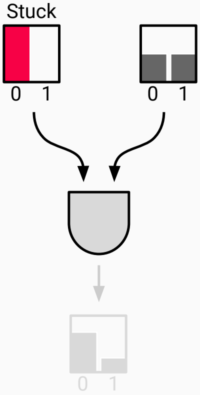
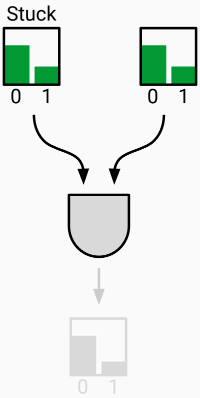
SIFA Intuition (cont.)



SIFA Intuition (cont.)



SIFA Intuition (cont.)