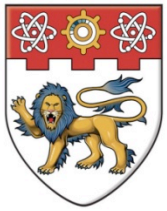

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Inaugural Youth Olympic Village

PRINTcipher: A Block Cipher for IC Printing

L. Knudsen, G. Leander, A. Poschmann, and M. Robshaw

Technical University of Denmark DTU

Axel Poschmann
Division of Mathematical Sciences,
School of Physical and Mathematical Sciences

18 August 2010

Outline

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- **Motivation**
- PRINTcipher
- Security Analysis
- Implementation Results
- Conclusions

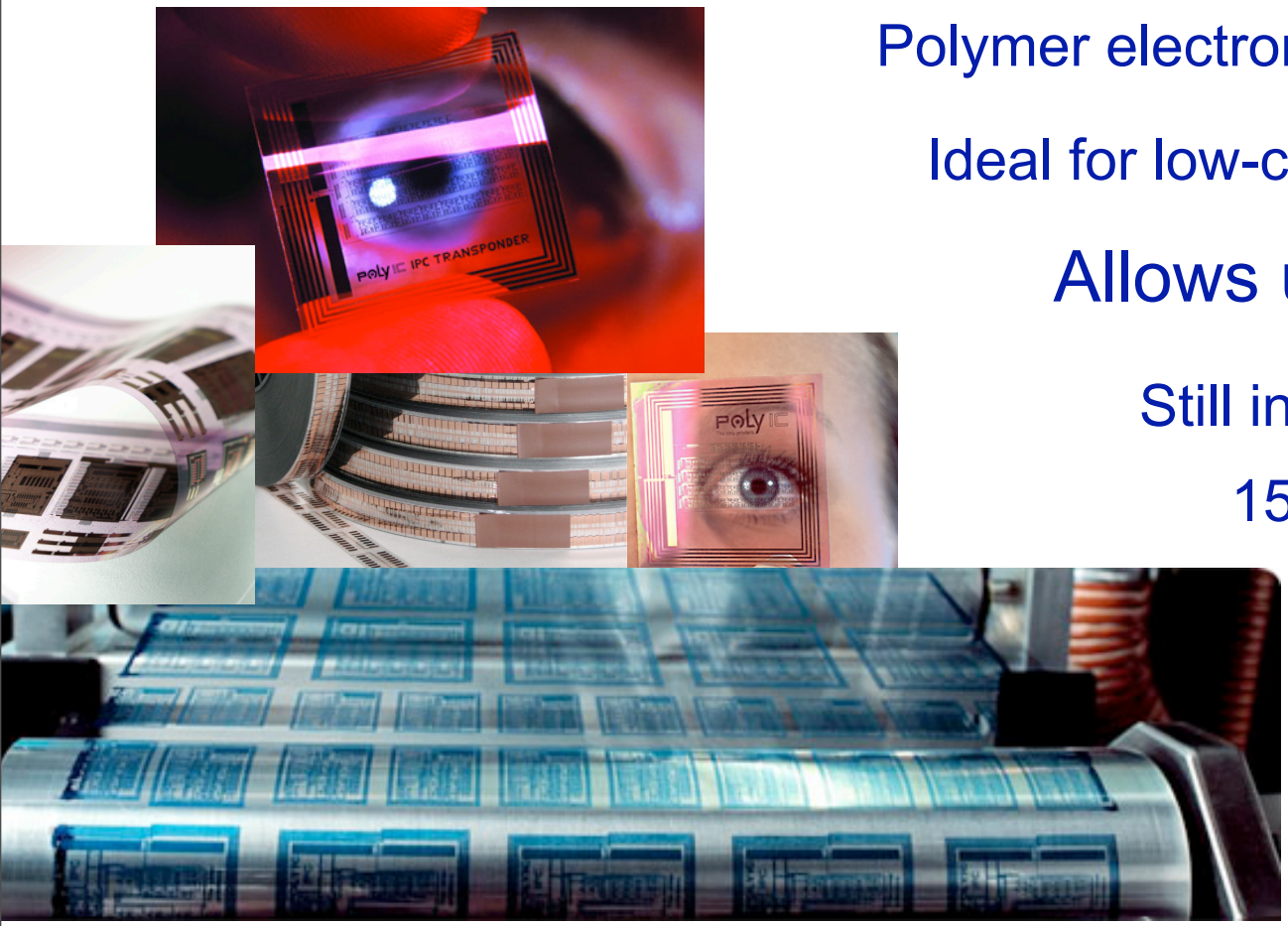
Acknowledgement

Project

Dr. Jasmin Wörle

Motivation

IC Printing **A.k.a.** Organic electronics,
Plastic electronics,
Polymer electronics



Ideal for low-cost RFID tags

Allows **unique** devices

Still in its infancy:

15**um** structure width

Ultra-constrained

Outline

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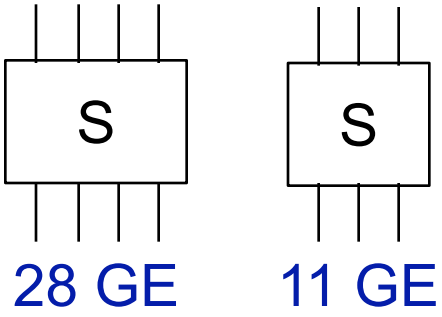
Observations

- Smaller S-box save GE
  (but need to increase rounds)



→ **- 50%**

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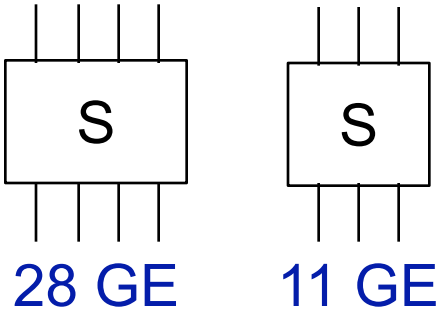

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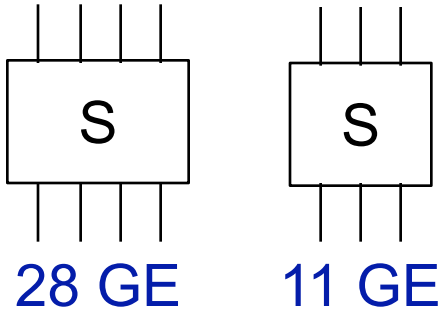

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NANYANG TECHNOLOGICAL UNIVERSITY

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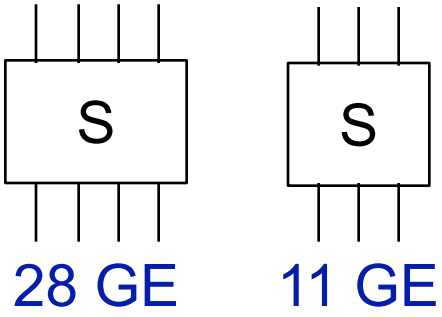

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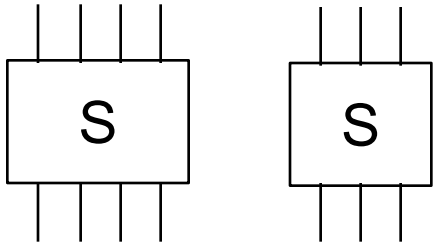

28 GE 11 GE

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- Storage is most expensive → minimize block size
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- Addition: **non-fixed** vs. **fixed value** (*n* bits)

n x 2.67 GE *n/2* x 0.67 GE

→ **- 87.5%**

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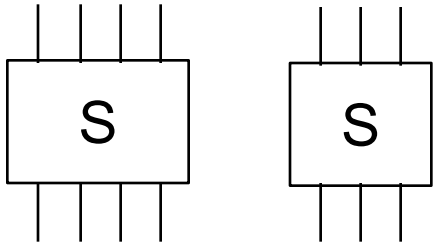

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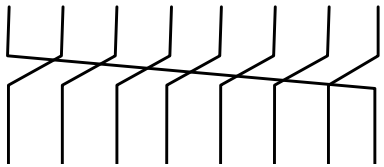
- Bit permutations are for free



0 GE

S-Box

x	0	1	2	3	4	5	6	7
$S[x]$	0	1	3	6	7	4	5	2

- 3 x 3 S-box
- optimal wrt. LC and DC
- min occurrence of single-bit to single-bit differences/masks
- 384 optimal S-boxes in total

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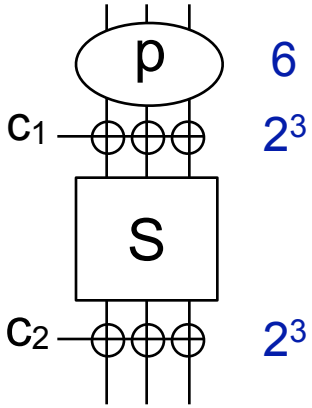

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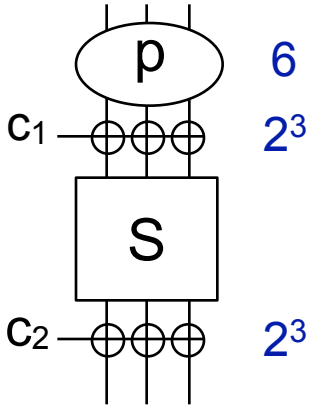
- min occurrence of single-bit to single-bit differences/masks
- ~~3~~1~~4~~ optimal S-boxes in total



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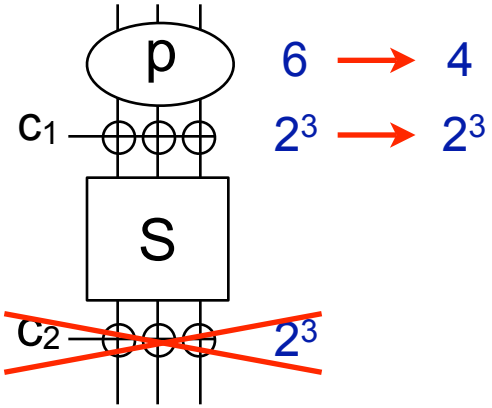

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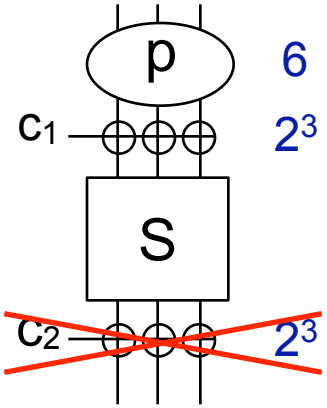
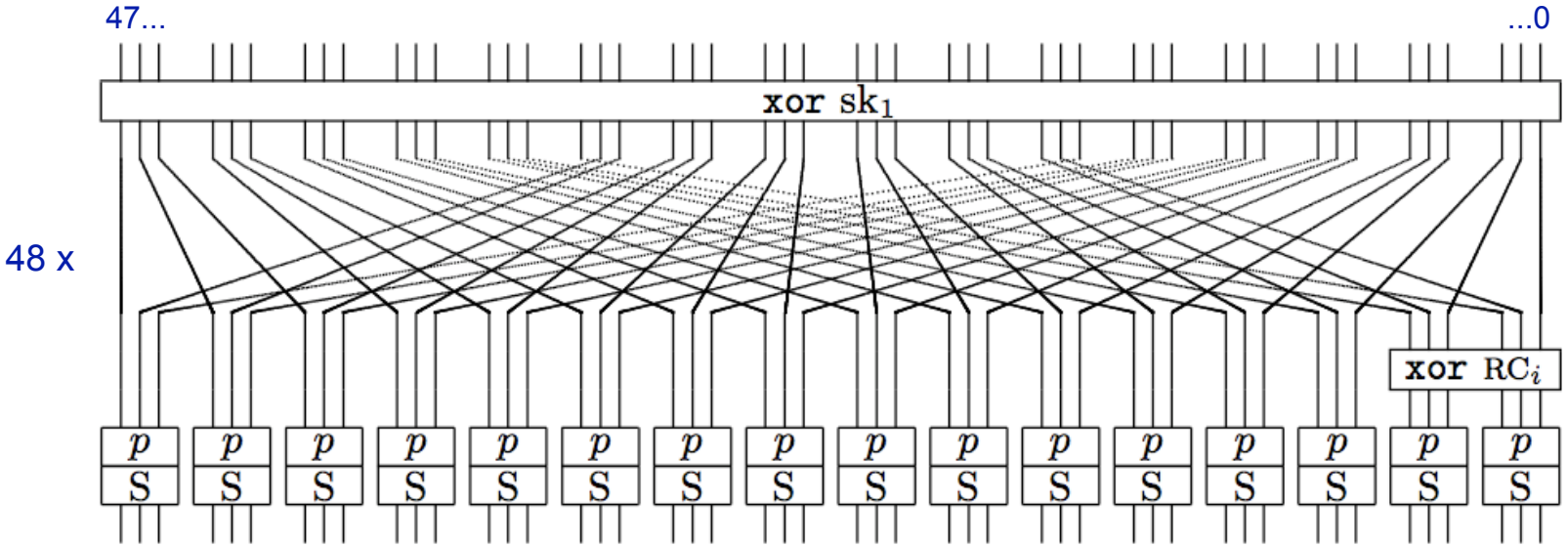
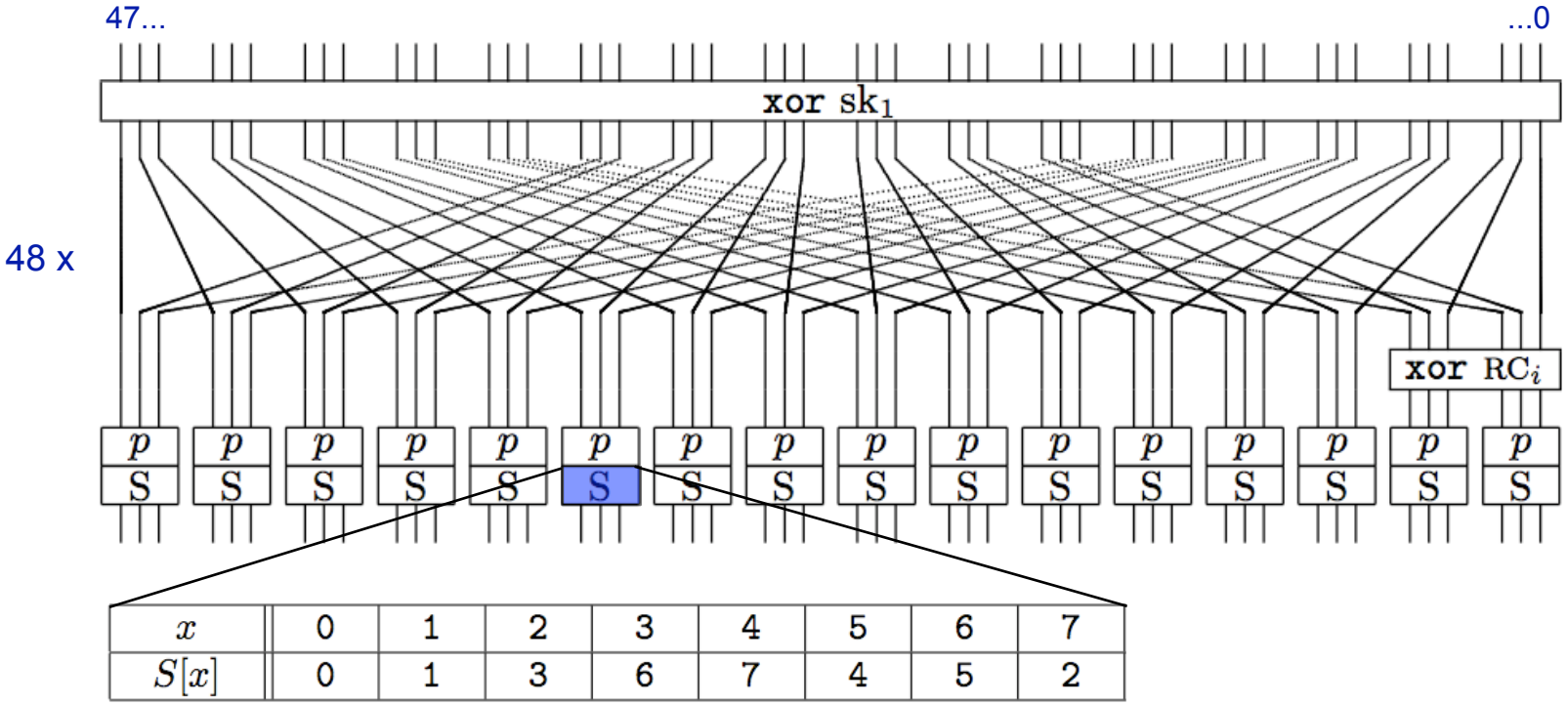


5 bit/S-box

PRINTcipher



PRINTcipher



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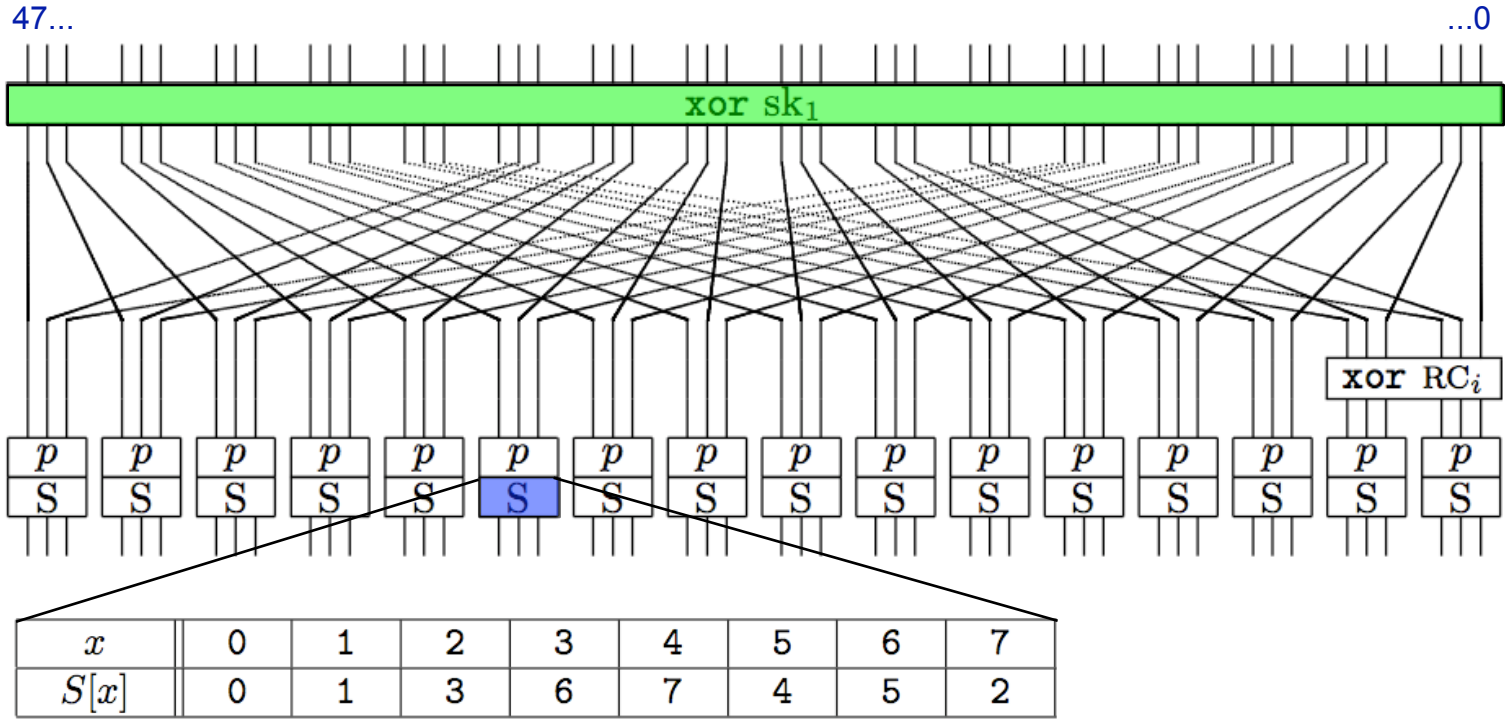

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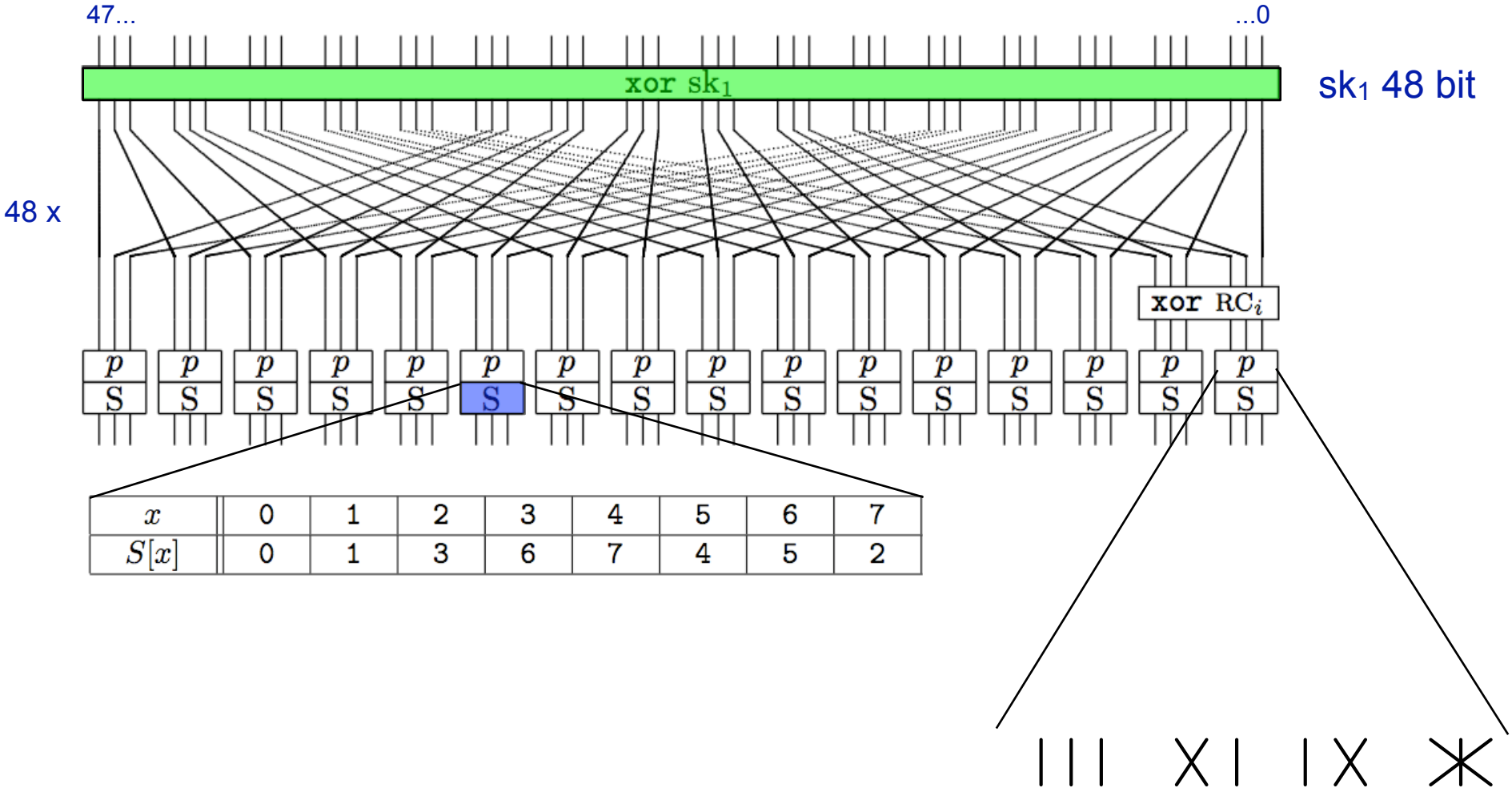

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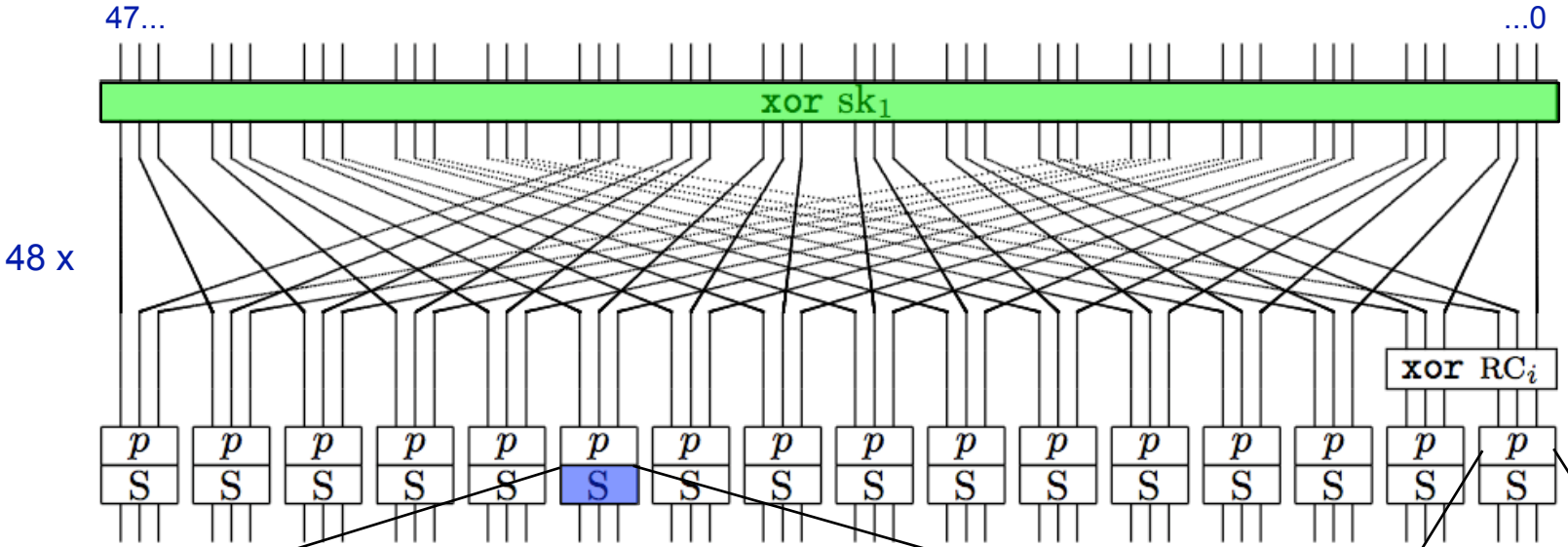

x	0	1	2	3	4	5	6	7
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x	0	1	2	3	4	5	6	7
$V_0[x]$	0	1	3	6	7	4	5	2
$V_1[x]$	0	1	7	4	3	6	5	2
$V_2[x]$	0	3	1	6	7	5	4	2
$V_3[x]$	0	7	3	5	1	4	6	2

PRINTcipher

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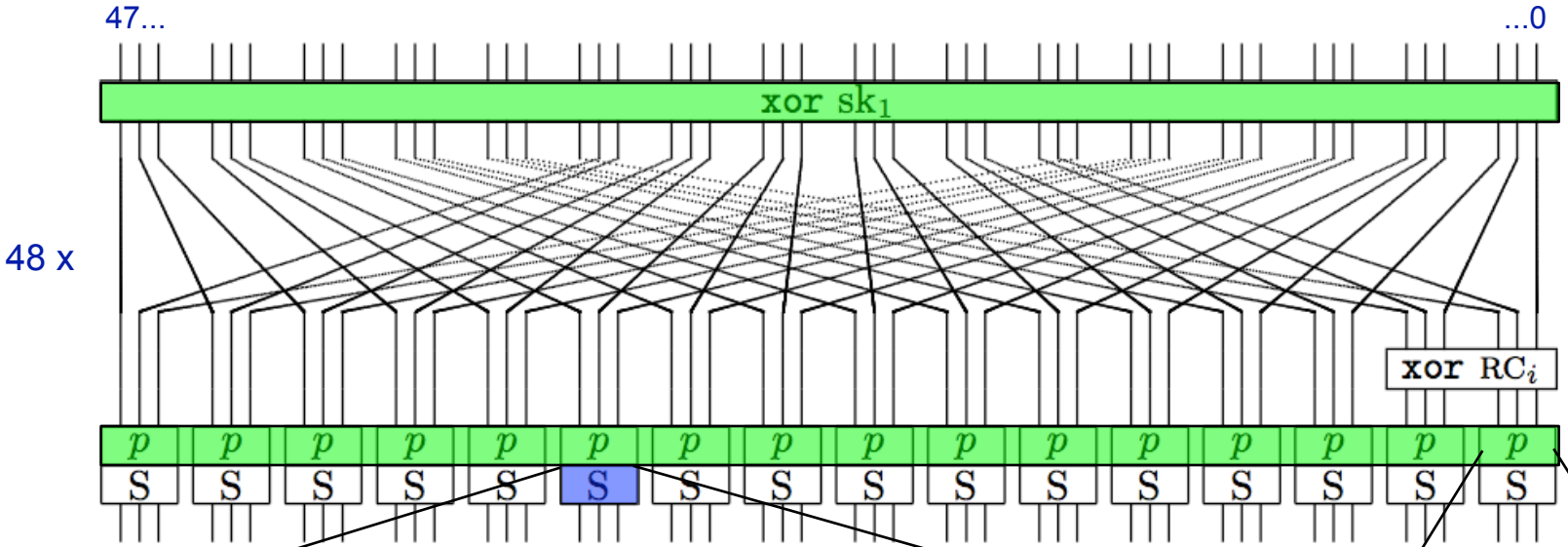
$k = sk_1 || sk_2 = 80$ bit



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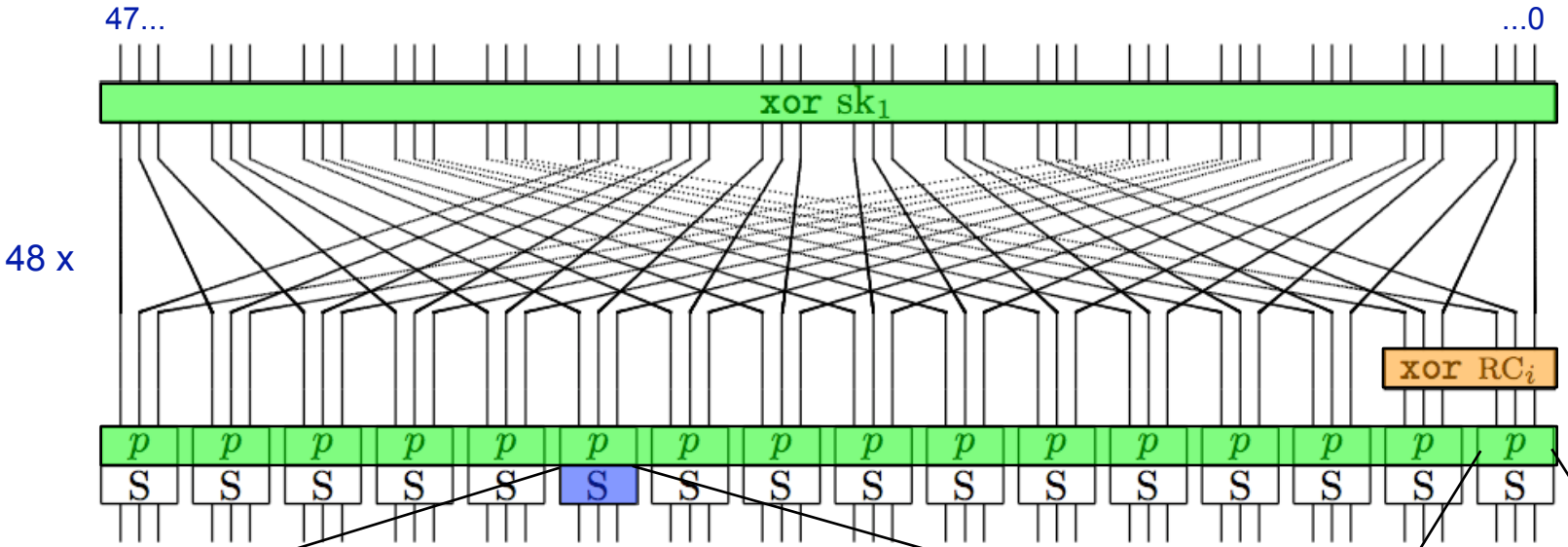
PRINTcipher

PRINTcipher-48 k = $sk_1||sk_2$ = 80 bit



sk_1 48 bit

vs. slide attacks

sk_2 32 bit

x	0	1	2	3	4	5	6	7
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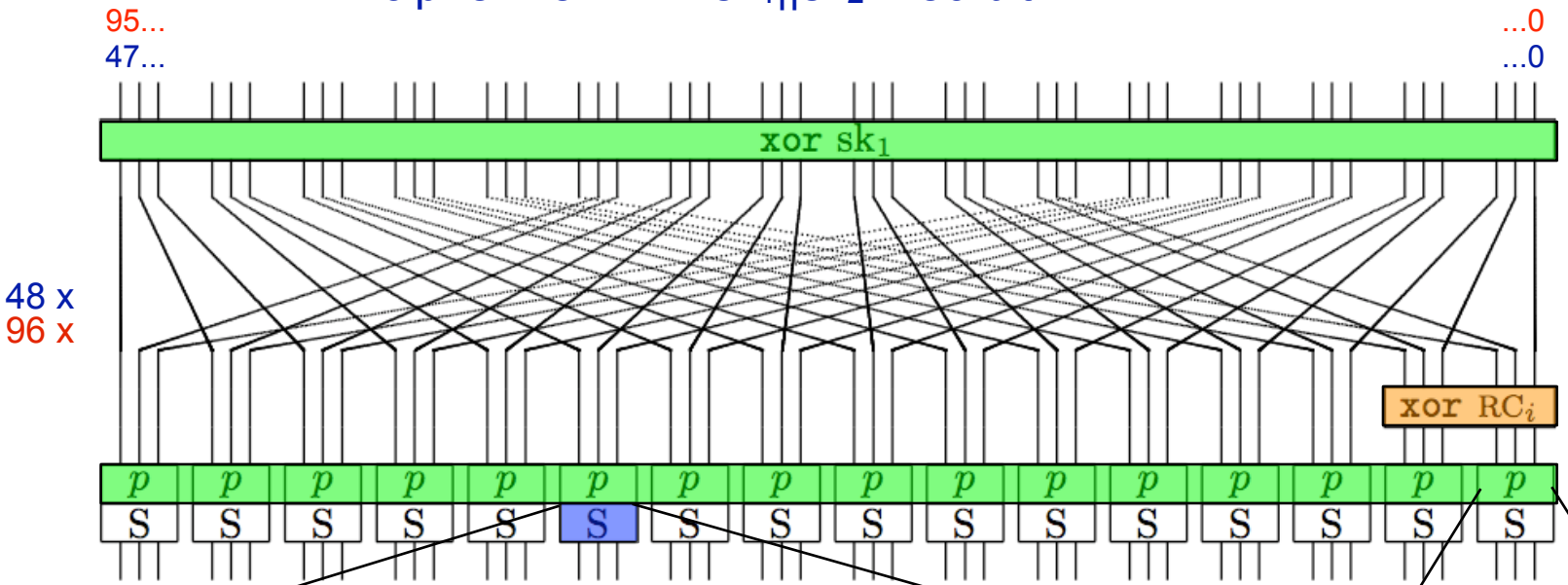
$V_2[x]$	0	3	1	6	7	5	4	2
$V_3[x]$	0	7	3	5	1	4	6	2

PRINTcipher

PRINTcipher-96 $k = sk_1 || sk_2 = 160$ bit

PRINTcipher-48 $k = sk_1 || sk_2 = 80$ bit



sk_1 48 bit

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vs. slide attacks

sk_2 32 bit

sk_2 64 bit

x	0	1	2	3	4	5	6	7
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Outline

- Motivation
- PRINTcipher
- **Security Analysis**
- Implementation Results
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Security Analysis I

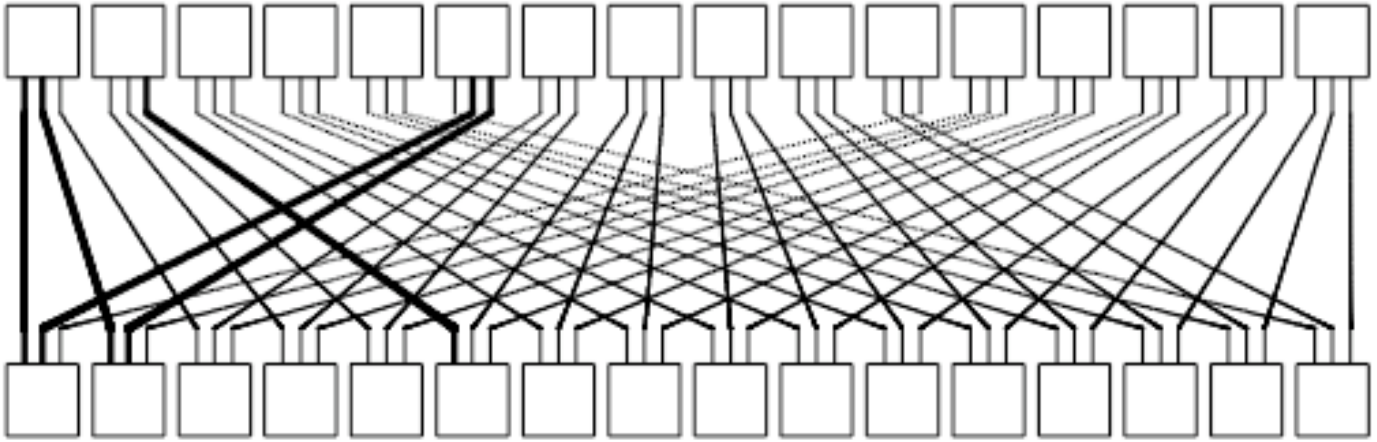
- **Differential and Linear Cryptanalysis**
  - let p denote the probability and
    $q = (2p-1)^2$ the correlation of a linear characteristic
  - max p = 1/4, max q = 1/4
  - same for any key-dependent permuted S-box
  - min 1 active S-box per round
  - *s* round characteristic $p_s = q_s = 2^{-2s}$

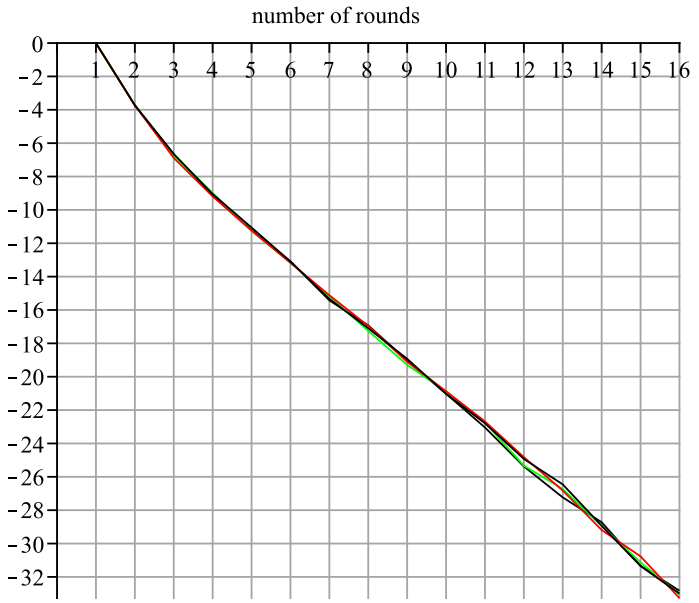
    ➡ **LC and DC impractical**

- **High order DC and Algebraic attacks**
  - S-box has deg 2, allows quadratic equation system
  - but 48 rounds -> expected deg close to max

    ➡ **not feasible**

Security Analysis II





- **Statistical Saturation attacks**
  - upper bounded by **30 rounds**

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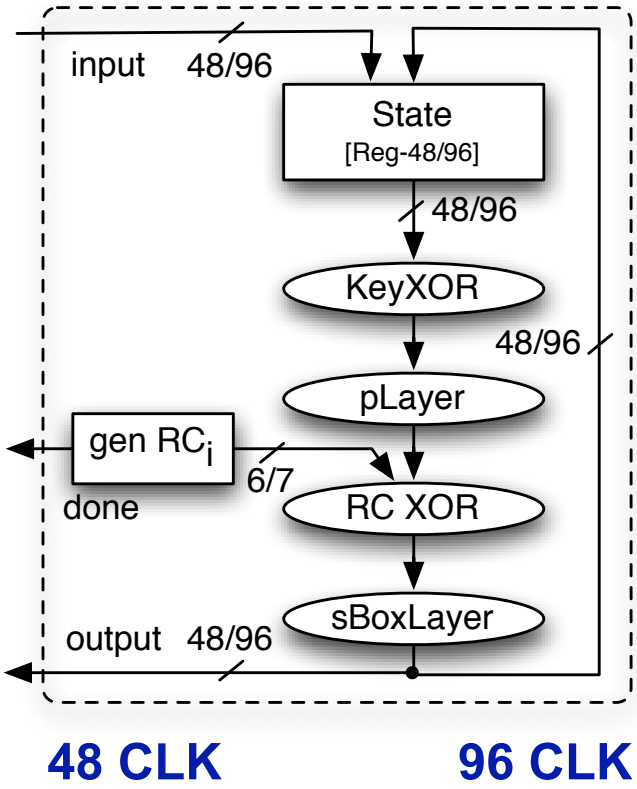
Implementation Results I

round *UMCL18G212T3* library



48 CLK **96 CLK**

Implementation Results I

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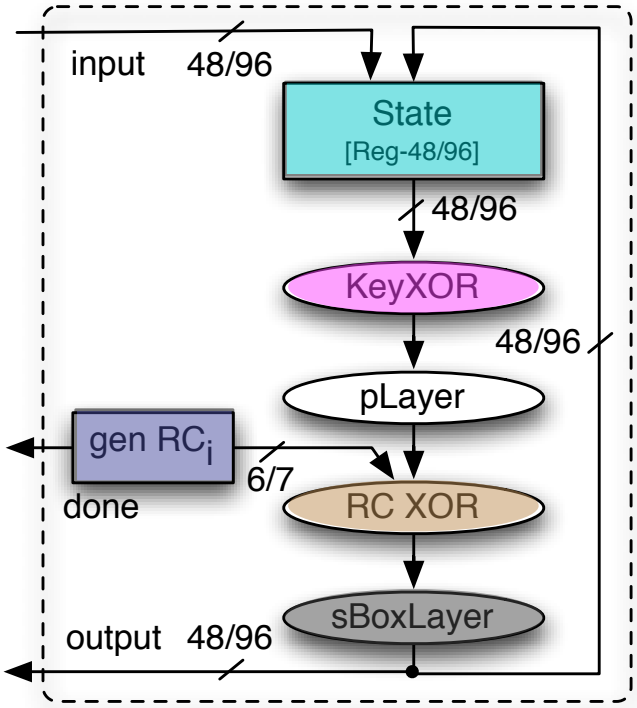
round *UMCL18G212T3* library



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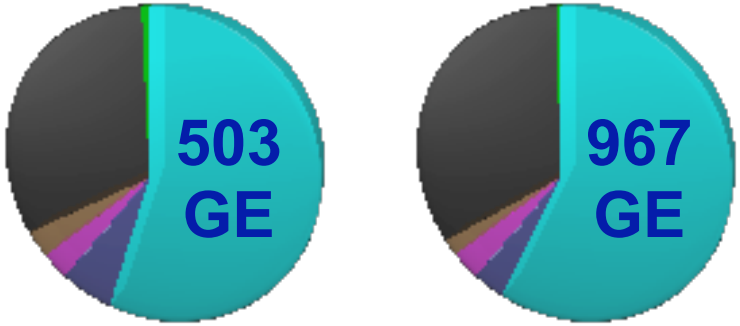

Implementation Results I

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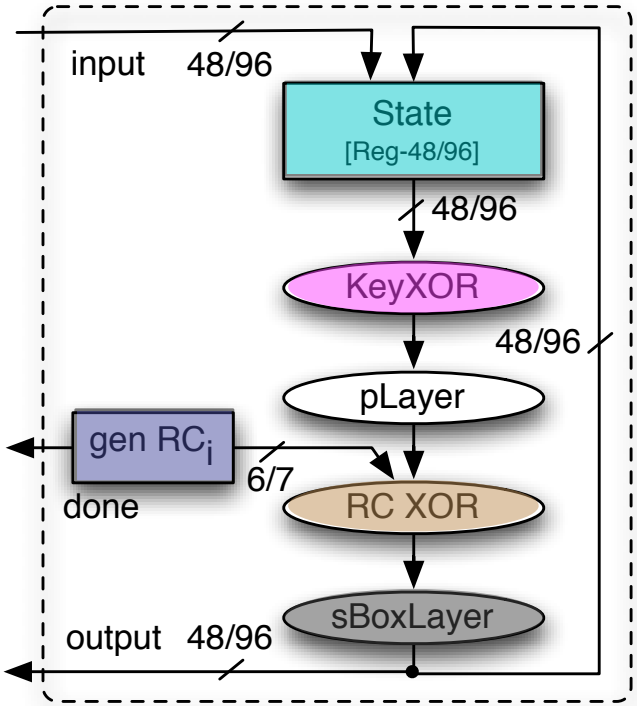
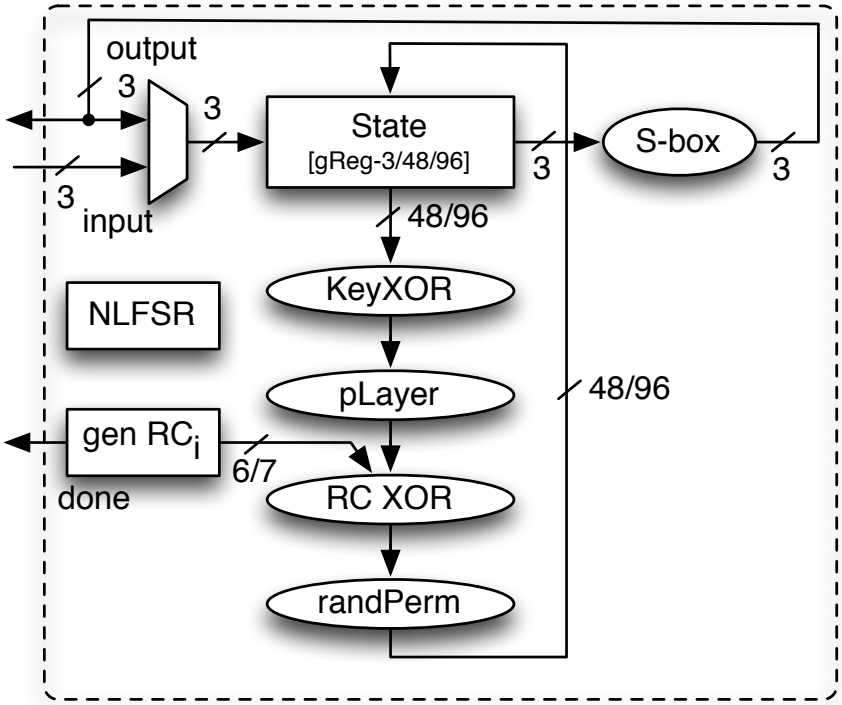
round *UMCL18G212T3* library **serial**





48 CLK **96 CLK**

48*16 = 768 CLK **96*32 = 3072 CLK**

Implementation Results I

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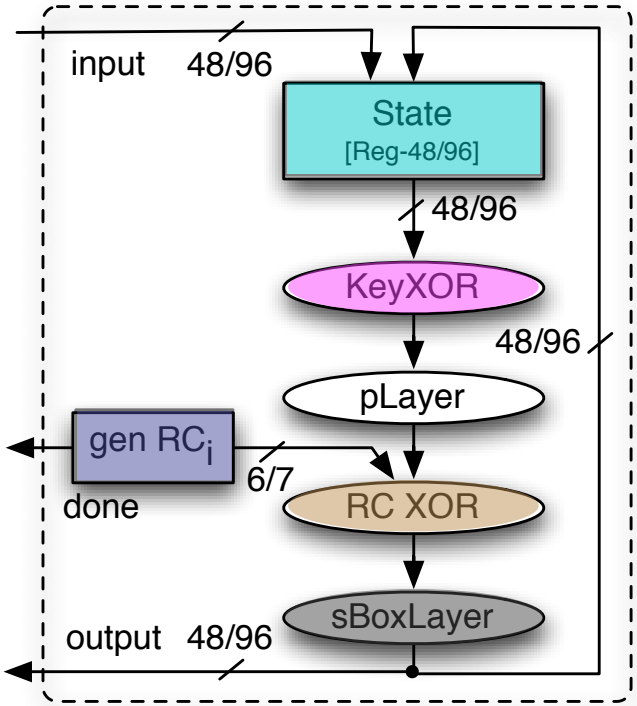

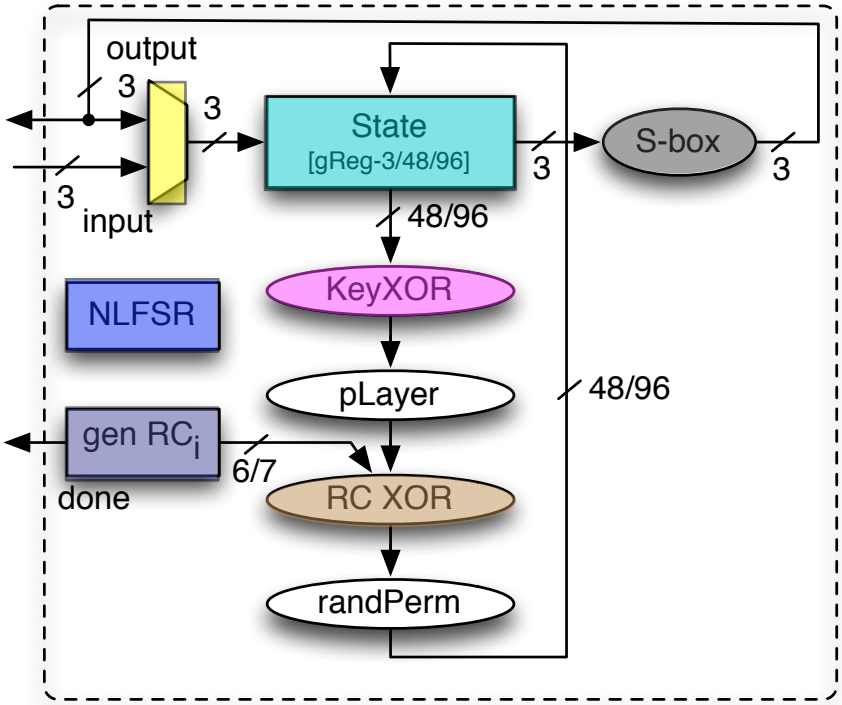

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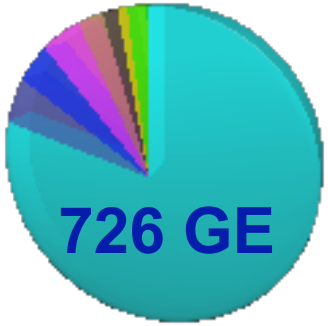
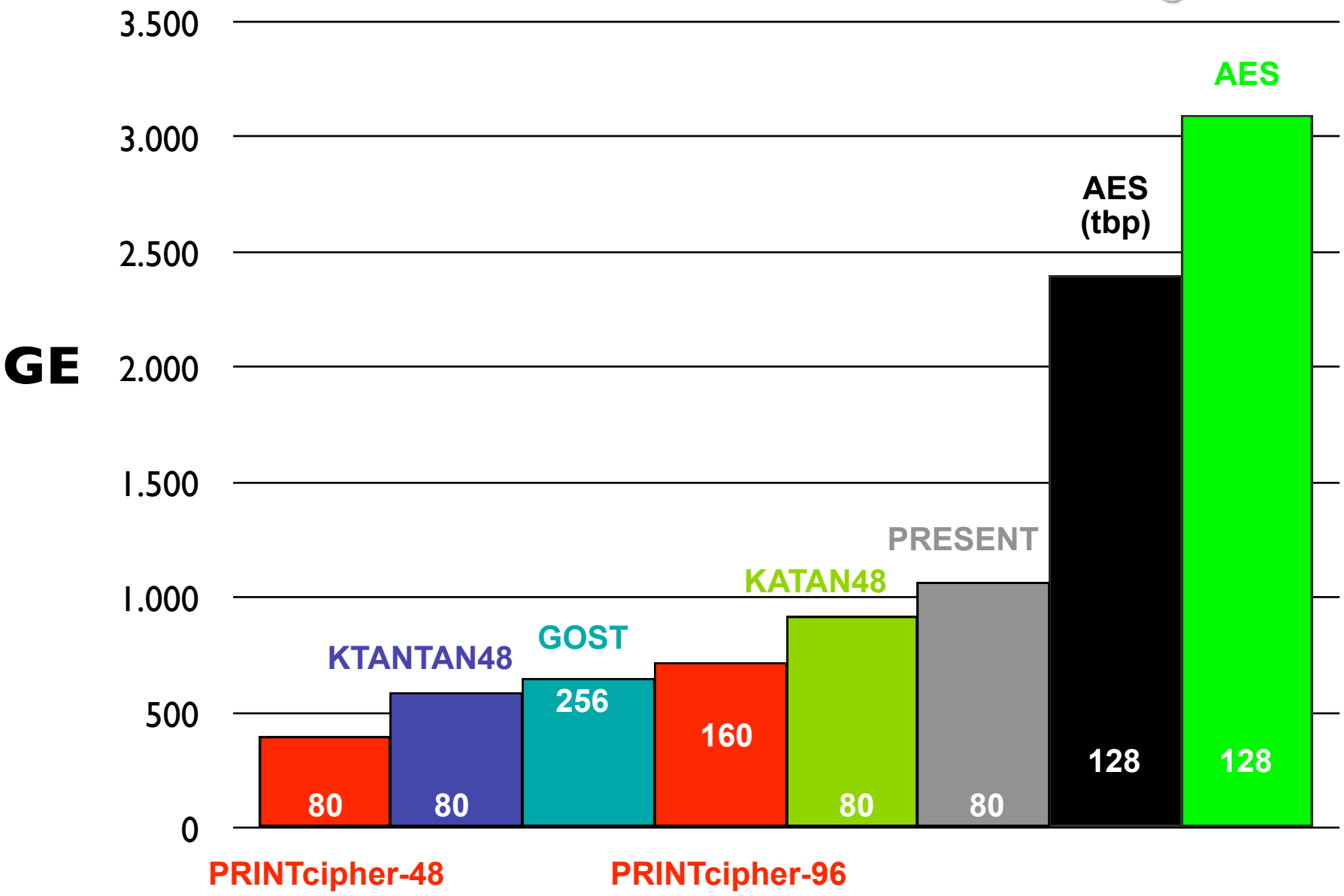


Implementation Results II



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Conclusions

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- considered IC printing
- proposed PRINTcipher-48 and PRINTcipher-96
- PRINTcipher:
  - takes advantage of unique features of IC printing
  - requires only 402 GE
  - provides good scalability: +100 GE = 16x faster
  - object of study rather than being suitable for deployment

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Please study PRINTcipher!

Thank you!

Questions?

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