RUHR-UNIVERSITÄT BOCHUM

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Side-Channel Protection by Randomizing Look-Up Tables on Reconfigurable Hardware

- Pitfalls of Memory Primitives -

COSADE 2015, Berlin, Germany

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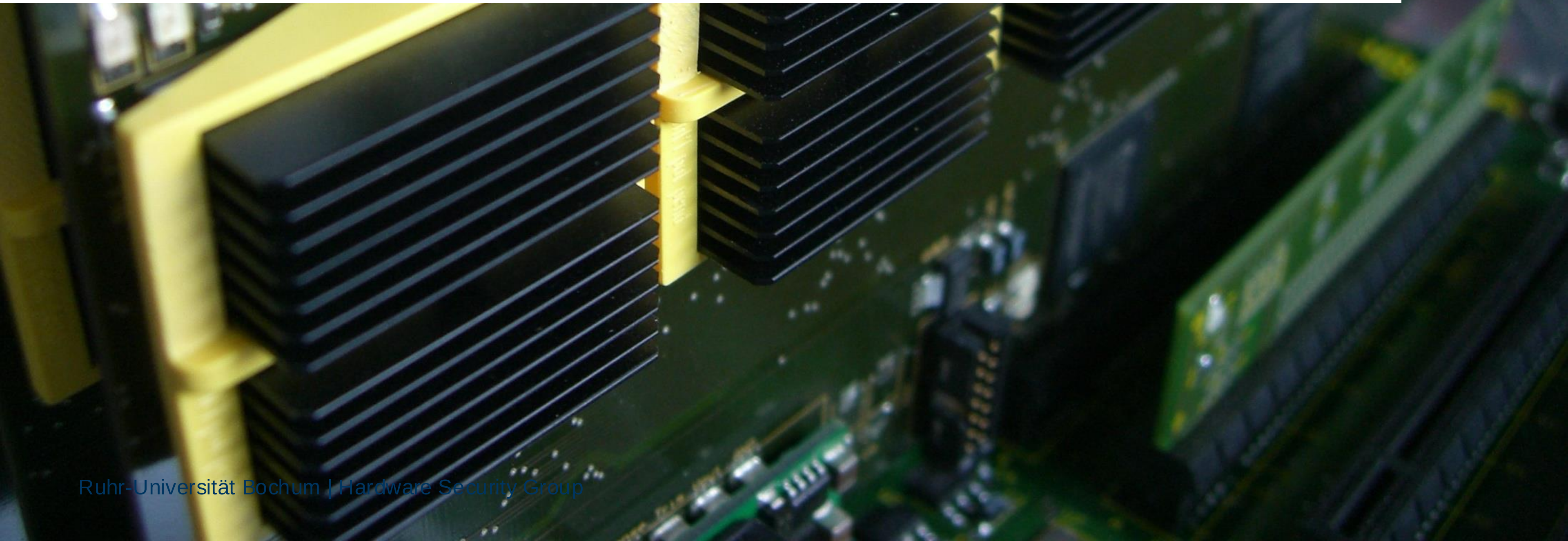
Amir Moradi, and Tim Güneysu

26.03.2015



Outline

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3. Block Memory Content Scrambling
4. Contribution
5. Randomized Look-Up Tables
6. Case Study and S-Box Designs
7. Evaluation and Results
8. Conclusion

Motivation

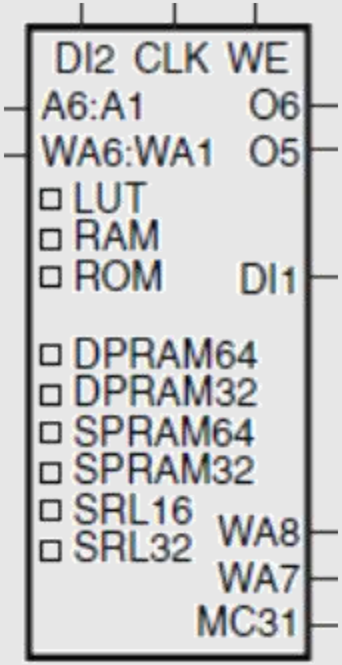
- At CHES 2011:

  Block Memory content Scrambling (BMS) was proposed as an effective way of 1st order side-channel protection.

- Our goals:
  - Analyze different ways for 1st order protection using randomized look-up tables.
  - Find optimal choices for FPGAs and 8-bit S-boxes.

Xilinx Memory Primitives

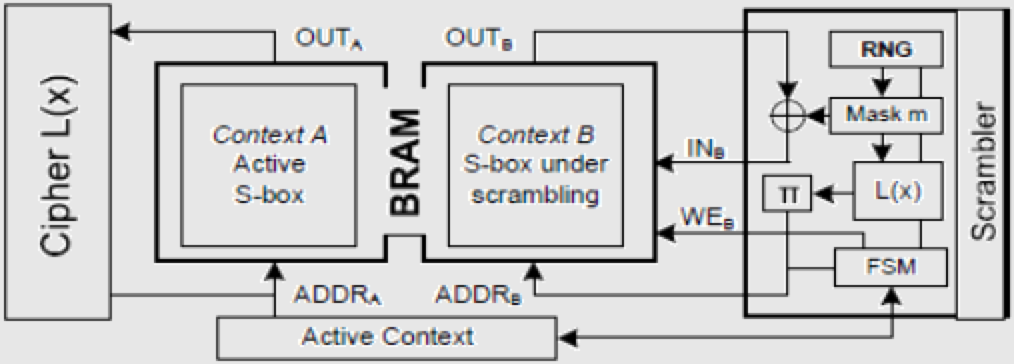
- Specific **slice logic** components can be implemented as distributed memory:
  - RAM32M (32x8bit SPRAM)
  - RAM64M (64x4bit SPRAM)
  - RAM256X1S (256x1bit SPRAM)
- Dedicated block memory primitives (RAMB8BWER) can be used as true dual-port block memory



Block Memory Content Scrambling

Main idea:

- Store 2 S-/T-Tables in one BRAM
- First table is active context and used for encryption.
- Second table is passive context and updated (scrambled) with fresh randomness.
- After update, contexts are switched.



T. Güneysu and A. Moradi. Generic Side-Channel Countermeasures for Reconfigurable Devices.

Disadvantages:

- Area overhead
- Latency
- Shared masks

Contribution

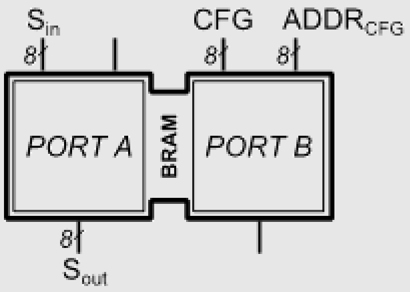
1. Analyzed **Xilinx FPGA memory** primitives to prevent 1st order side-channel leakage.

2. Built **randomized look-up tables** of different memory primitives.

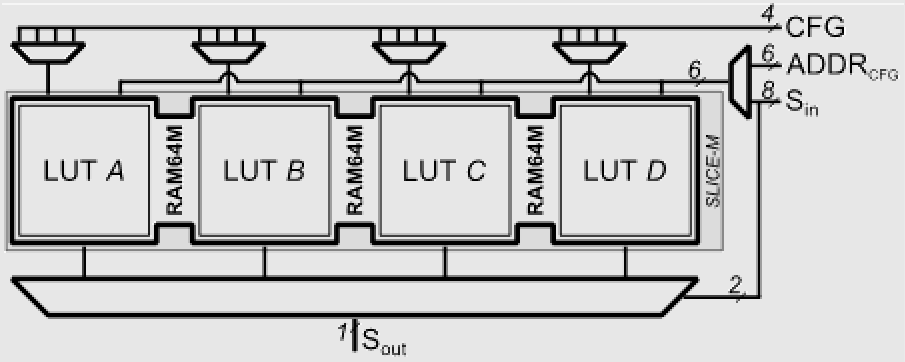
3. Evaluated designs using a state-of-the-art **leakage assessment methodology**.

4. We **revealed pitfalls** of using memory primitives for side-channel protection.

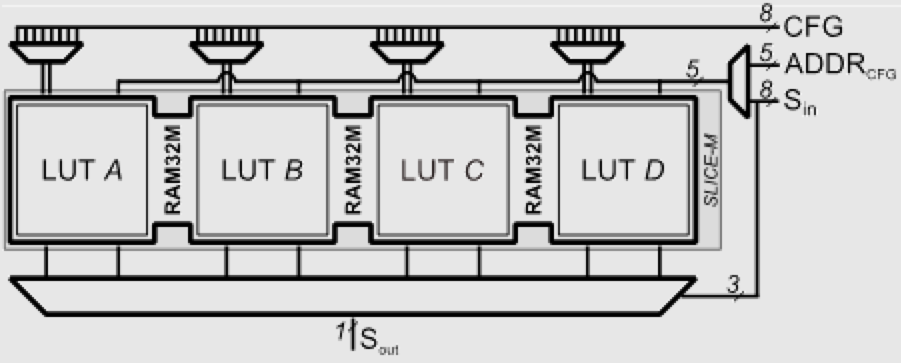
Randomized Look-Up Tables



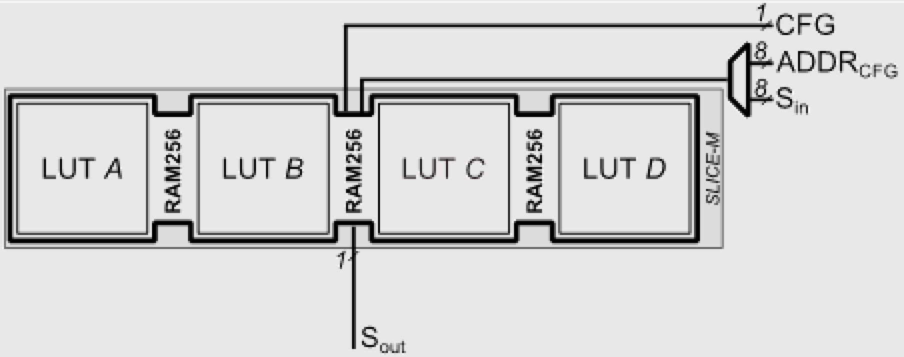
RAMB8BWER



RAM64M

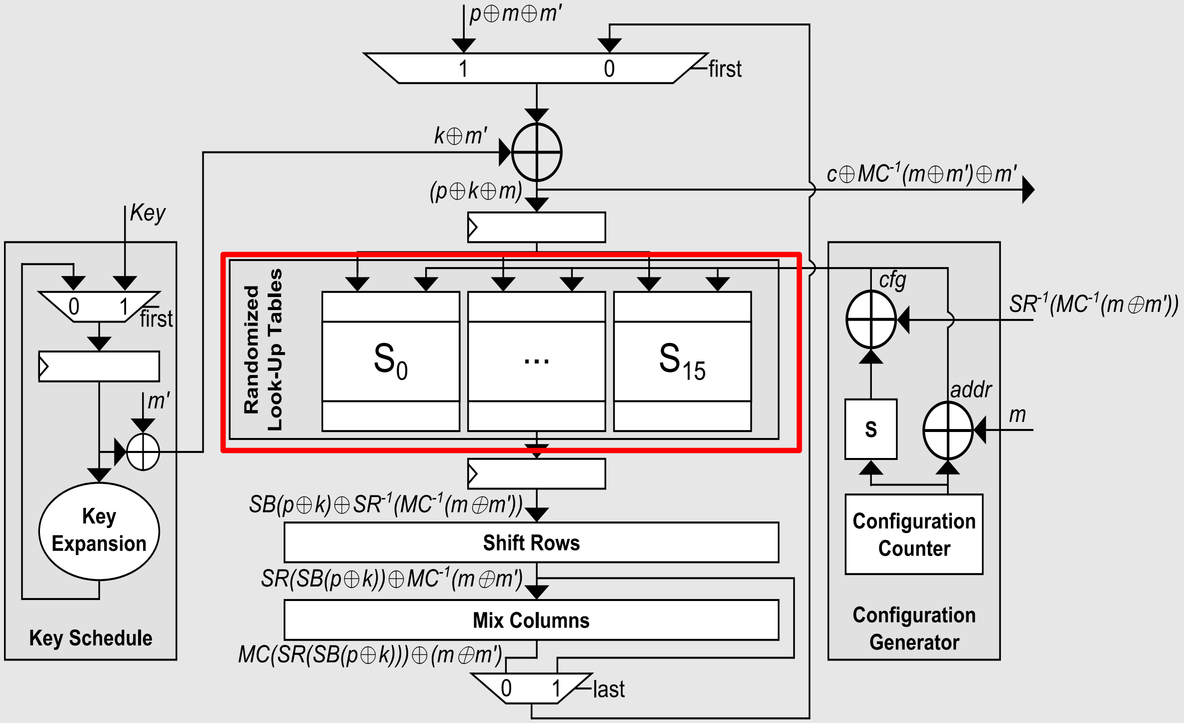


RAM32M



RAM256X1S

Case Study


$p \oplus m \oplus m'$
1
0
first
$k \oplus m'$
$(p \oplus k \oplus m)$
$c \oplus MC^{-1}(m \oplus m') \oplus m'$
Key
0
1
first
m'
Key Expansion
Key Schedule
Randomized Look-Up Tables
S_0
...
S_{15}
cfg
$SR^{-1}(MC^{-1}(m \oplus m'))$
addr
m
S
Configuration Counter
Configuration Generator
$SB(p \oplus k) \oplus SR^{-1}(MC^{-1}(m \oplus m'))$
Shift Rows
$SR(SB(p \oplus k)) \oplus MC^{-1}(m \oplus m')$
Mix Columns
$MC(SR(SB(p \oplus k))) \oplus (m \oplus m')$
0
1
last

- AES as case study
- Build randomized look-up tables using different memory primitives
- Replaced SubBytes with different designs.

S-Box Designs

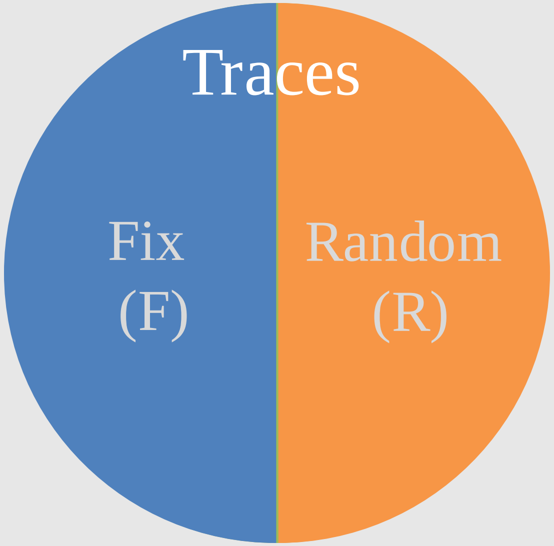
Memory		**SubBytes**		**Configuration**		**Max.**
Primitive	*Logic*	*Dist. Mem.*	*Block Mem.*	*Logic*	*Memory*	**Throughput**
	(LUT)	*(LUT)*	*(BRAM16)*	*(LUT)*	*(FF)*	*(Mbit/s)*
BMS [CHES11]	-	-	16	1706	1169	35.4
RAMB8BWER	-	-	8	298	8	68.6
RAM256X1S	128	512	-	298	8	77.0
RAM64M	768	512	-	727	6	247.3
RAM32M	1920	512	-	1222	5	363.3

Evaluation

Welch‘s T-Test

fix vs. random:

- 1 fix plaintext

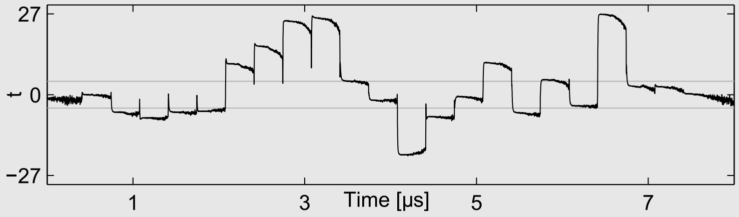


$\mathrm{N_F} = \text{Size of F}$
$\mathrm{X_F} = \text{Mean of F}$
$\mathrm{S_F} = \text{Std. deviation of F}$

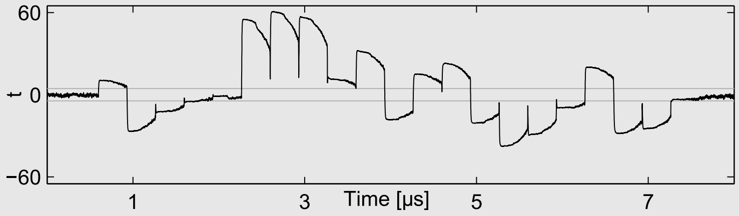
$\mathrm{N_R} = \text{Size of R}$
$\mathrm{X}_R = \text{Mean of R}$
$\mathrm{S}_R = \text{Std. deviation of R}$

$$\mathrm{T} = \frac{X_F - X_R}{\sqrt{\frac{S_F^2}{N_F} + \frac{S_R^2}{N_R}}}$$

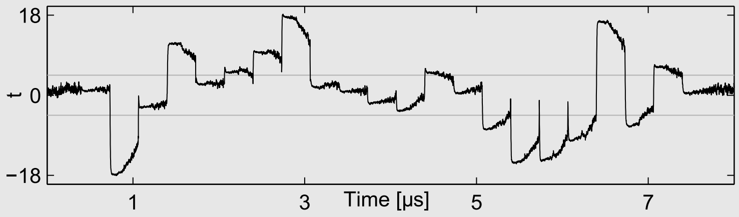
Results



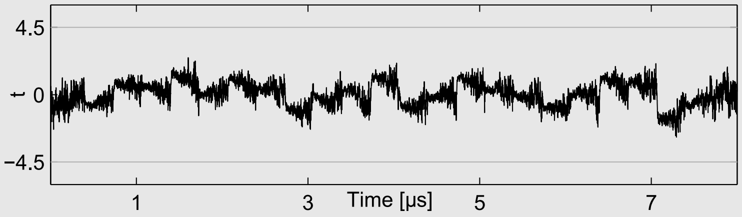
RAM32M (1 million traces)



RAM64M (1 million traces)



RAM256X1S (1 million traces)



RAMB8BWER (10 million traces)

- leakage is detectable for distributed memory primitives
- assume that leakage is due to internal slice architecture
- BRAM primitives exhibit no detectable leakage (even for larger trace numbers)

Conclusion

Our results infer the pitfall of using distributed memory primitives:

- Distributed memory causes a secure scheme to exhibit 1st order leakage.
- Replaced with Block Memory 1st order leakage is not detectable.

Besides, our designs achieve higher throughput and require less randomness than original BMS scheme.

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Thank you for your attention!

Any Questions?