FIDES:
Lightweight Authentication Cipher with Side-Channel Resistance for Constrained Hardware

Begül Bilgin, Andrey Bogdanov, Miroslav Knežević, Florian Mendel, and Qingju Wang

DIAC 2013, Chicago

Side Channel Resistance

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The Game...

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- Mathematically secure crypto algorithms

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  - ✓ AES, RSA, Keccak, OCB, …

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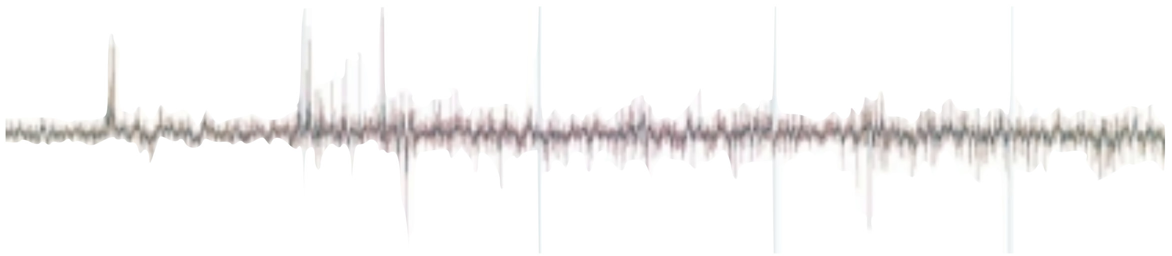

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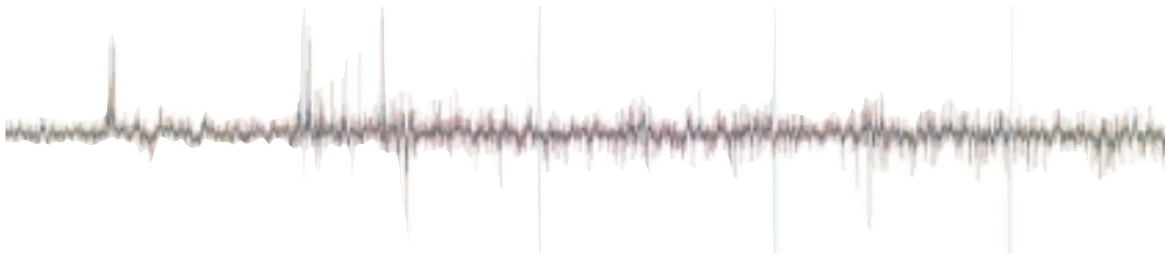

Dependency between power consumption and intermediate value (depends on the key)

Side Channel Resistance

Side Channel Resistance

- Change the key frequently

Side Channel Resistance

- Change the key frequently
- Equalize power consumption

Side Channel Resistance

- ✗ Change the key frequently
- ✗ Equalize power consumption
- ✓ Randomize power consumption

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    - Boolean masking

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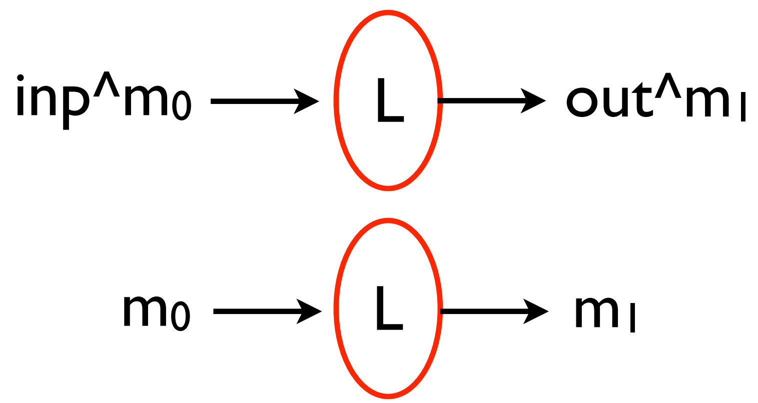

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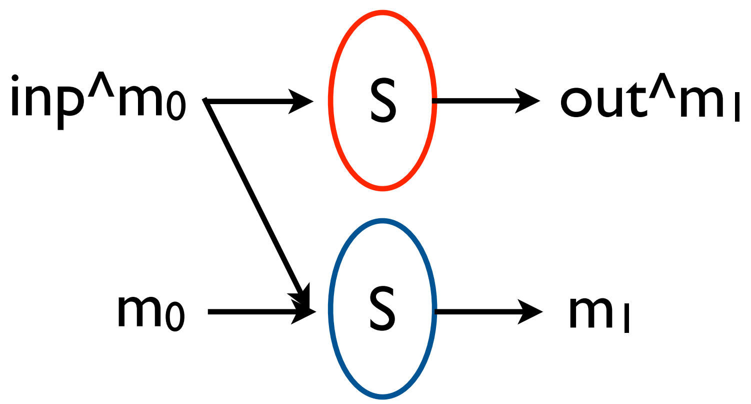

Side Channel Resistance

- ✗ Change the key frequently
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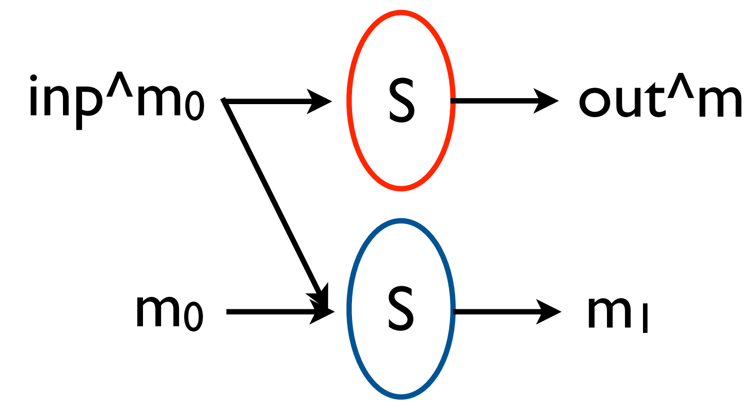
  - Multiplicative masking



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  - Secret sharing e.g. Threshold Implementations [Nikova'11]

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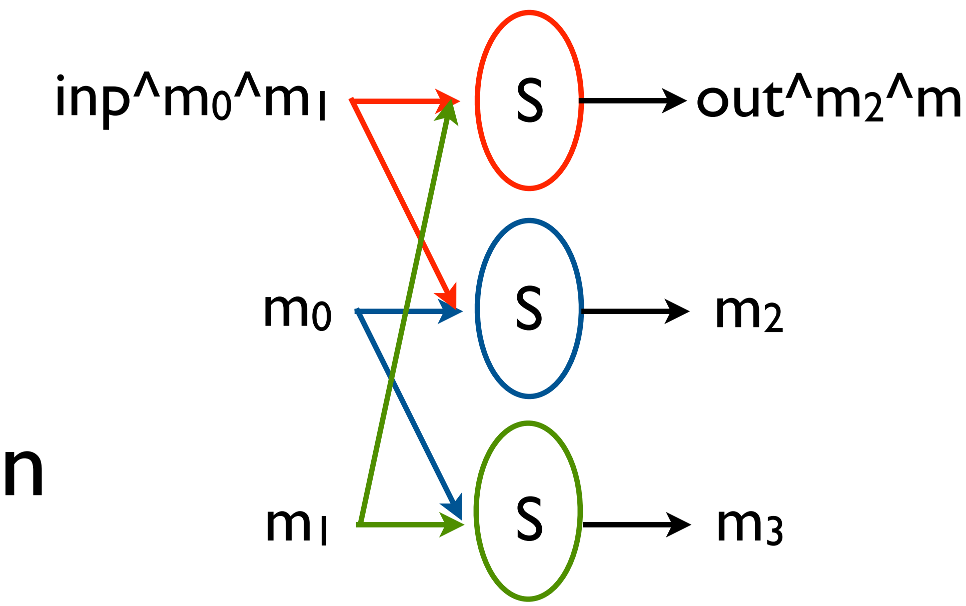

Side Channel Resistance

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Side Channel Resistance

Need
efficient impl.

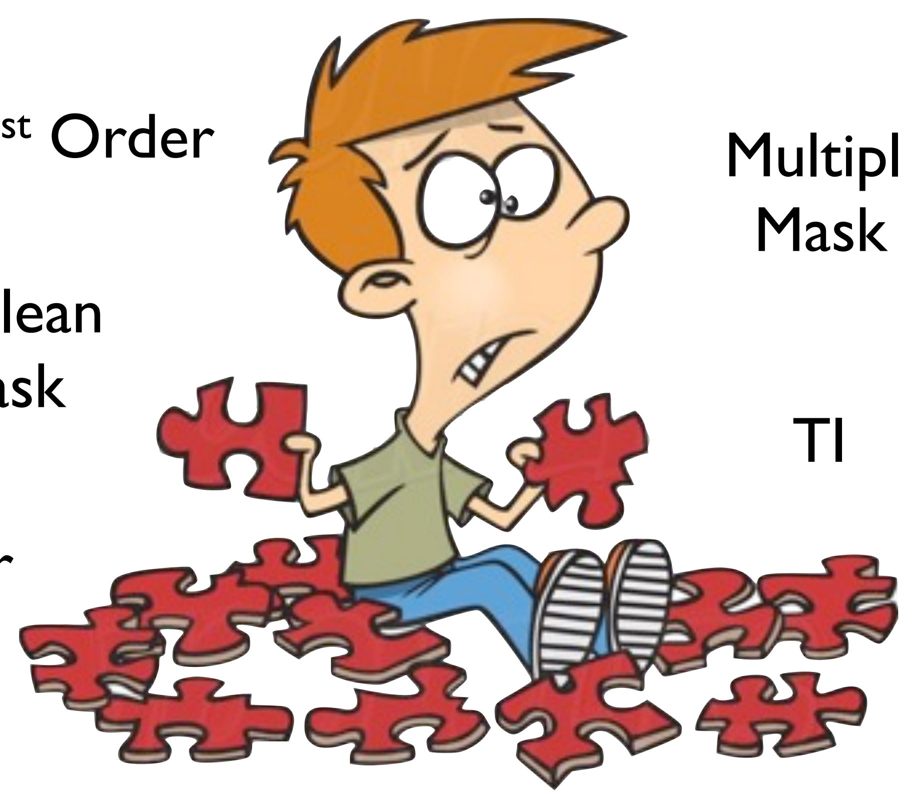
Have the
design

Need
secure impl.

1st Order

Boolean
Mask

2nd Order



Multipl.
Mask

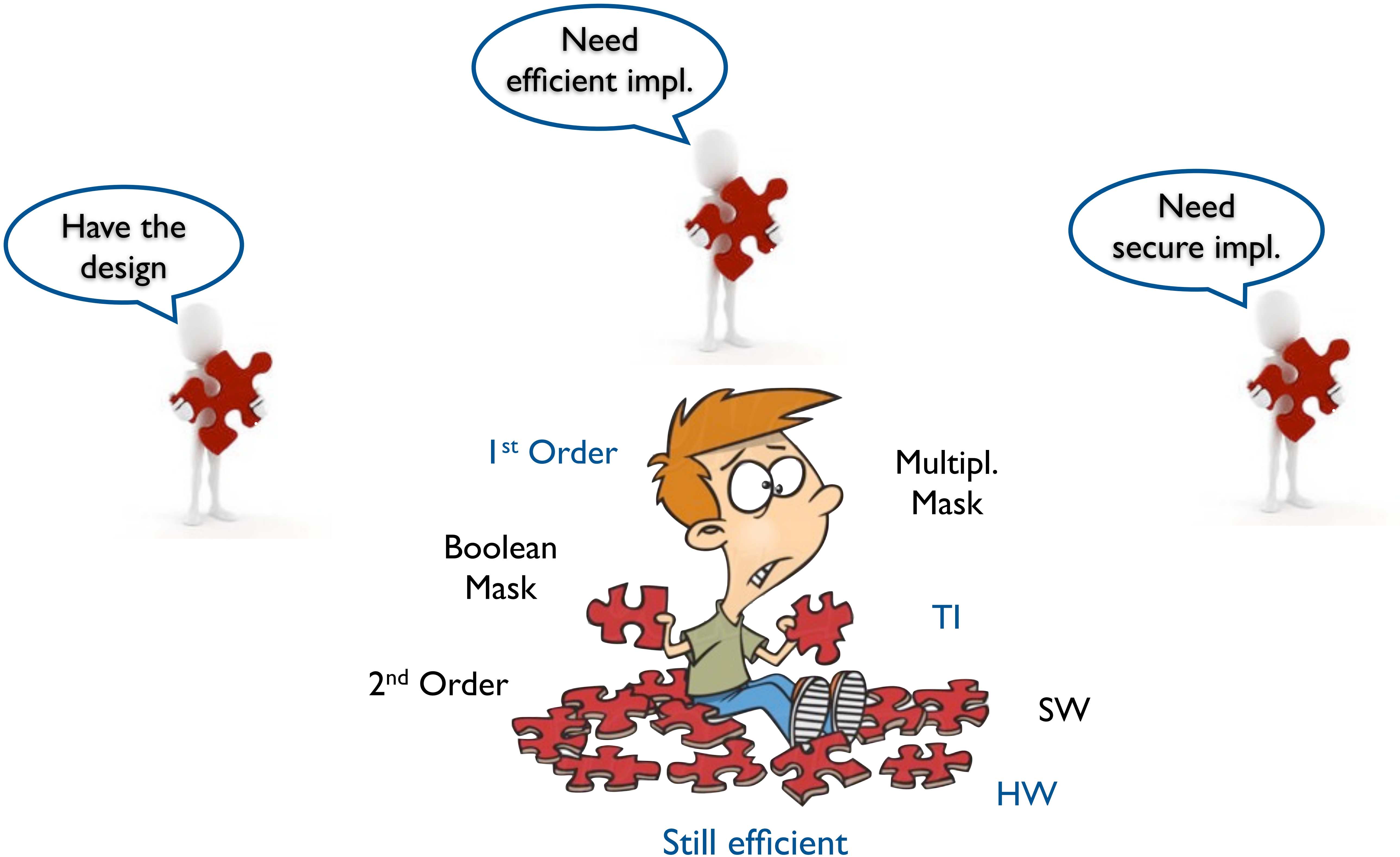
TI

SW

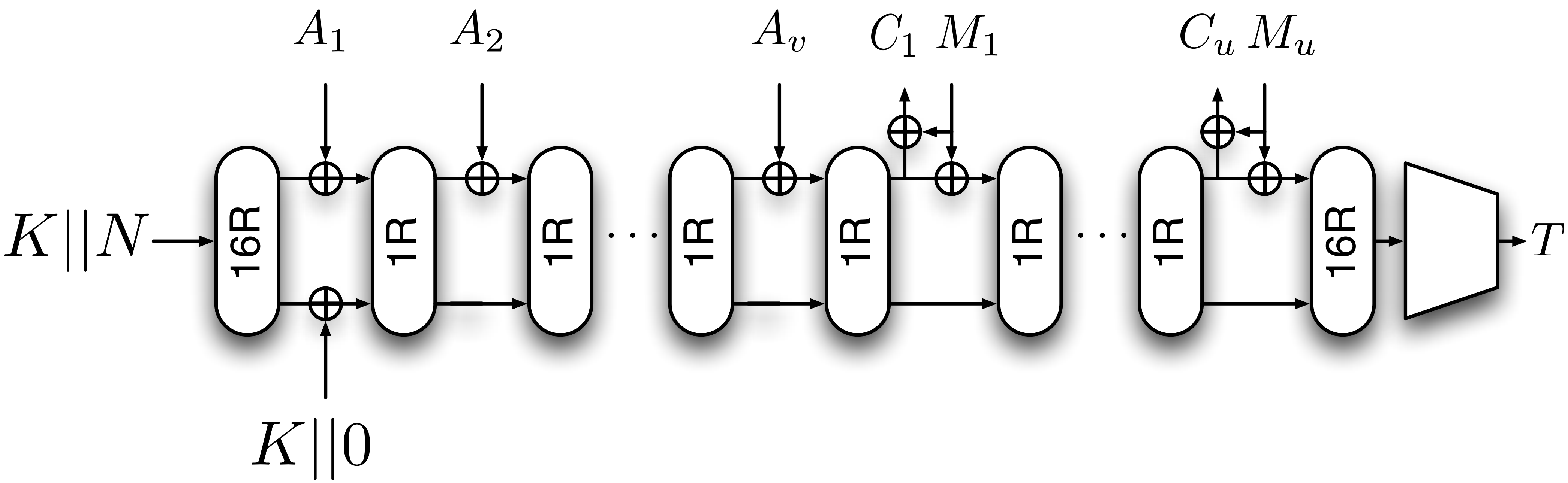
HW

?? Still efficient ??

Side Channel Resistance



Design - Structure



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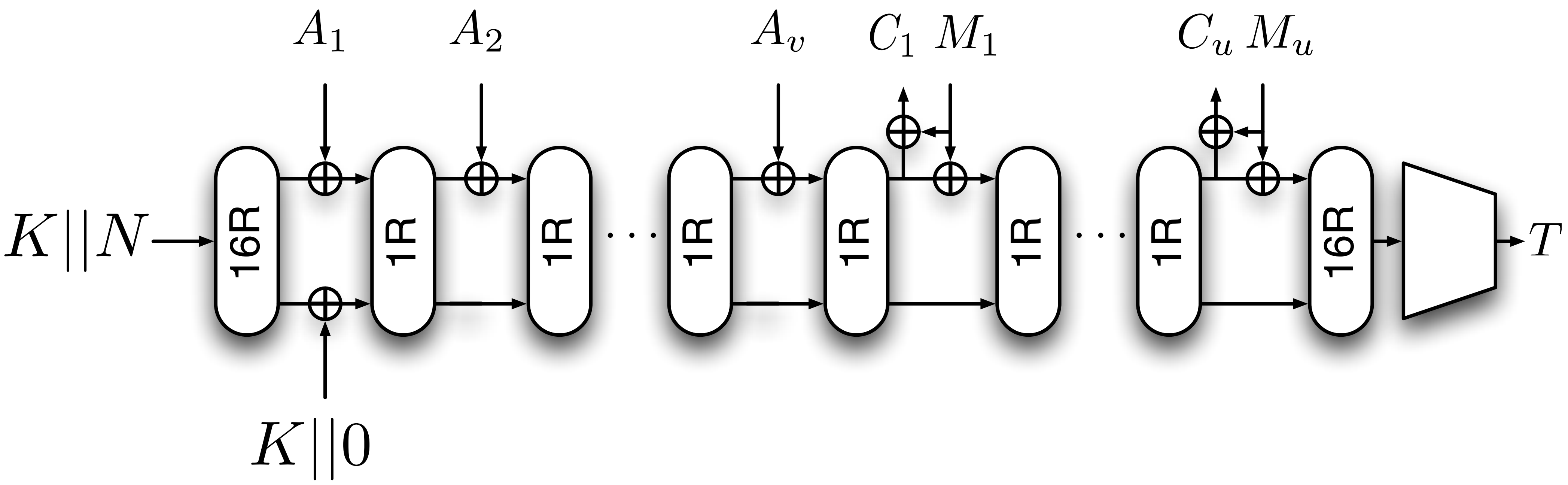
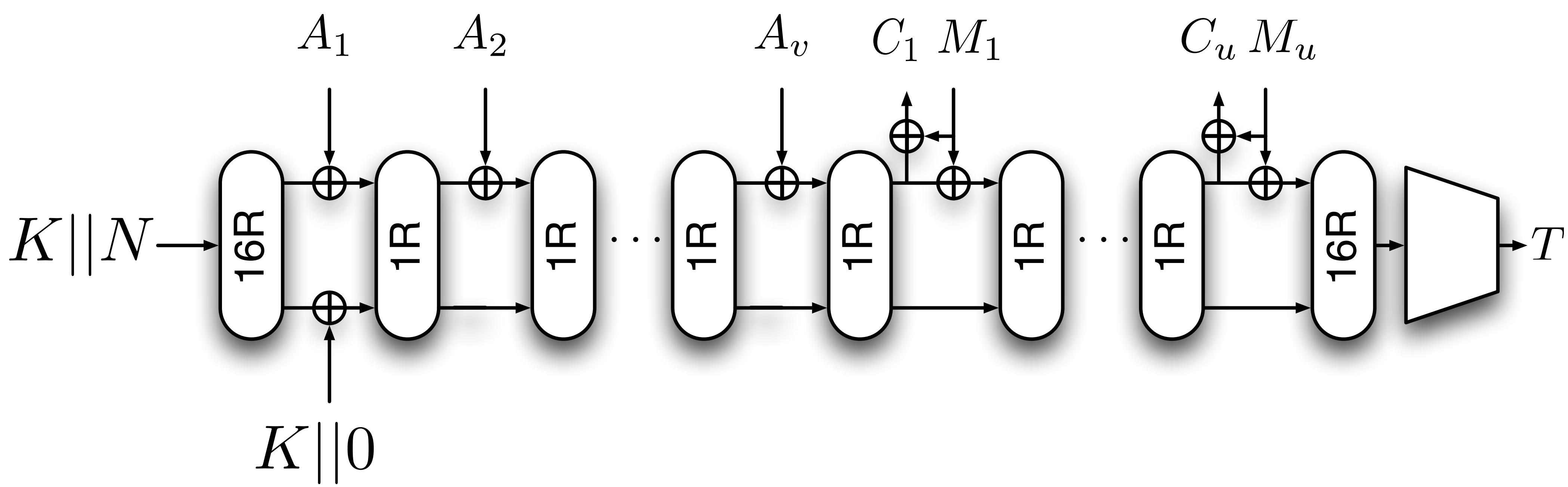


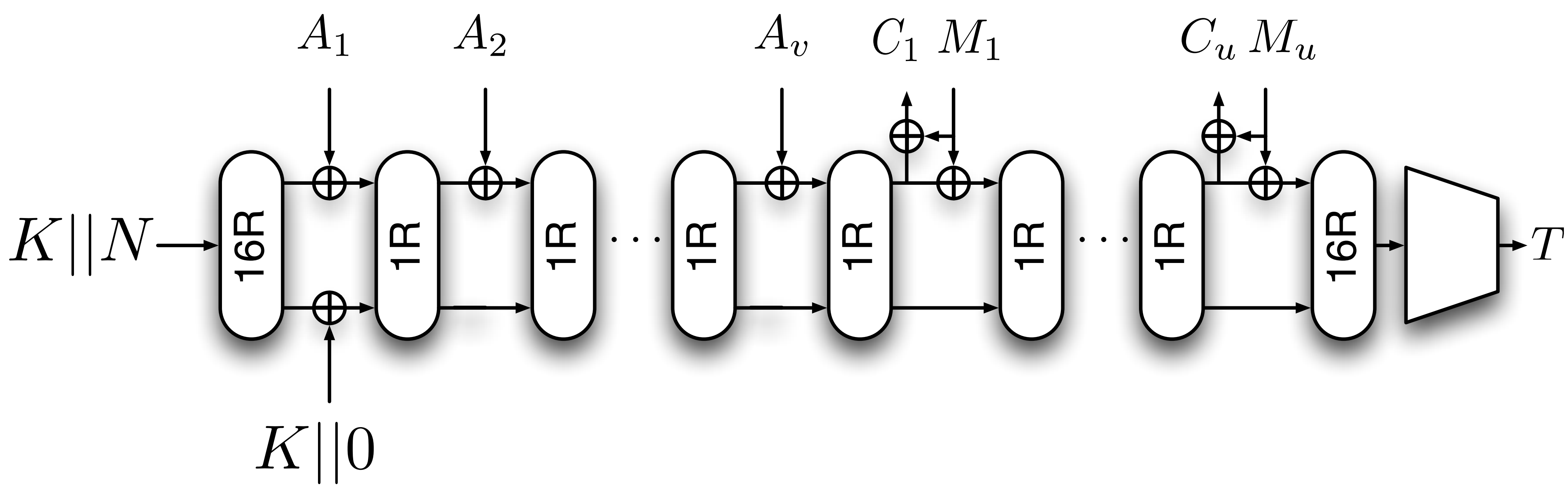
- Similar to duplex sponge

Design - Structure



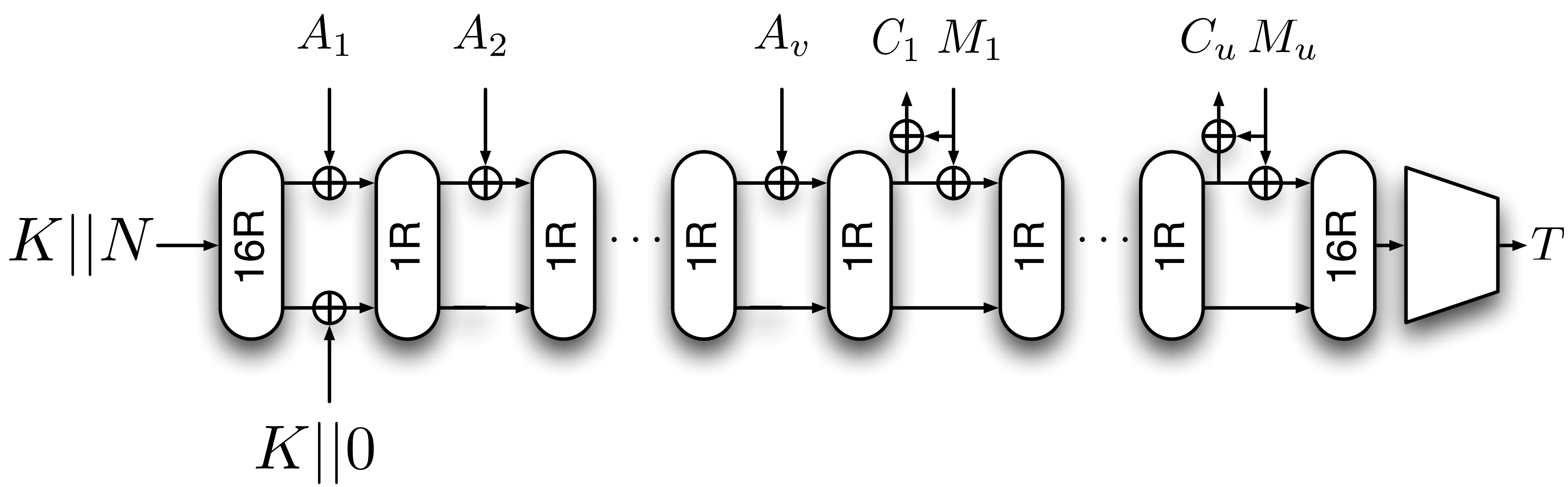
- Similar to duplex sponge
- Rounds are not keyed

Design - Structure



- Similar to duplex sponge
- Rounds are not keyed
- ✓ Online

Design - Structure

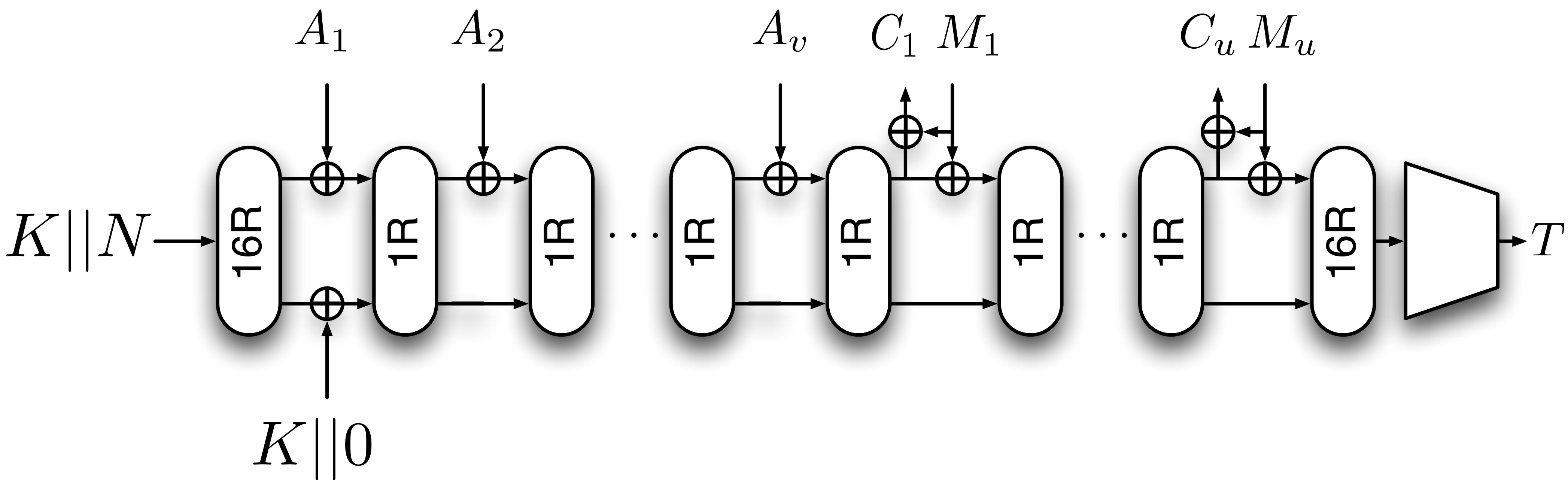


- Similar to duplex sponge
- Rounds are not keyed

✓ Online

✓ Single pass

Design - Structure



- Similar to duplex sponge
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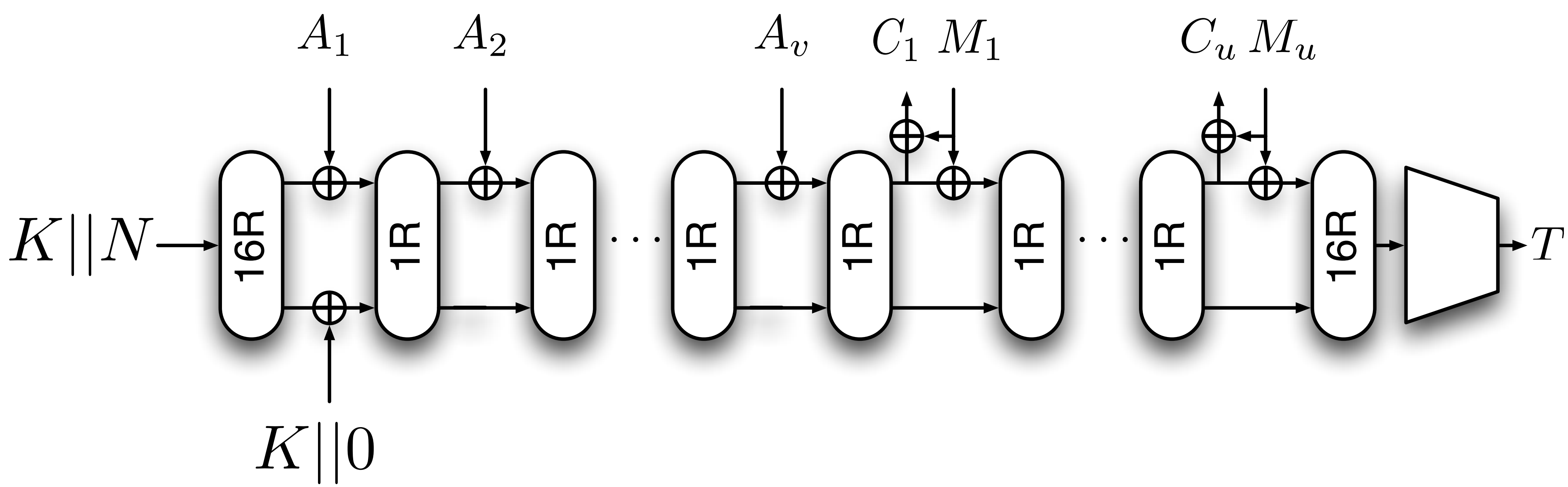
FIDES-80

FIDES-96

Design - Structure



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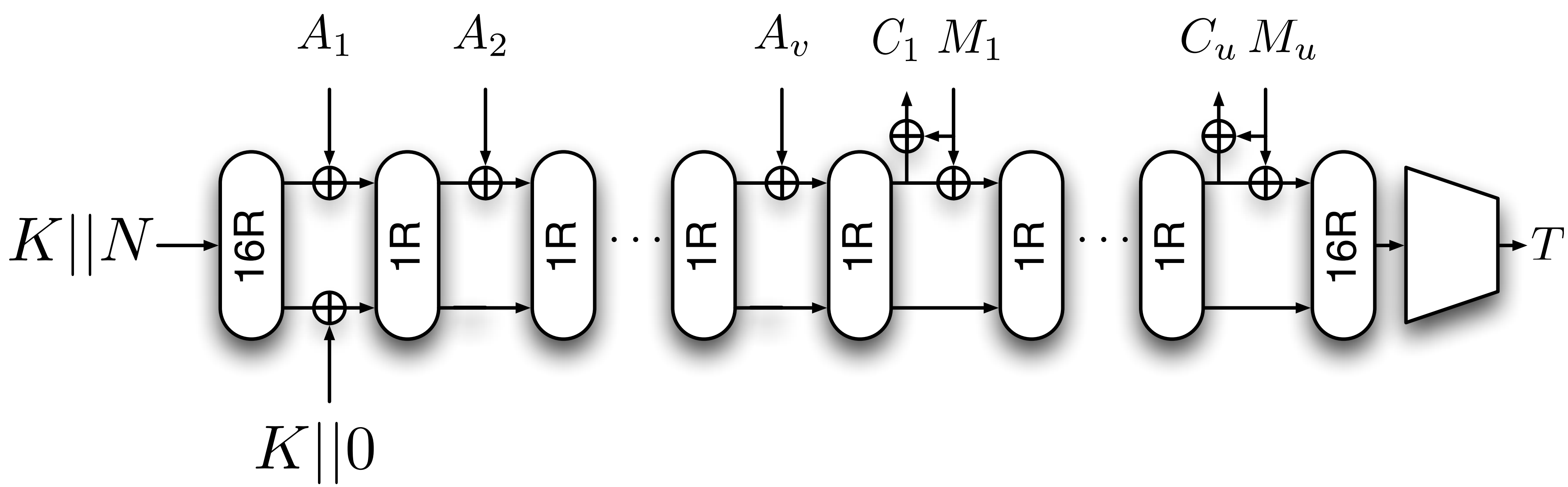
	b
FIDES-80	160
FIDES-96	192

Design - Structure



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	b	*k/n/t*
FIDES-80	160	80
FIDES-96	192	96

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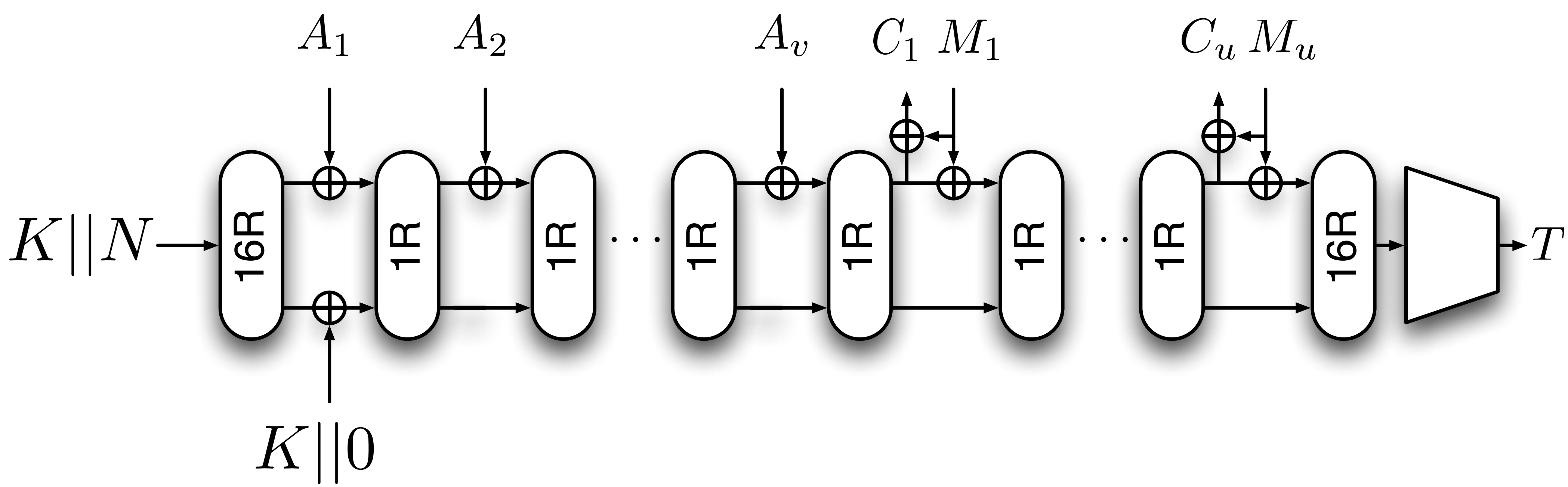

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	b	*k/n/t*	*r*
FIDES-80	160	80	10
FIDES-96	192	96	12

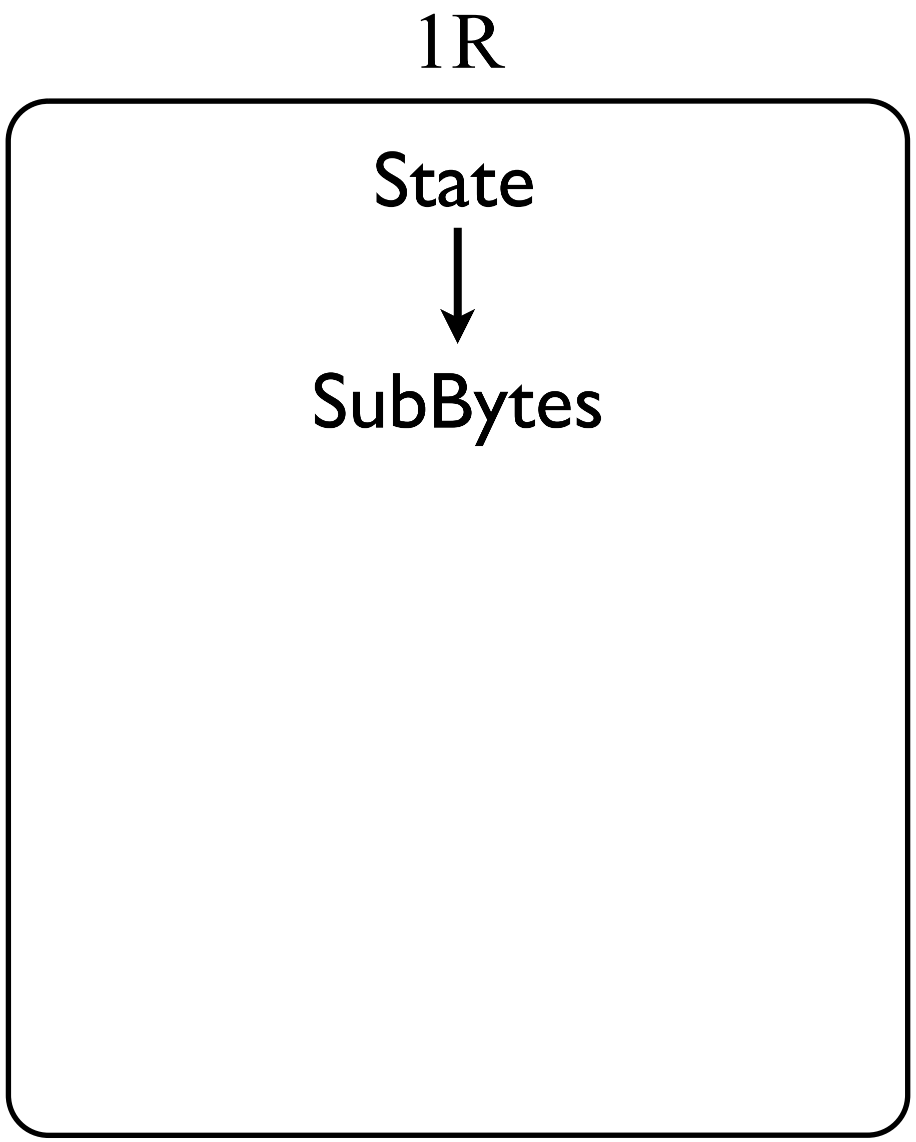
Design - Structure

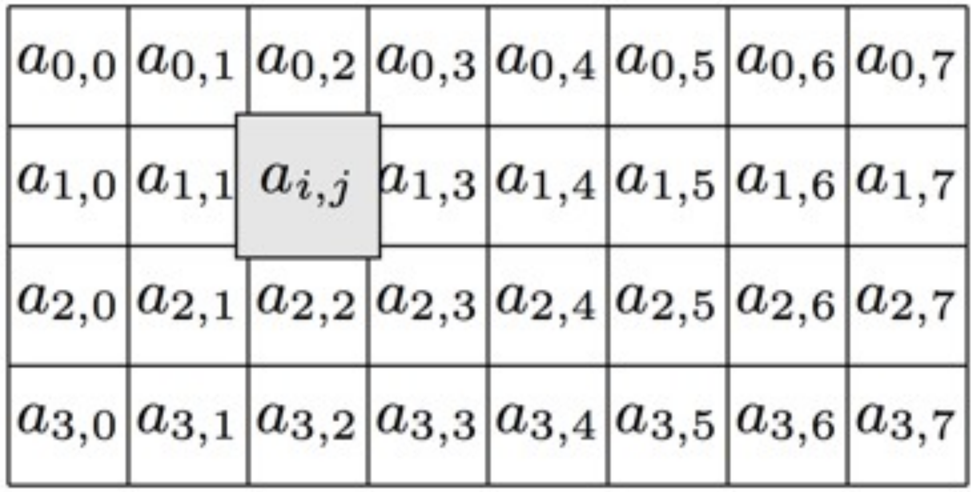
1R

State

$a_{0,0}$	$a_{0,1}$	$a_{0,2}$	$a_{0,3}$	$a_{0,4}$	$a_{0,5}$	$a_{0,6}$	$a_{0,7}$
$a_{1,0}$	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$a_{1,4}$	$a_{1,5}$	$a_{1,6}$	$a_{1,7}$
$a_{2,0}$	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,5}$	$a_{2,6}$	$a_{2,7}$
$a_{3,0}$	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$	$a_{3,6}$	$a_{3,7}$

Design - Structure





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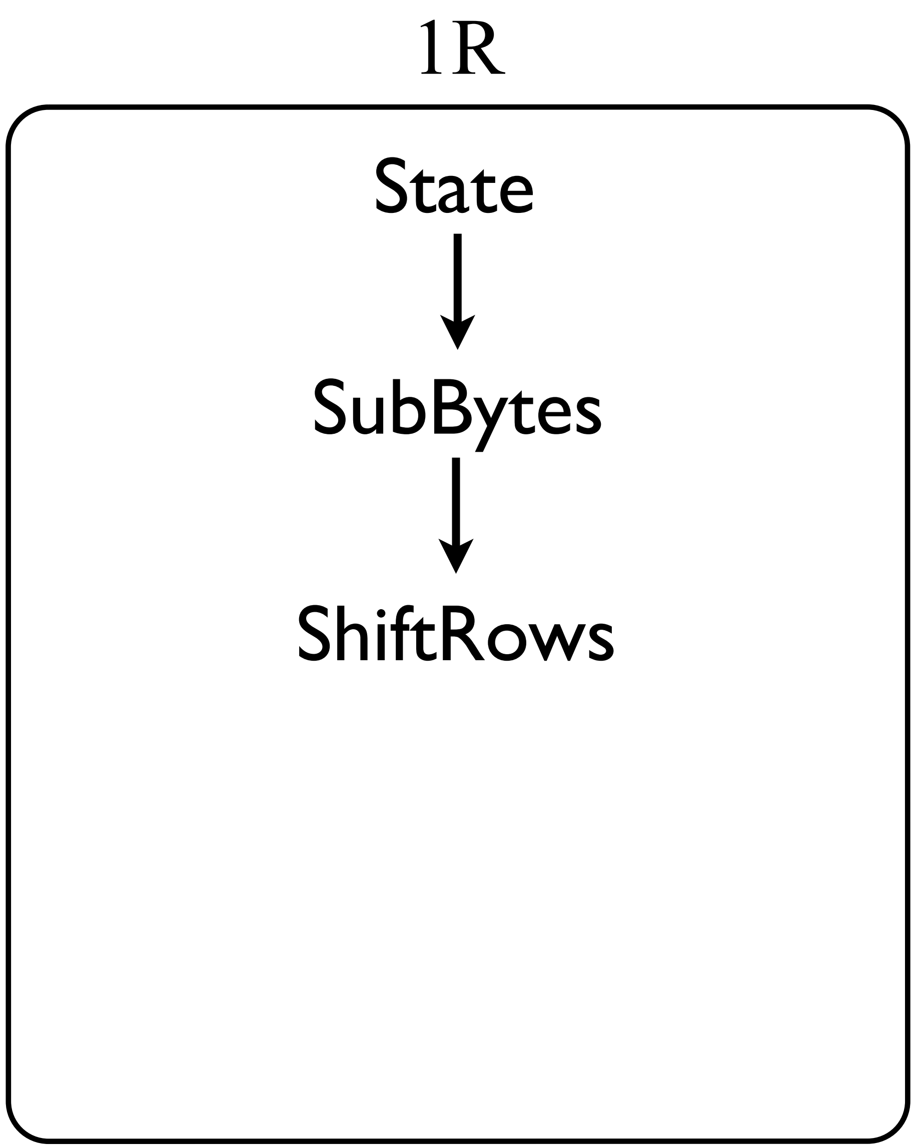
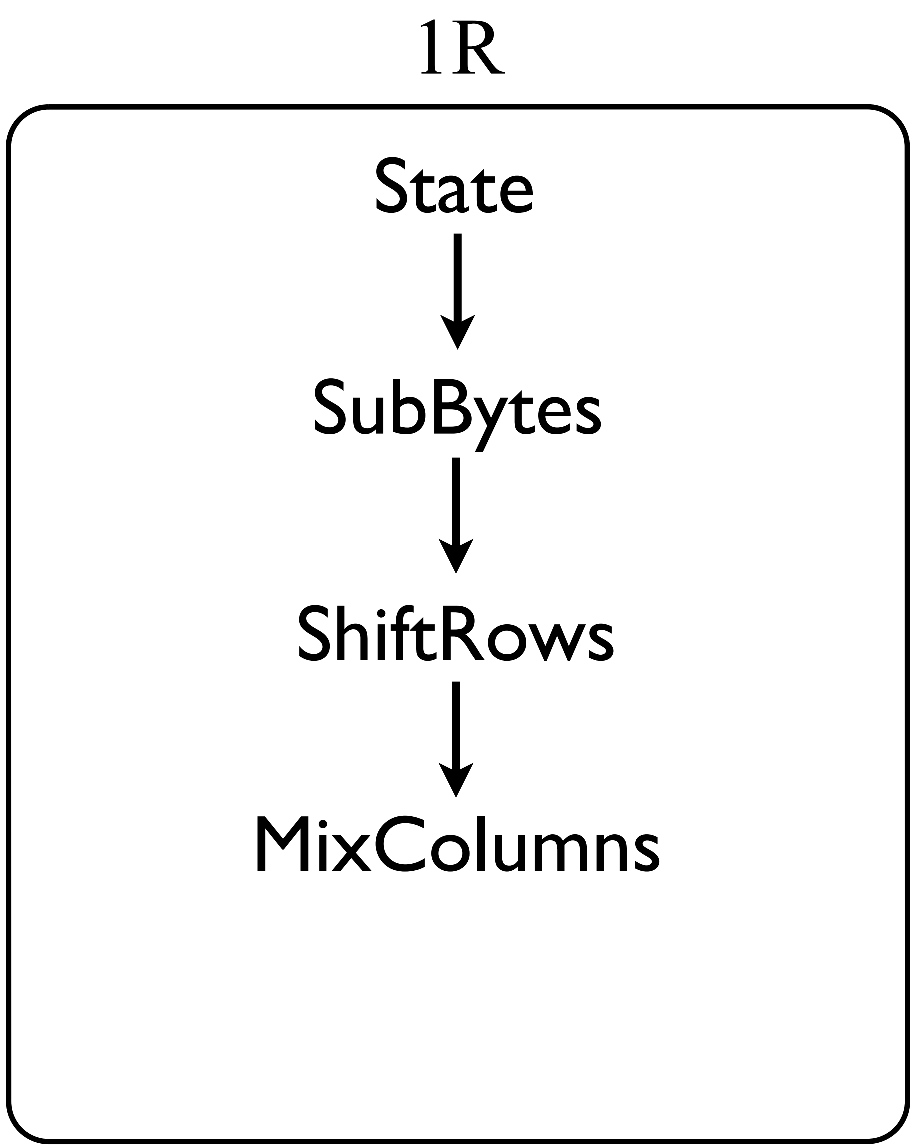


$a_{0,0}$	$a_{0,1}$	$a_{0,2}$	$a_{0,3}$	$a_{0,4}$	$a_{0,5}$	$a_{0,6}$	$a_{0,7}$	*0*
$a_{i,0}$	$a_{i,1}$	$a_{i,2}$	$a_{i,3}$	$a_{i,4}$	$a_{i,5}$	$a_{i,6}$	$a_{i,7}$	*1*
$a_{2,0}$	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,5}$	$a_{2,6}$	$a_{2,7}$	*2*
$a_{3,0}$	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$	$a_{3,6}$	$a_{3,7}$	*7*

Design - Structure



$a_{0,0}$	$a_{0,1}$	$a_{0,j}$	$a_{0,3}$	$a_{0,4}$	$a_{0,5}$	$a_{0,6}$	$a_{0,7}$
$a_{1,0}$	$a_{1,1}$	$a_{1,j}$	$a_{1,3}$	$a_{1,4}$	$a_{1,5}$	$a_{1,6}$	$a_{1,7}$
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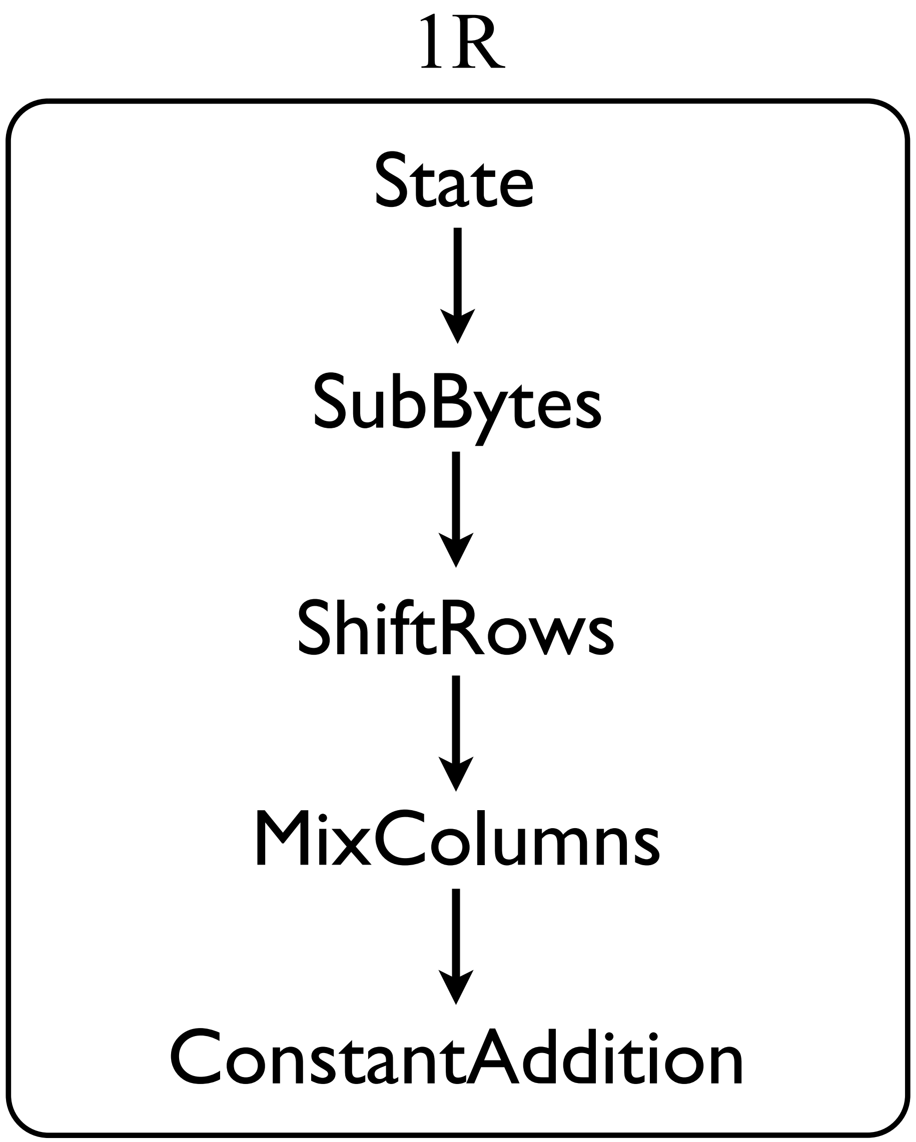
$a_{3,0}$	$a_{3,1}$	$a_{3,j}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$	$a_{3,6}$	$a_{3,7}$

$$\otimes \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$$

Almost MDS
branch number is 4

Design - Structure



Design - S-boxes

- FIDES-80: 5-bit Almost Bent (AB)
  - optimal resistance against differential & linear cryptanalysis
- FIDES-96: 6-bit Almost Perfect Nonlinear (APN)
  - optimal resistance against differential cryptanalysis

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++Low latency++

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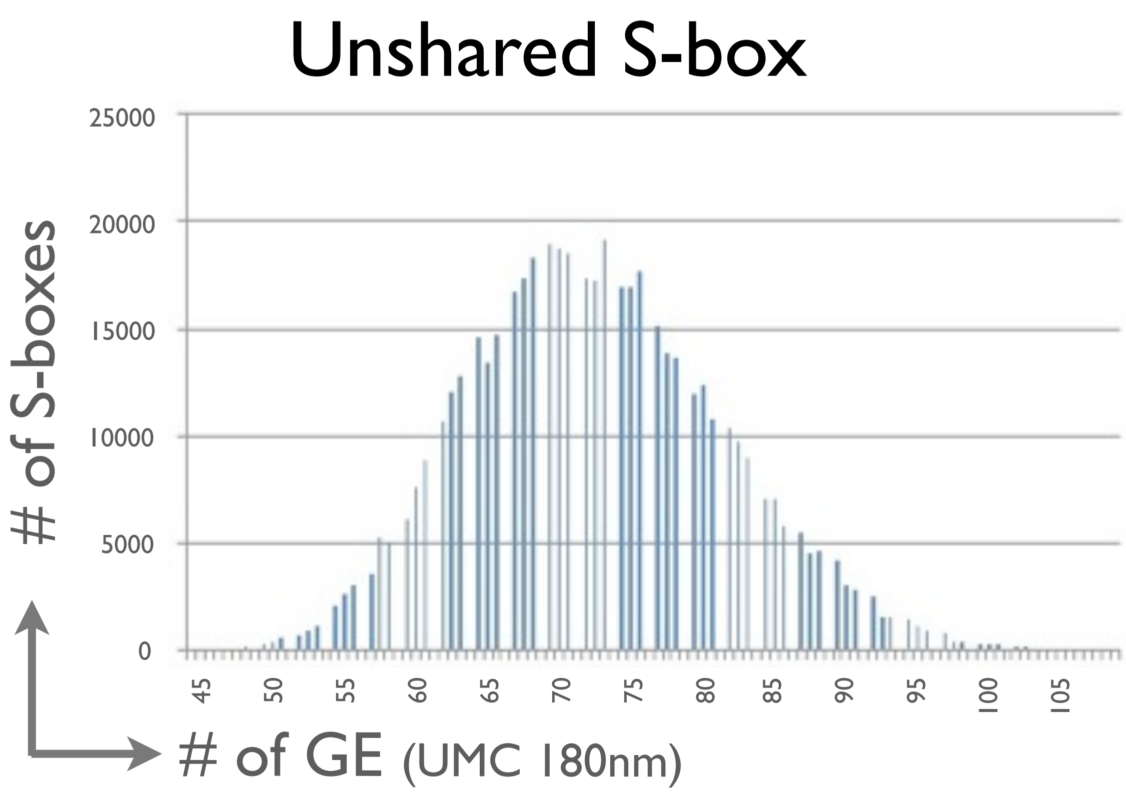
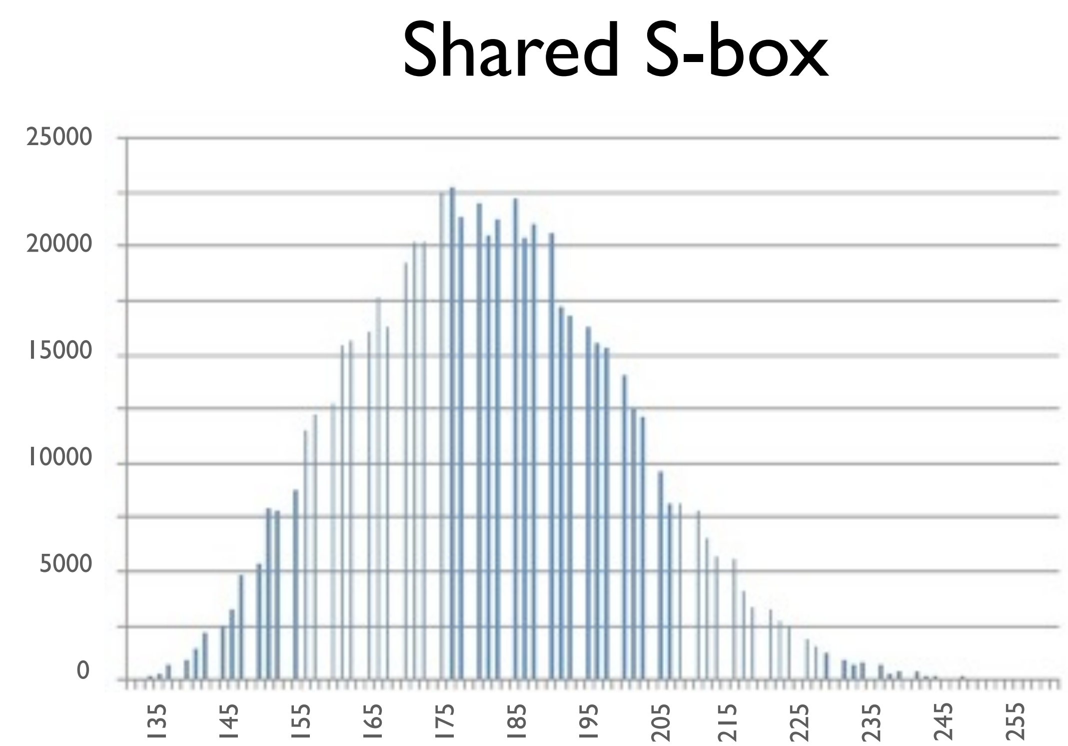
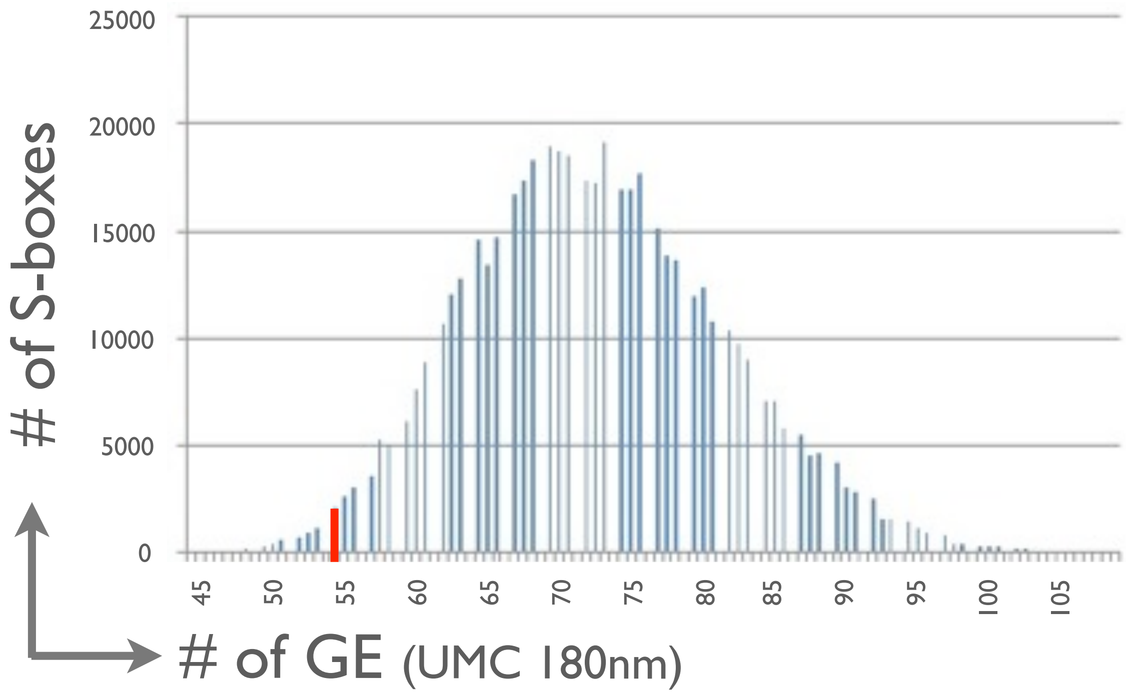




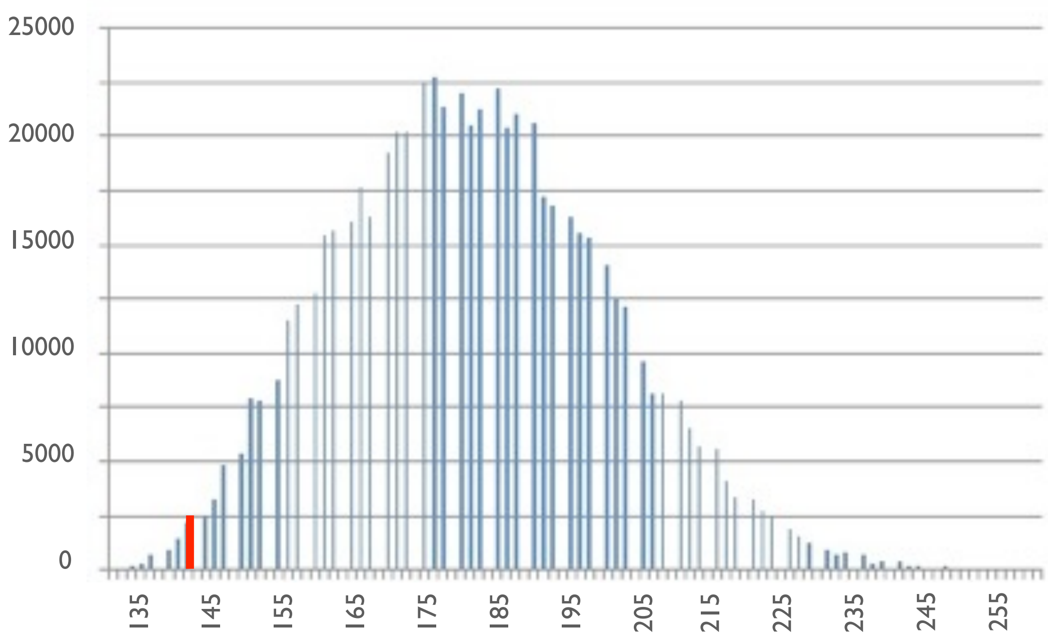
Design - S-boxes

Affine Equivalent to AB permutation with degree 2

Unshared S-box



Shared S-box



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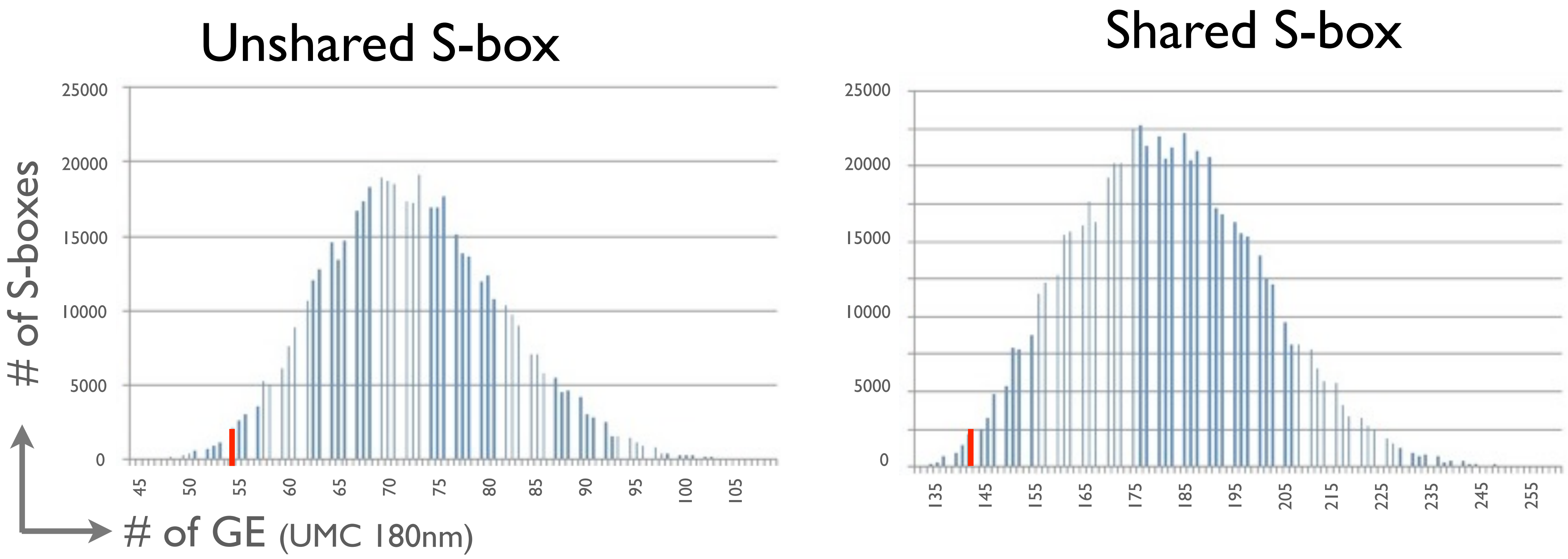
Affine Equivalent to AB permutation with degree 2



Similar for APN

Security Analysis

# rnd.	# Active S-box	
	any diff.	zero diff.
1	0	-
2	4	-
3	7	-
4	16	-
5	22	-
6	32	52
7	42	49
8	48	48

Security Analysis

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- Differential & Linear Cryptanalysis

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  16 rounds: $2^{-4 \times 48 \times 2} = 2^{-384}$

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  16 rounds: $2^{-4x(48+48)} = 2^{-384}$
- Impossible Differential
  9 rounds

Implementation

- FIDES-S
- FIDES-4S
- FIDES-R
- FIDES-T

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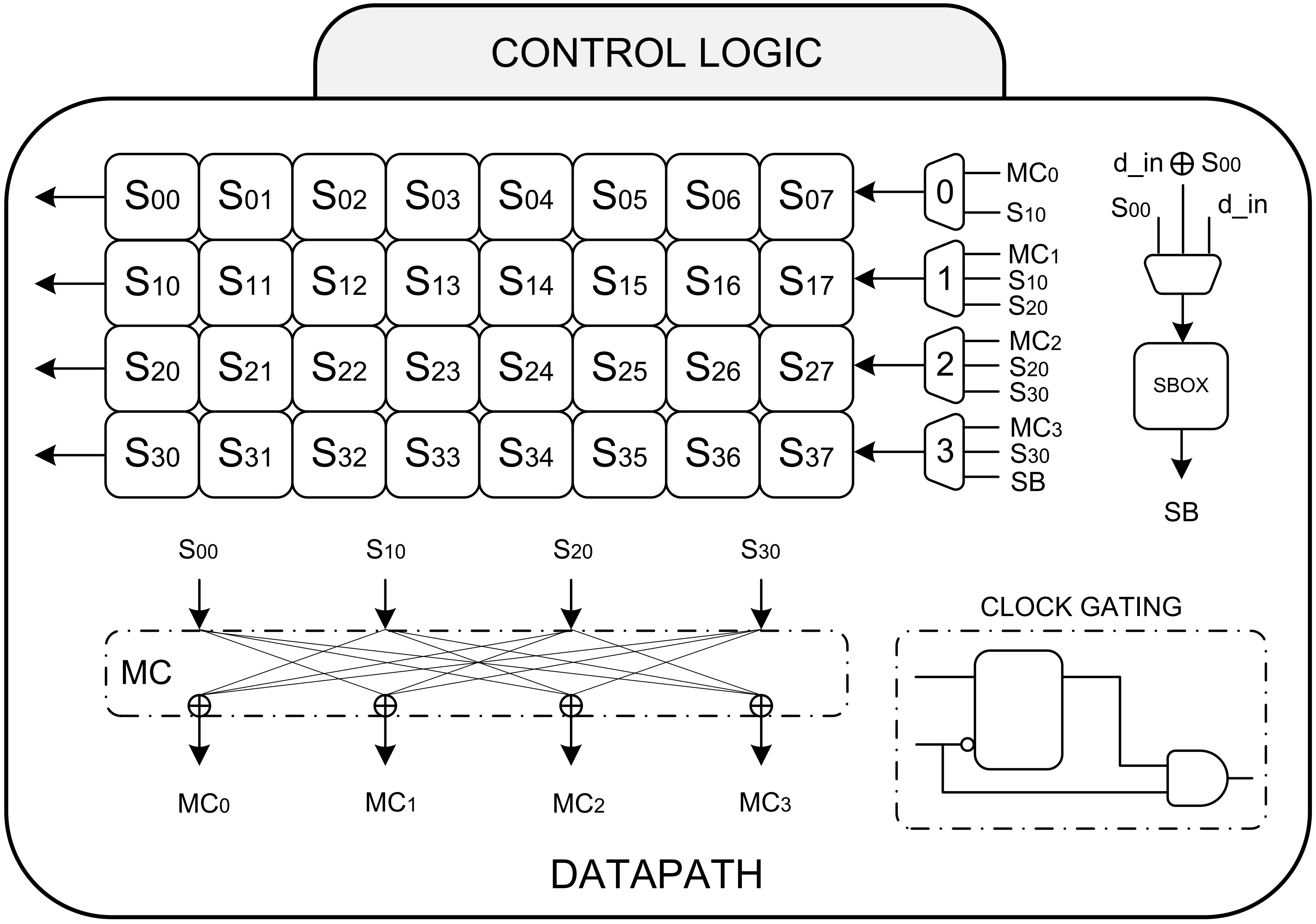

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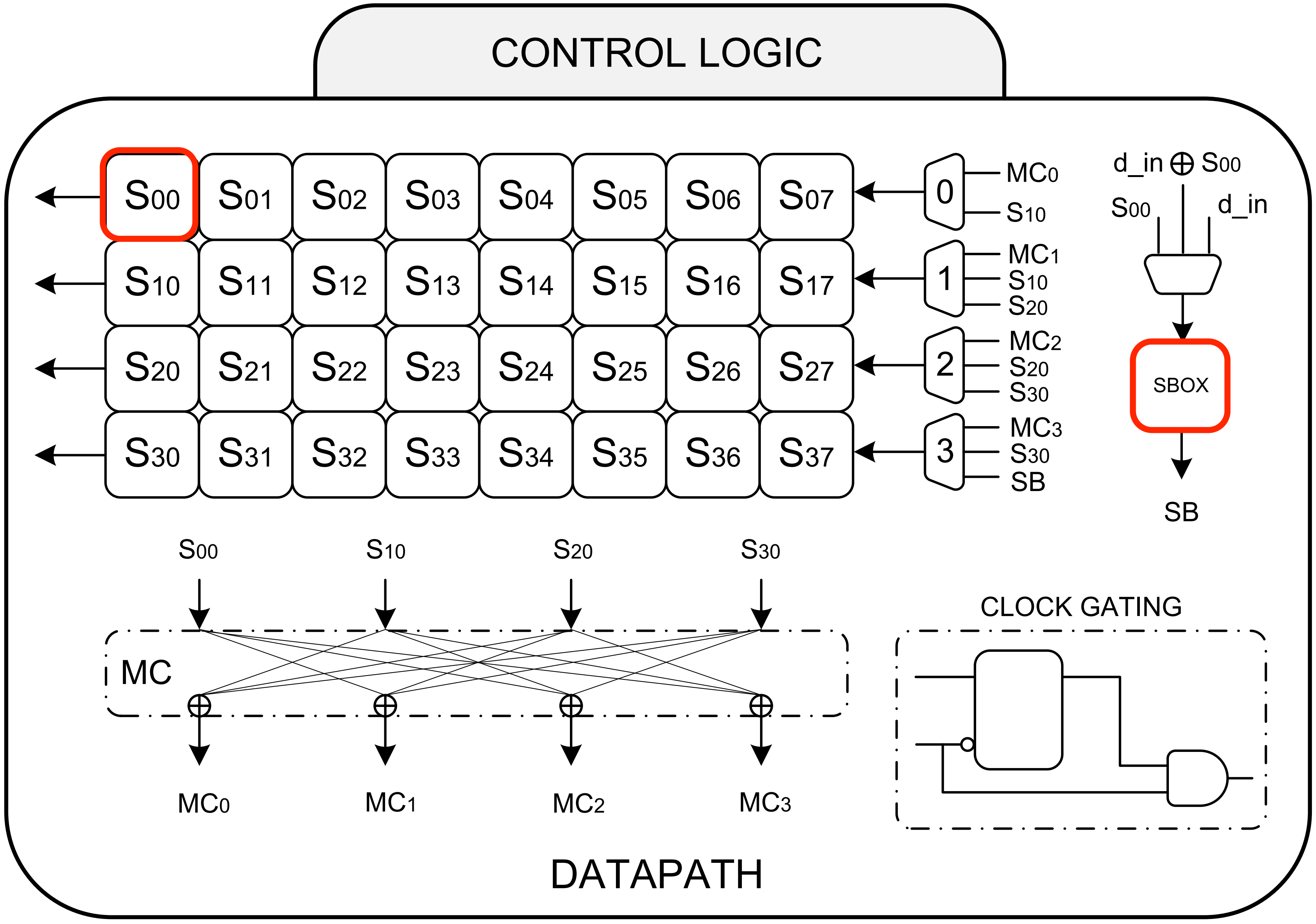

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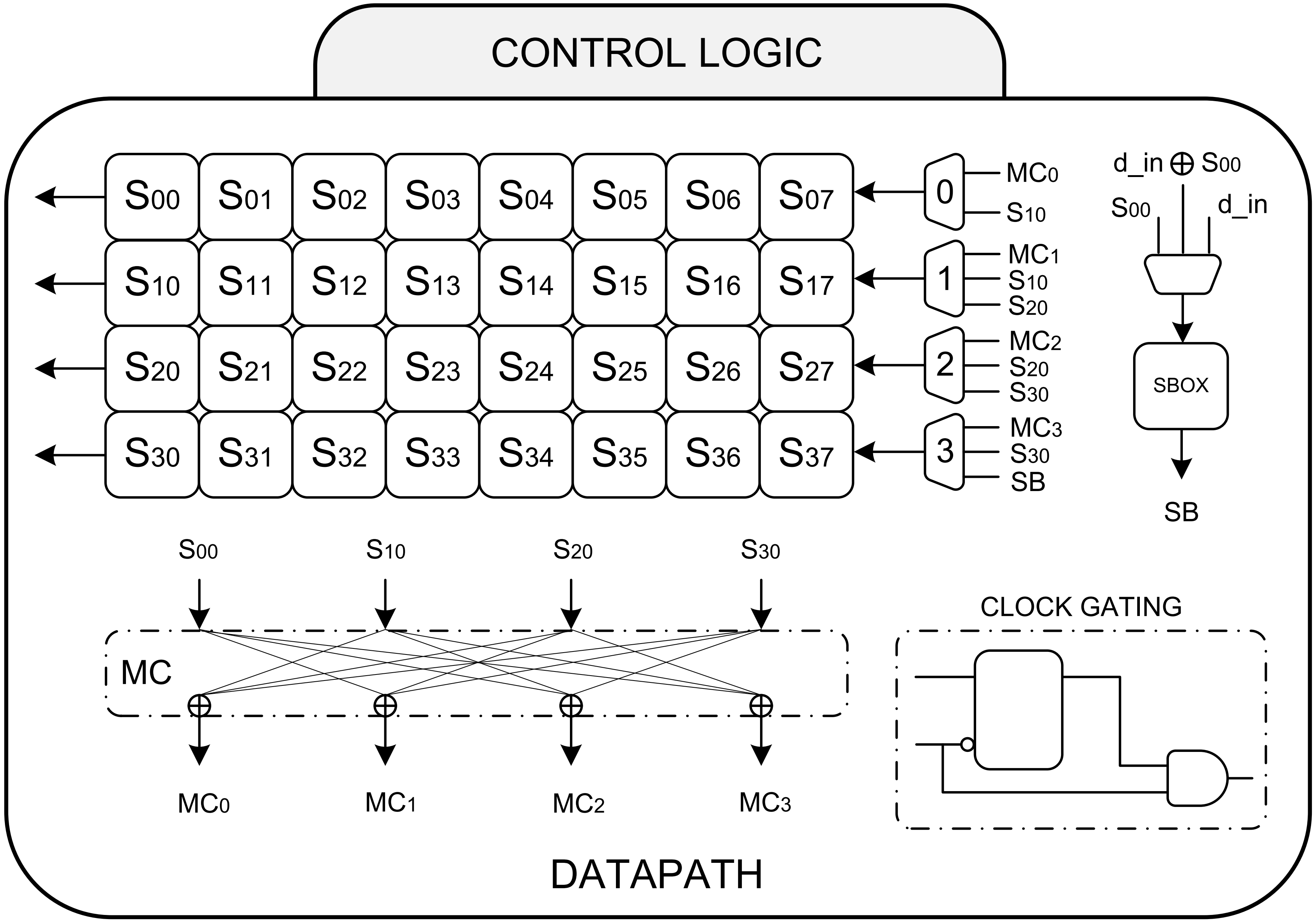

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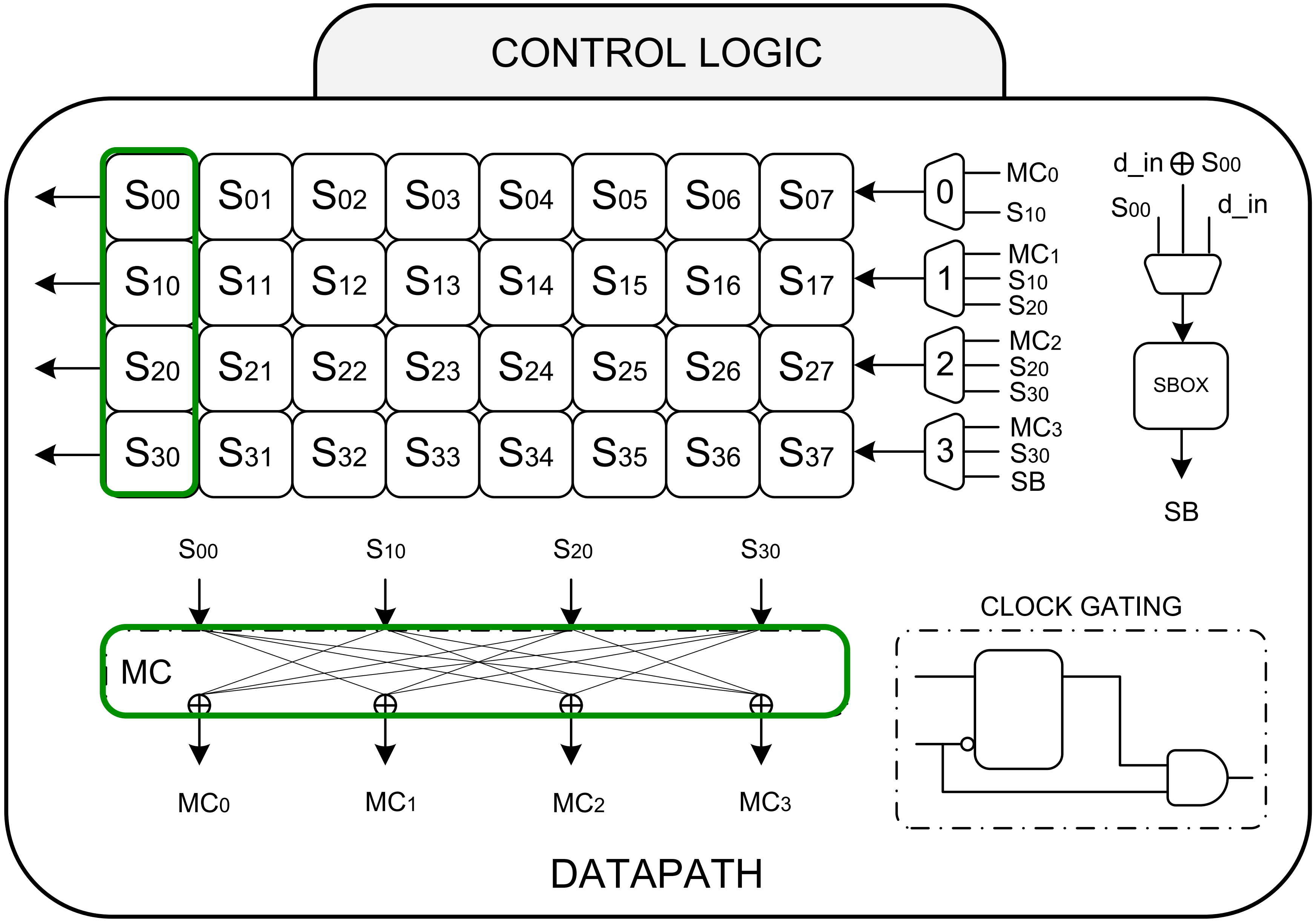

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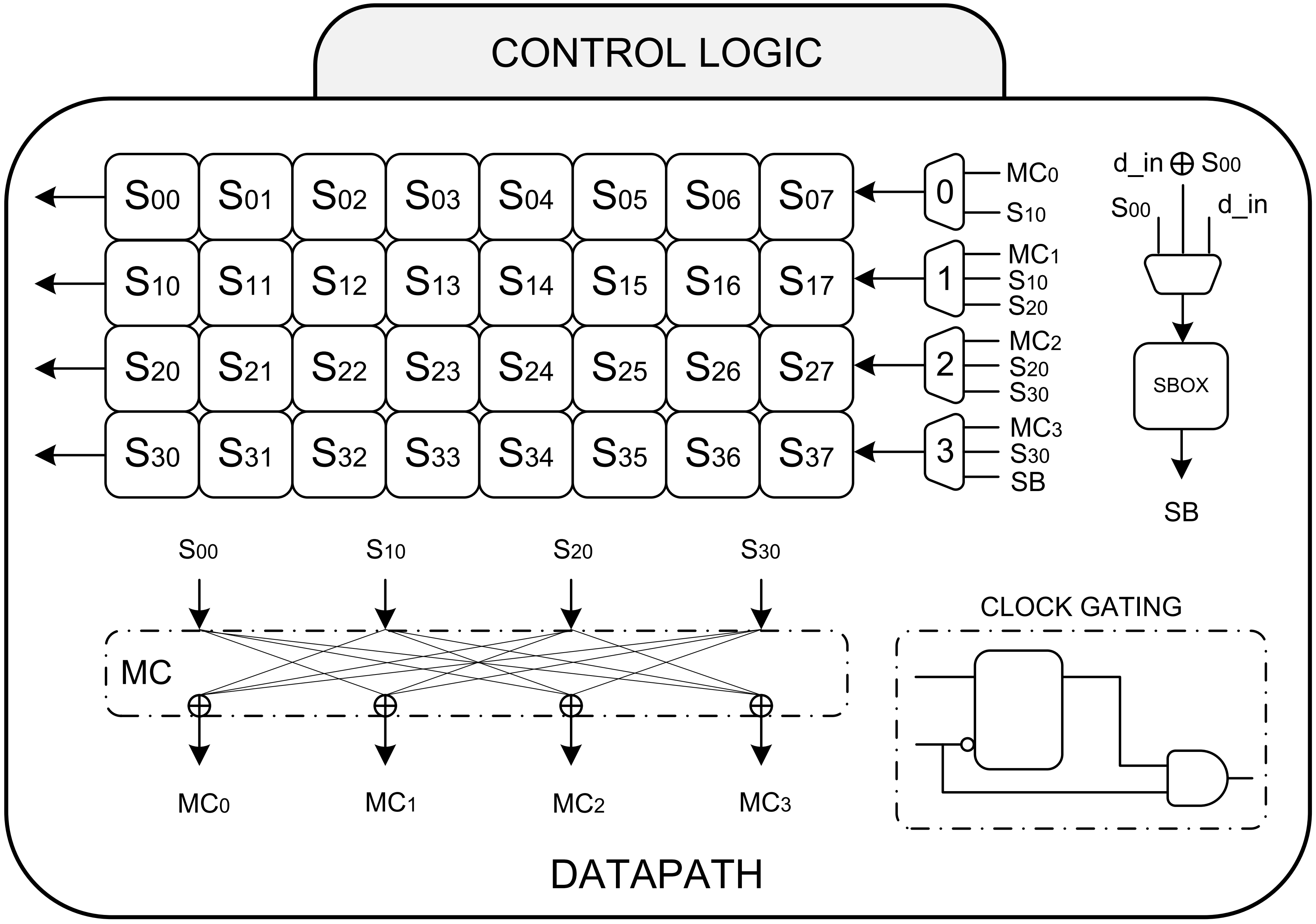

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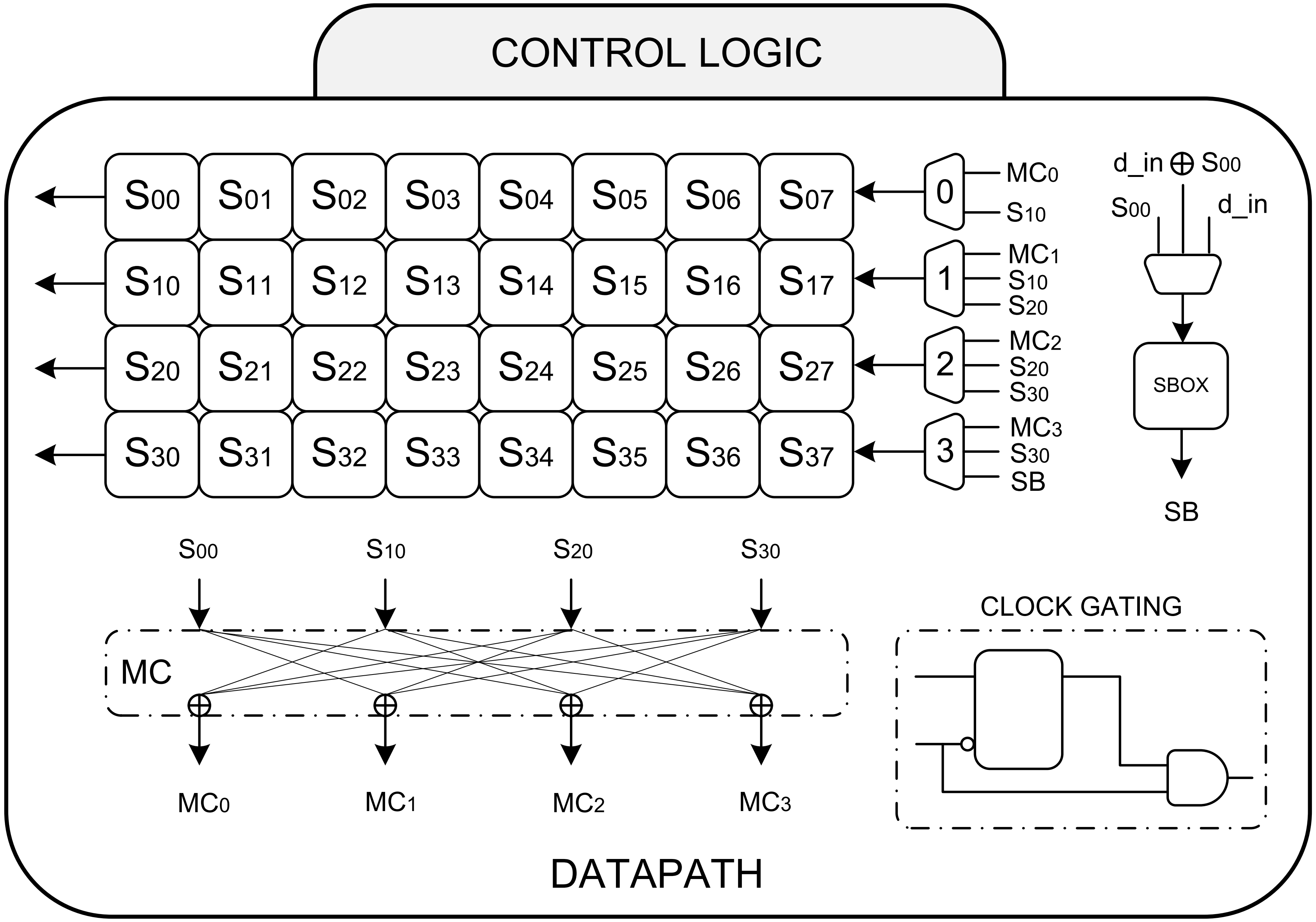

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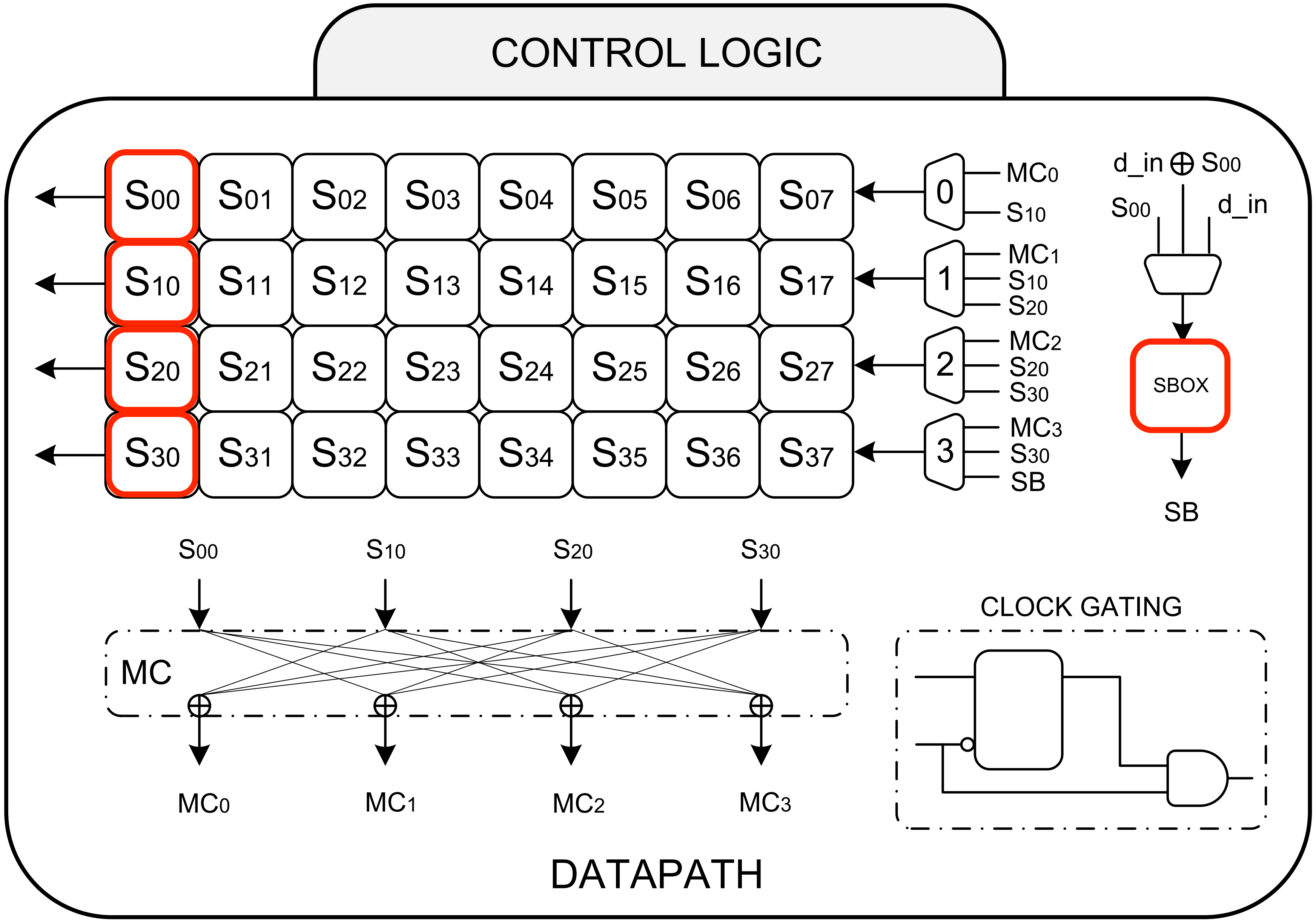

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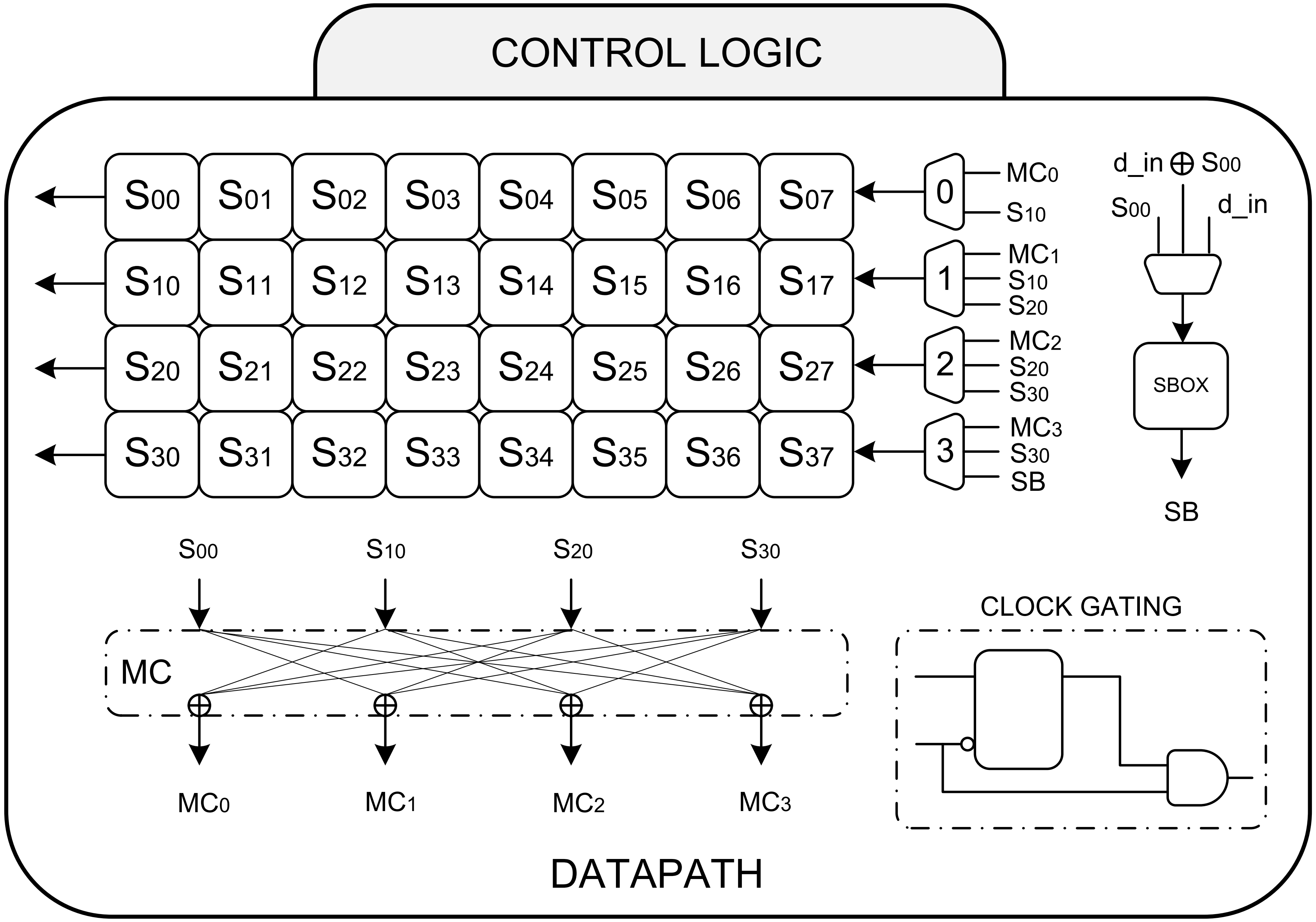

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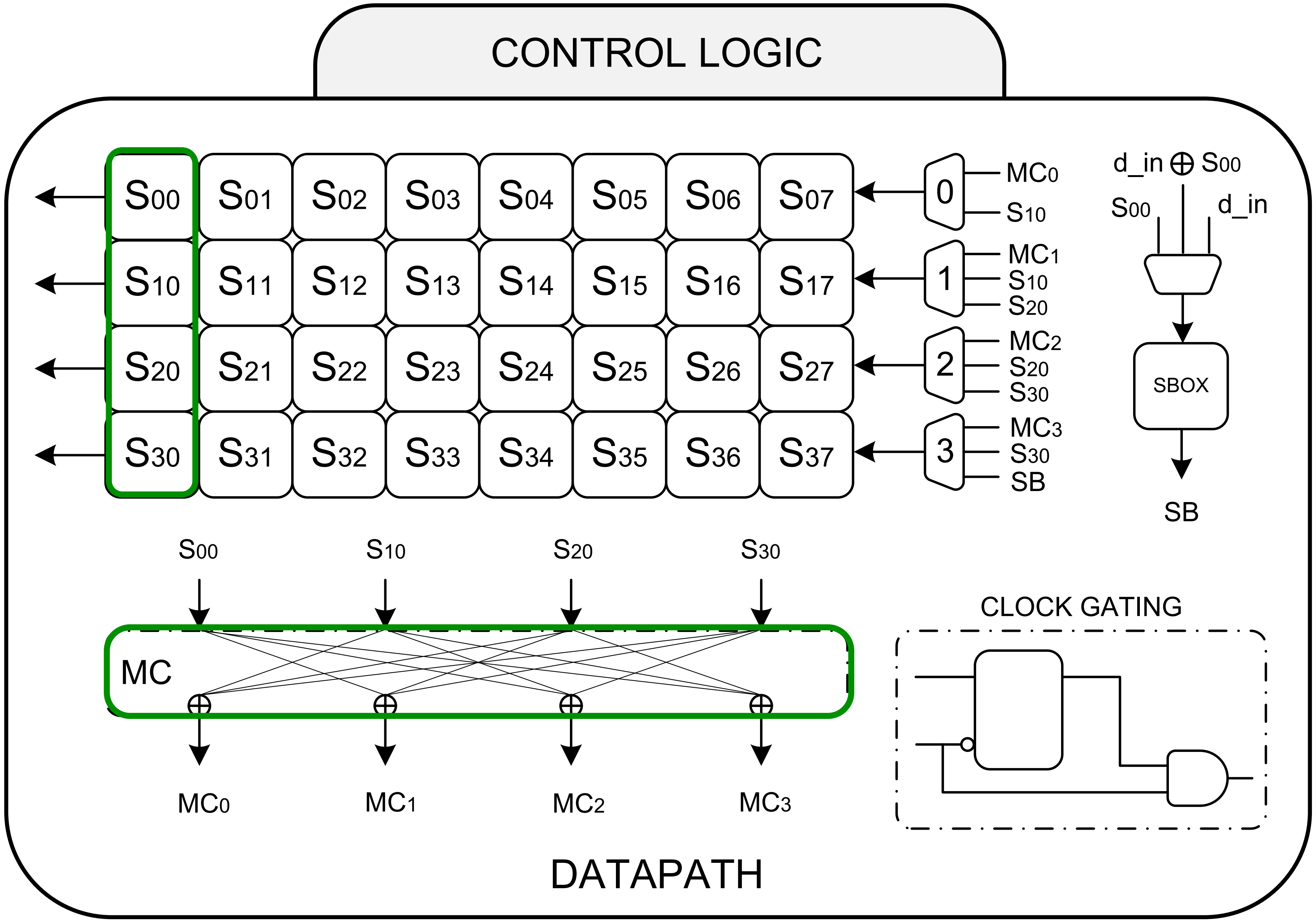

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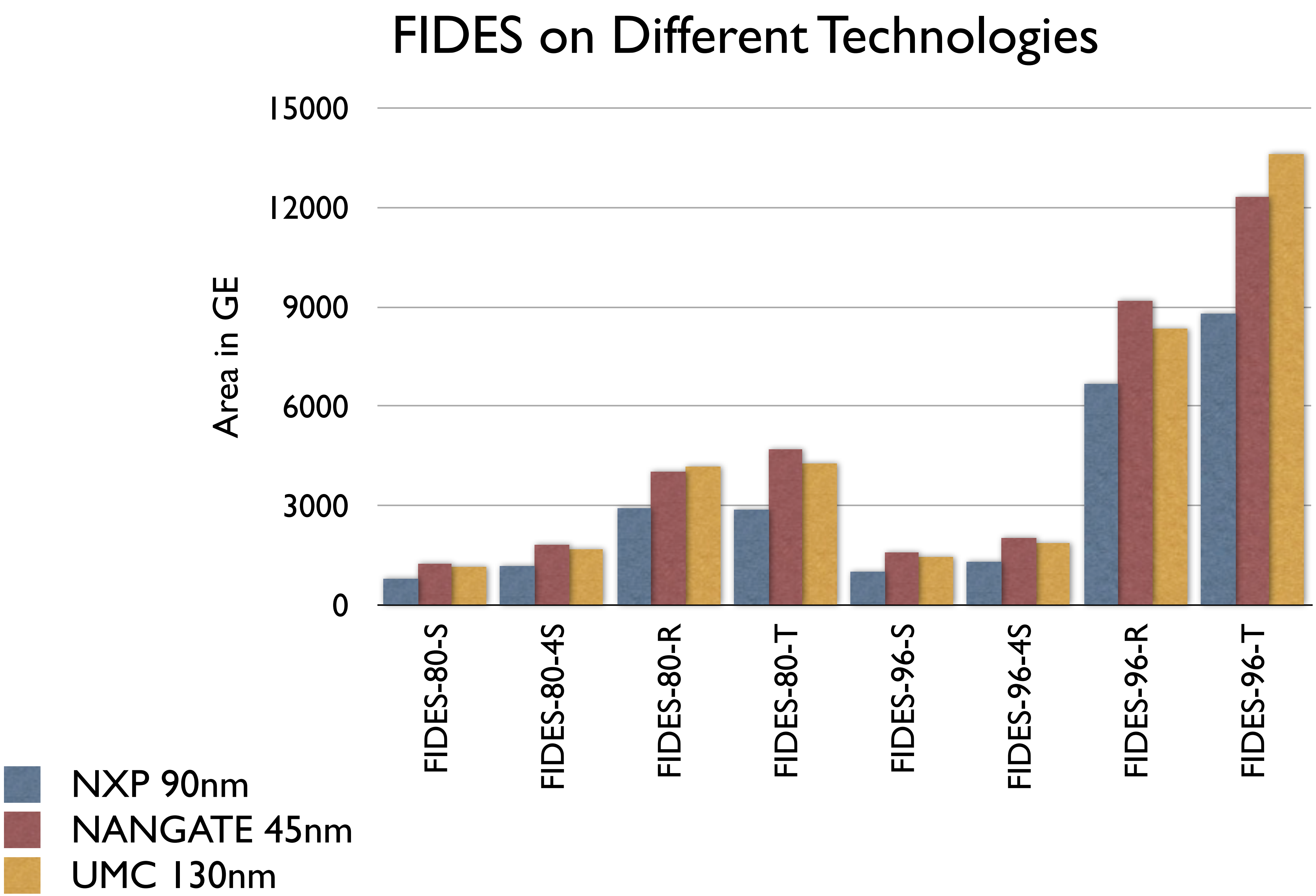
Performance



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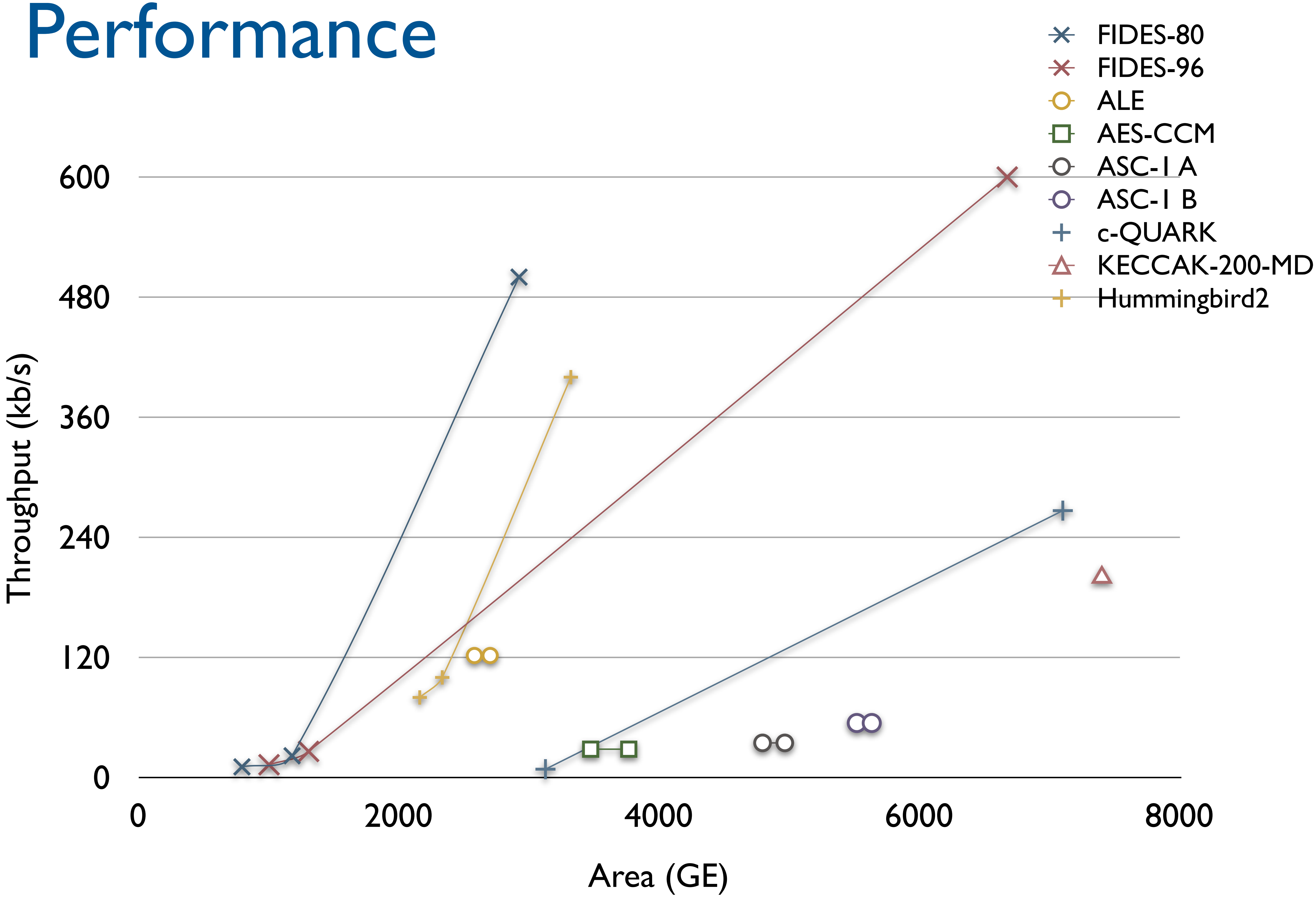

Conclusion

FIDES

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FIDES

- Lightweight AE
  - less than 1500GE
  - online, single-pass

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- with Side Channel Resistance
  - TI less than 5000 GE

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FIDES

- Lightweight AE
  - less than 1500GE
  - online, single-pass
- with Side Channel Resistance
  - TI less than 5000 GE
- and 80-bit or 90-bit security
  - AB and APN permutations
  - almost MDS

THANK YOU!