Practical Evaluation of FSE 2016 Customized Encoding Countermeasure

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Side-Channel Attacks (SCA)

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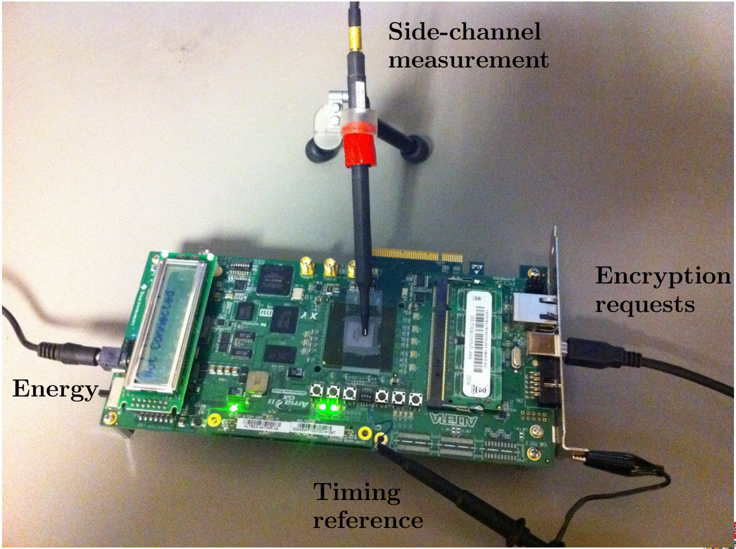
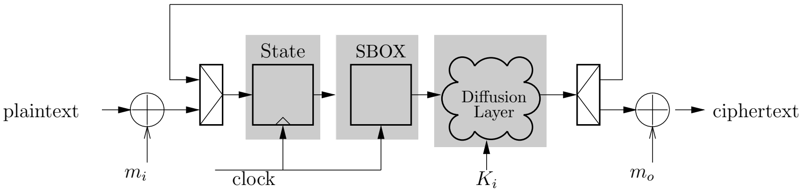


SCA Countermeasure: Masking

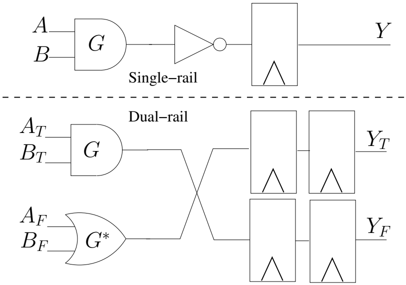


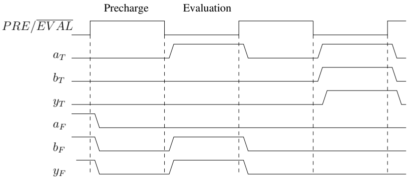
Basic Principle

- ⇒ Randomization of the sensitive data[1].
- Power consumption uncorrelated to data.

[1] Coron et al, CHES 2000

SCA Countermeasure: Hiding





Dual Rail and Precharge Logic (DPL)

- $\Rightarrow$ Data-Independent Power Consumption
- Duplication $\Rightarrow$ Balanced Activity[2]
- Two Phases $\Rightarrow$ Constant Transitions.
- $0 \mapsto 01$, $1 \mapsto 10$, precharge$\mapsto 00$, invalid$\mapsto 11$.

[2] Tiri et al, DATE 2004.

Hiding Countermeasure in Software

- Idea introduced by Hoogvorst el al in 2011[3]
- Adopt DPL principle for data representation in software.
- Aimed to reduce (or remove) data dependence of power consumption. Both data and operations are adjusted to enable processing of encoded data.
- Two further proposals:
    - Balanced bit slicing, following DPL method[4]: $0 \mapsto 01$, $1 \mapsto 10$
    - Balanced Encoding[5]: $b_3\overline{b_3}b_2\overline{b_2}b_1\overline{b_1}b_0\overline{b_0}$.
- In practice, both leak but reduce SNR.
- Shows additional fault resistance properties[6].

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[3] Hoogvorst et al, COSADE 2011.

[4] Rauzy et al., PROOFS 2014

[5] Chen et al., CARDIS 2014

[6] Breier et al, HOST 2016.

Why Does it Leaks?

- Device physics
- DPL assumes equal bit contribution/weight
- In reality, bits have unequal contribution
- Perfect HW/HD model are hard to realise

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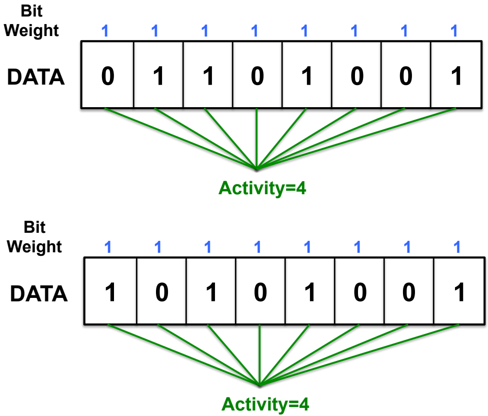

Perfect Setting

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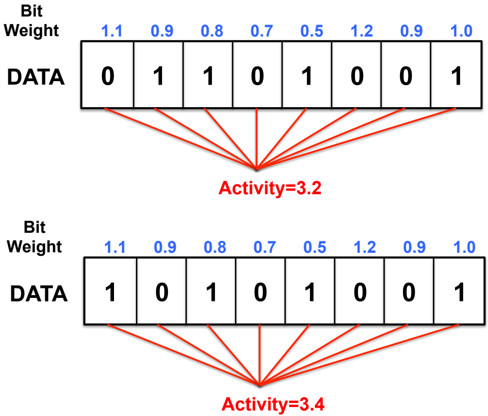

Real Setting

Customised Encoding Countermeasure

- Proposed by Maghrebi et al.[7]
- *There is Wisdom in Harnessing the Strengths of Your Enemy*
- Profile actual bit weights (β) from the device
- Compute encoding from the bit weights to minimise bias
- Longer encodings (vs 2 bits for DPL)
- Previously demonstrated to protect *Sbox look-up*
- Vary from one device copy to another

[7] Maghrebi et al, FSE 2016.

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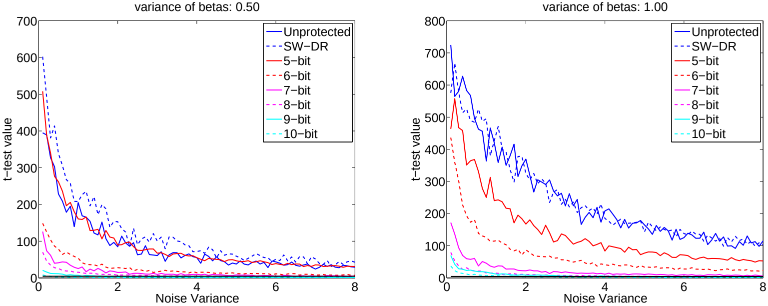
Simulated Analysis of Customised Encoding

- Derived values from real EM measurements
- AES on 8-bit AVR microcontroller
- Profile for β and noise variances
- Variance of $\beta \in [0.2, 0.8]$
- Variance of noise $\in [5.5, 6.8]$
- Use TVLA[8] based analysis
- Considered leaking data-dependant information if $t \notin [-4.5, 4.5]$

[8] Goodwill et al, NIAT 2011.

Simulated Analysis of Customised Encoding



(a) var(β)= 0.5 (b) var(β)= 1

Figure: TVLA results for unprotected and countermeasure (5 to 10 bits encoding and software dual-rail (SW-DR)) with different β variances.

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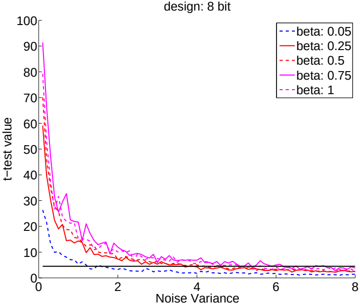
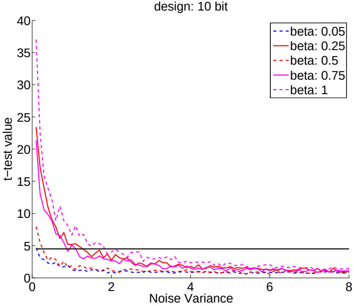


(a) 8-bit encoding

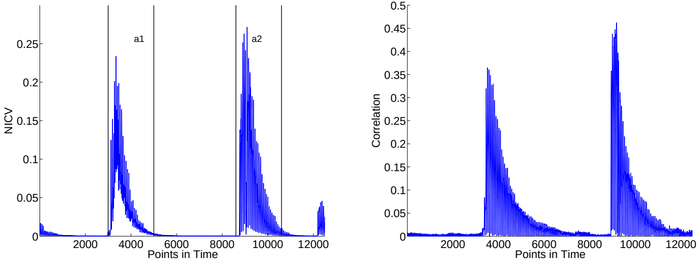


(b) 10-bit encoding

Figure: TVLA results for 8 to 10-bit encoding schemes with different noise levels

Longer encoding helps

Building Customised Encoding

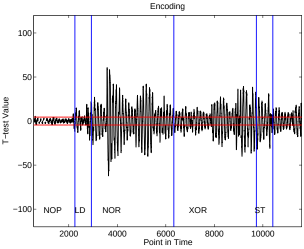


(a) Region of Interest (b) CPA results

Figure: Feature selection for β.

- EM measurement on AVR for AES Sbox (LDR+STR)
- β averaged over clock of highest correlation
- Two encodings $a1$ and $a2$ derived
- Used to implement lightweight SKINNY

Impact of Changing the Register

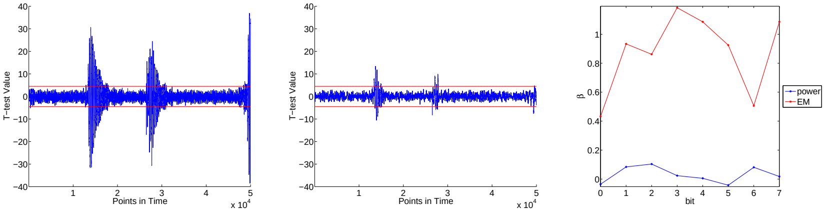


(a) r16 (b) r17

Figure: TVLA on encoding a1

- Implementing whole cipher with one instruction and register can be difficult
- Protecting one instruction and register is possible
- Encoding must be updated with change in register

Impact of Measurement Method



(a) TVLA EM (b) TVLA Power (c) β EM vs power

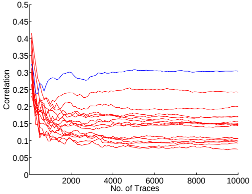
Figure: Leakage profiling comparison: EM vs Power. (c) The β coefficients obtained from EM and power under the same setup.

- Similar observations for different EM positions, time samples.
- Updating/Converting encoding can be costly and leak

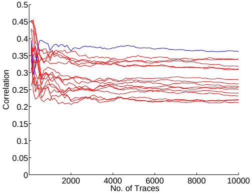
Longer & Higher Order Encoding

- Tested longer encodings with 32-bit ARM microcontroller
- Limited to 10 bit encoding due to memory size
- Also tested higher order (HO) encoding taking not only individual β but their coupling affect to arrive at a more precise encoding.

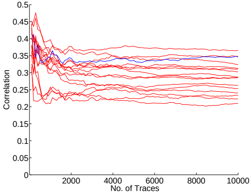
Longer & Higher Order Encoding



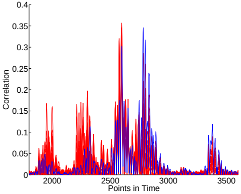
(a) Key rank unprotected



(b) Key rank customized encoding



(c) Key Rank HO customized encoding



(d) CPA HO customised encoding

Conclusion

- Practically evaluated Customised encoding countermeasure
- Shown sound in simulations
- In practice, temporal and spatial variance of β prevents effective encoding
- Hard to obtain a generic encoding
- Implementing a full cipher was difficult
- Several test cases highlighted on two different microcontrollers
- β based estimation works well for attacks but its relation with device physics is not clear
- Studying it will help develop strong countermeasures

Thank you!

Any questions?