SPARX: A Family of ARX-based Lightweight Block Ciphers with Provable Bounds

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https://www.cryptolux.org

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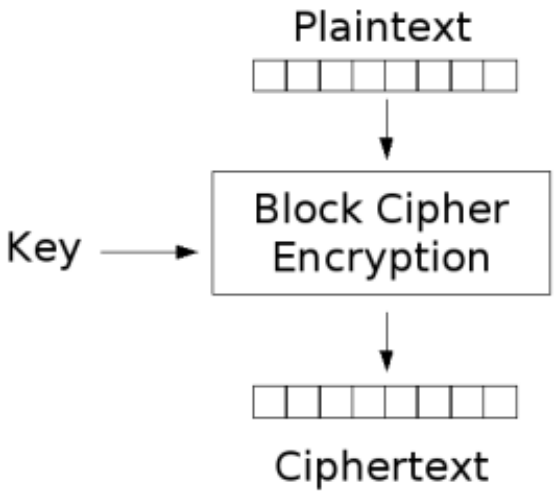
(FELICS framework, block ciphers with key size at least 128 bits)

Outline

Plan

Block Ciphers



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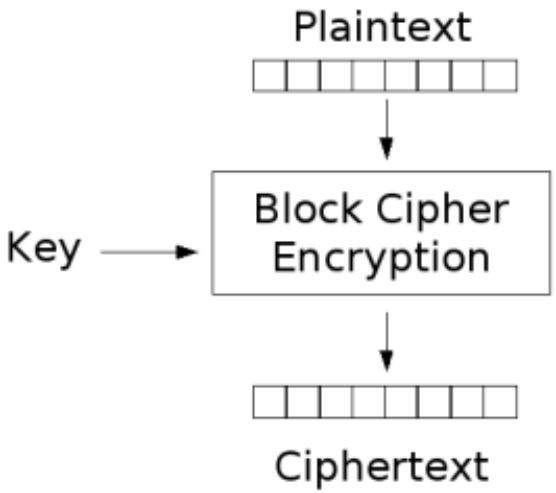

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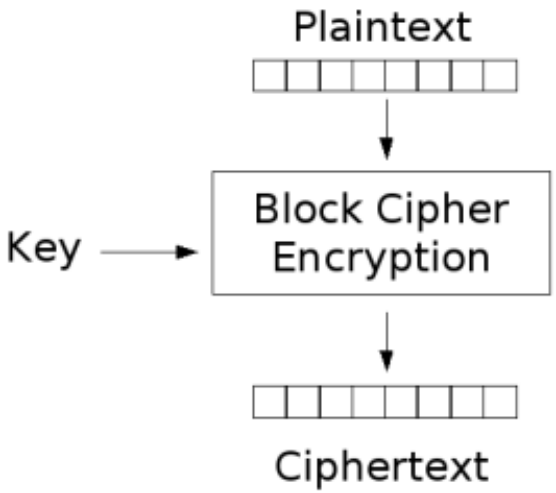

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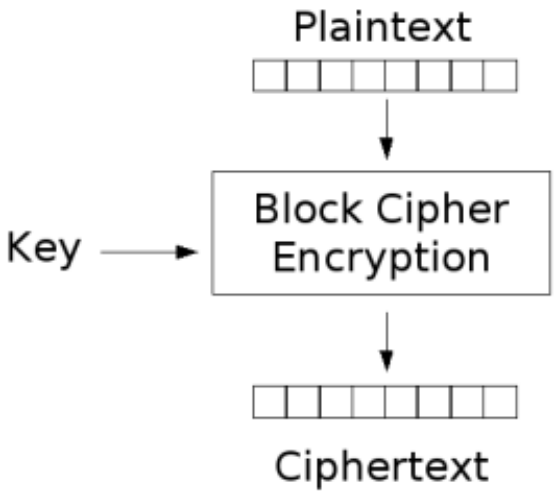

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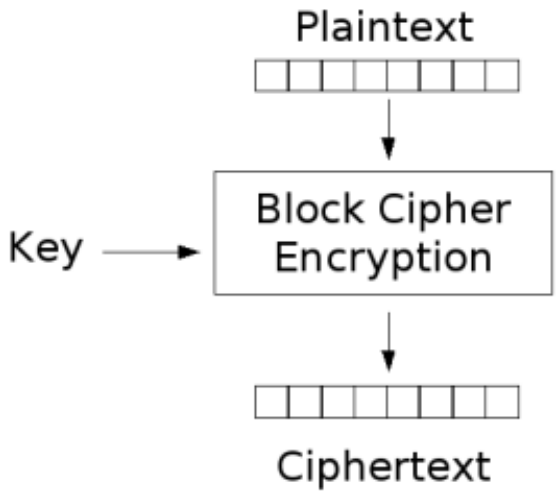

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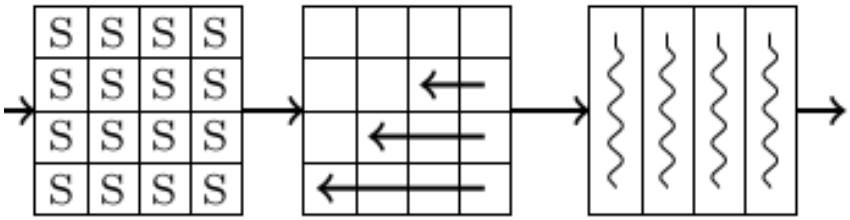
4. $\Rightarrow$ BC is the weakest part.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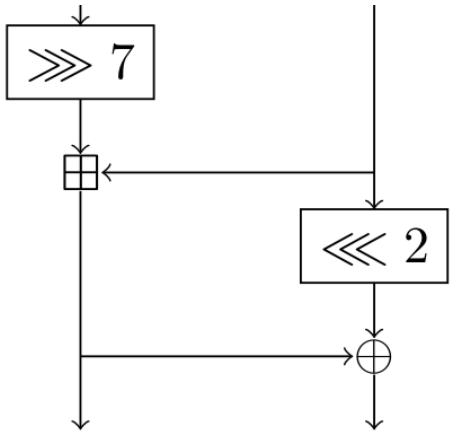
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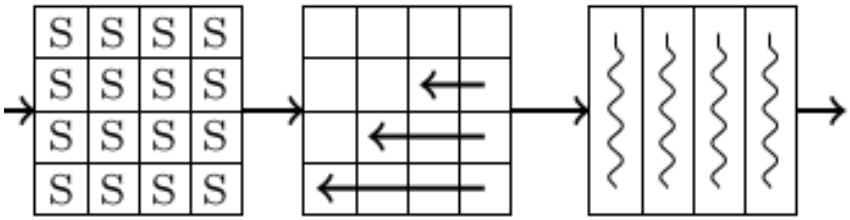
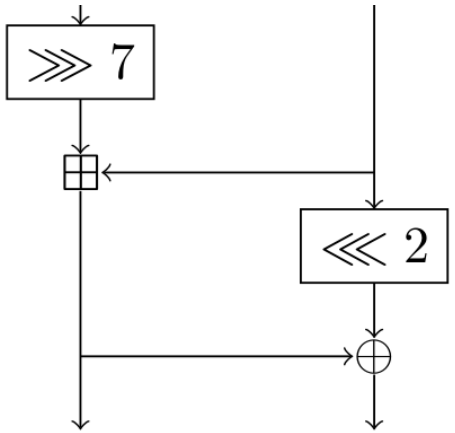




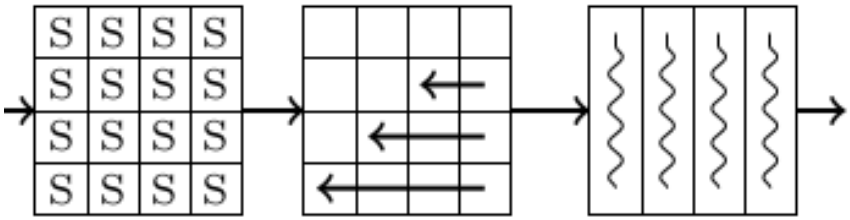
S-Box Based

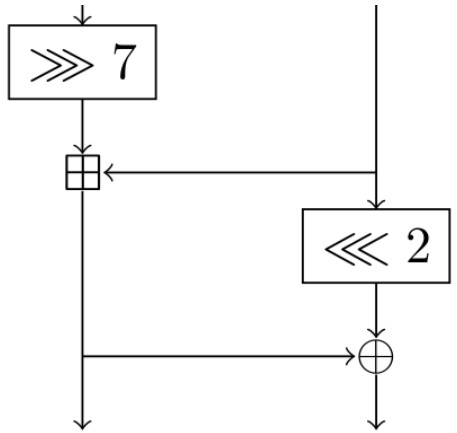
Pros.

- Easy security argument (*wide trail strategy*).

Cons.

- Might store "big" table.
- Vulnerable to side-channel attacks.





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ARX Based

Pros.

- Lightweight implementations.
- Less vulnerable to side-channel attacks.

Cons.

- Security hard to justify.

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Substitution-Permutation, **ARX**-Based $\Longrightarrow$ **SPARX**

Plan

High Level View

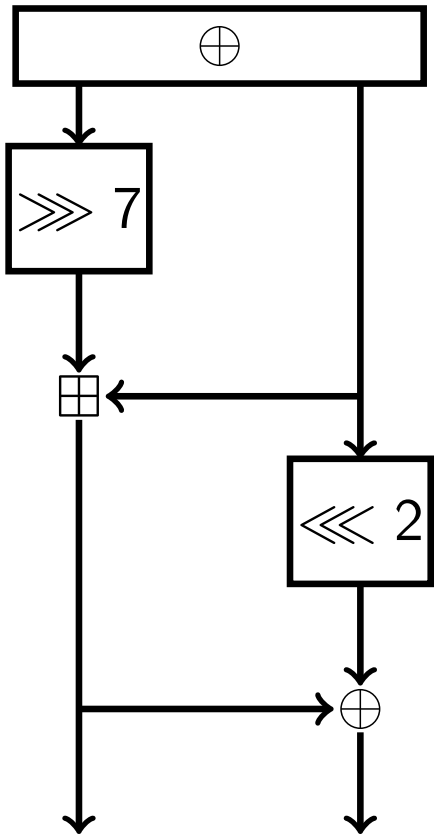
SPARX family of block ciphers

- Designed using a long trail strategy (our contribution).
- 64 or 128 bit **block**, 128 or 256 bit **key**.
- Only 16-bit operations: $\lll i$, $\oplus$, $\boxplus$.

ARX-Boxes

SPECKEY

1. Start from SPECK-32
2. XOR key in full state (Markov assumption)
3. Find best trails



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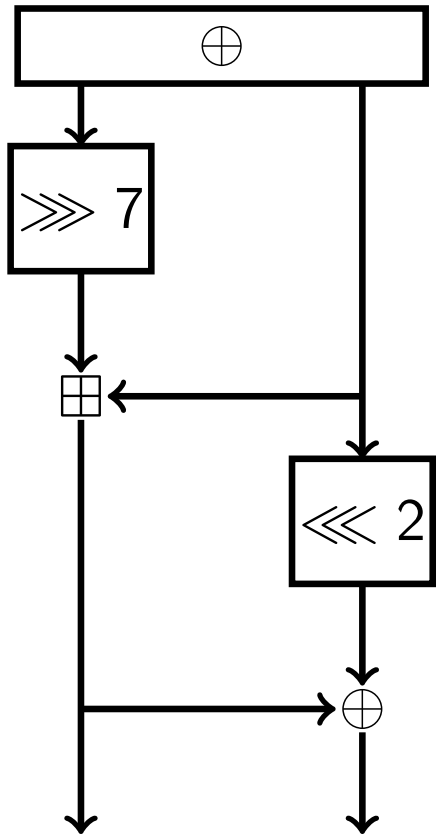
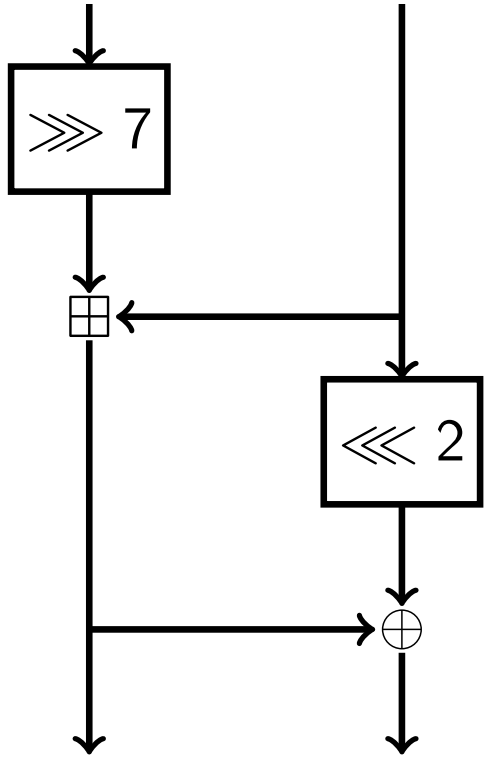
Parameter Search

- Rotations $7, -2$
- Second best crypto properties, lightest
- NSA design strategy?



SPECKEY

Notations



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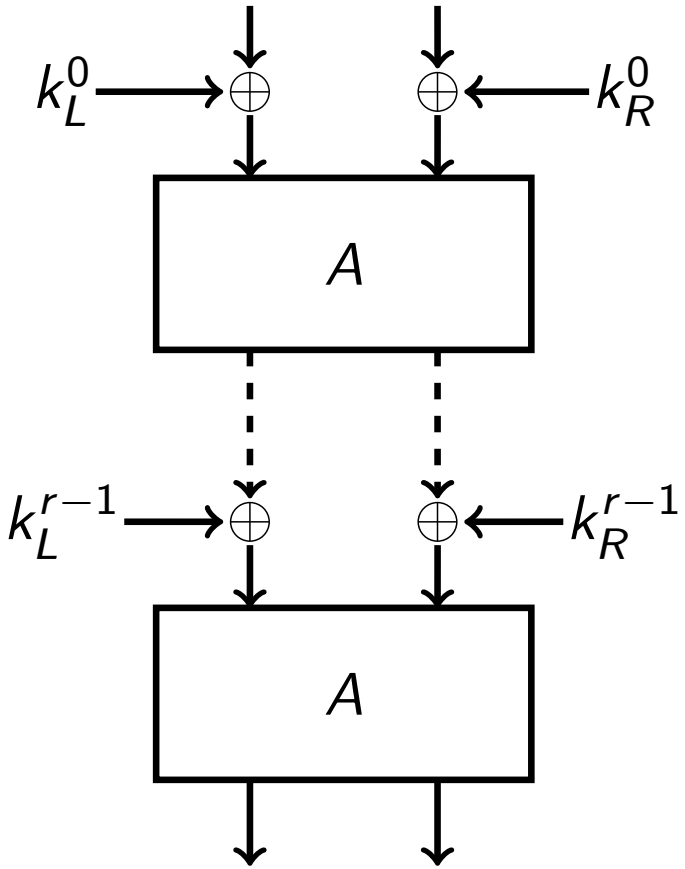

A_k^r

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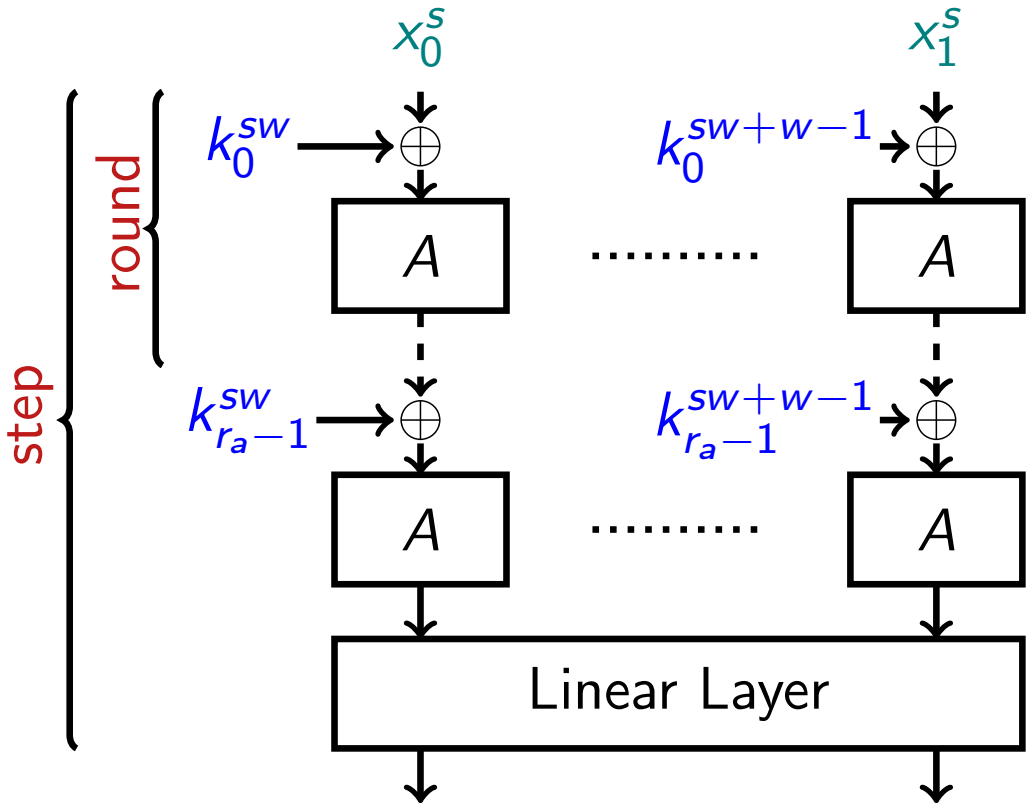
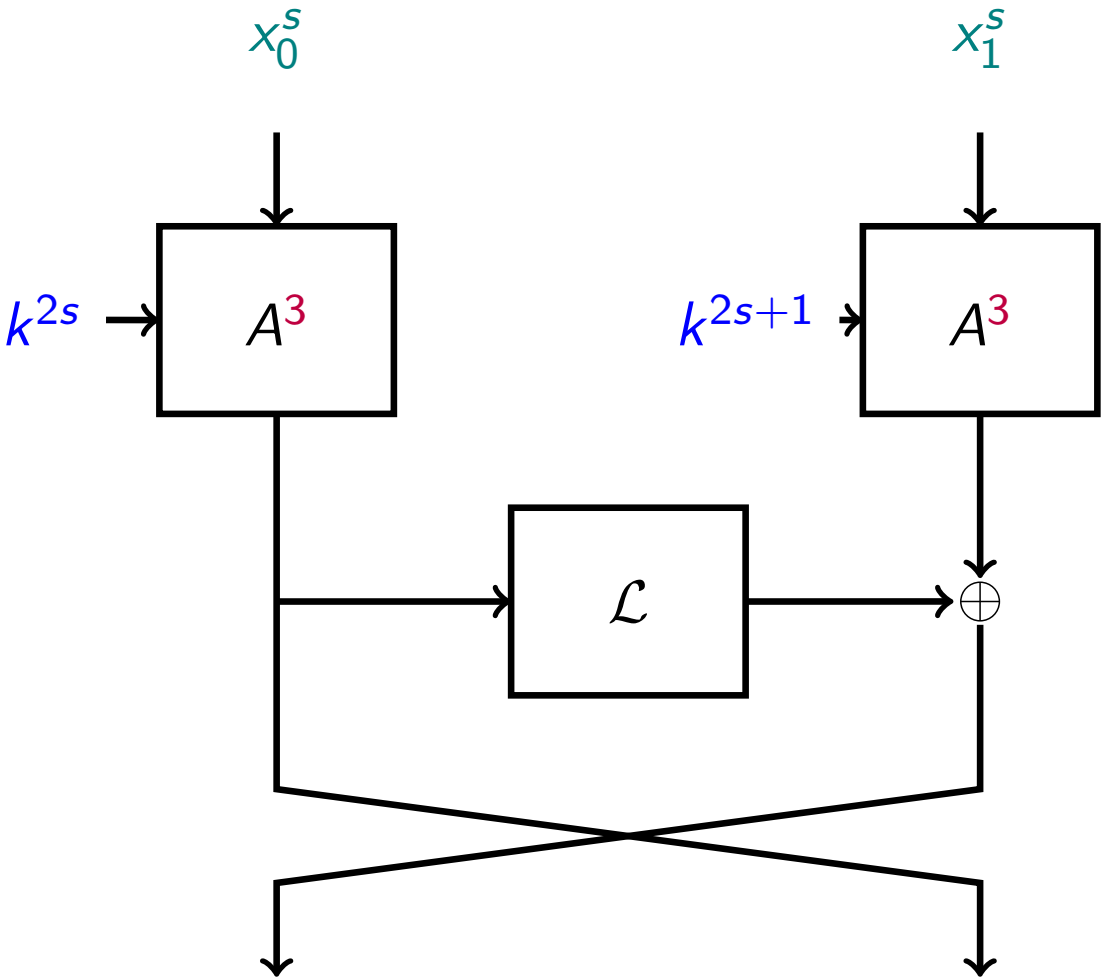
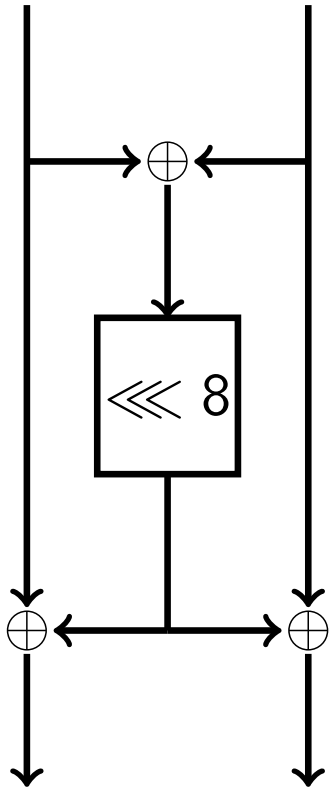


Round function of SPARX.

SPARX-64/128

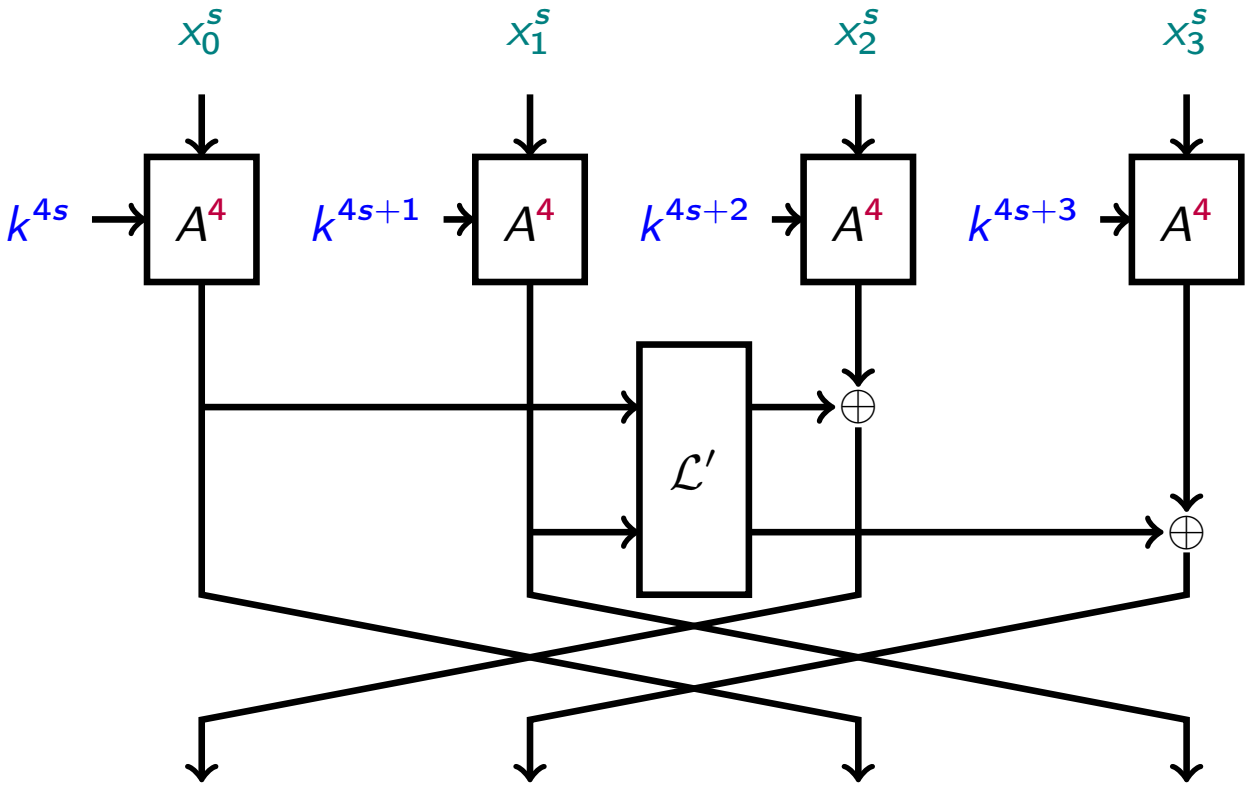


Step Function.



$\mathcal{L}$.

SPARX-128/128 and SPARX-128/256



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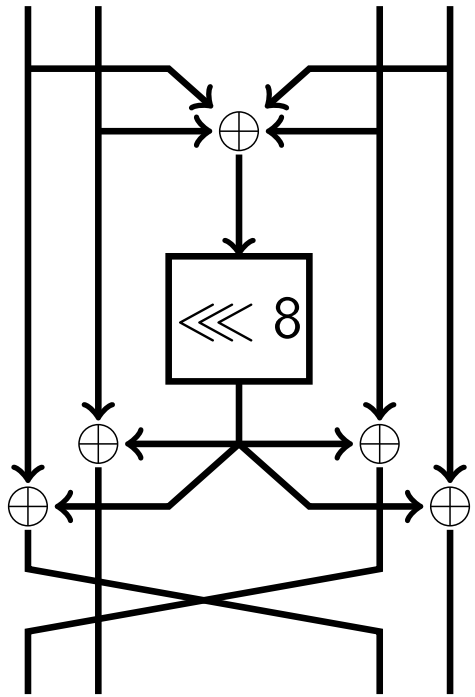

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n/k	64/128	128/128	128/256
rounds attacked/total	15/24	22/32	24/40
security margin	38 %	31 %	40 %

"Attack" means recovering secret key faster than exhaustive search.

Plan

Benchmarking

`https://www.cryptolux.org/index.php/FELICS`

- **F**air **E**valuation of **L**ightweight **C**ryptographic **S**ystems
- 8-bit ATMEL AVR ; 16-bit TI MSP ; 32-bit ARM Cortex-M3
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- Figure Of Merit aggregates: all metrics accross all platforms for the best implementations of one algorithm.

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Gray: designers did not provide differential/linear bounds.

Flexibility of the Implementation

Implem.	Block size [bits]	AVR			MSP			ARM		
		Time [cyc.]	Code [B]	RAM [B]	Time [cyc.]	Code [B]	RAM [B]	Time [cyc.]	Code [B]	RAM [B]
1-step ro	64	1789	248	2	1088	166	14	1370	176	28
1-step un		1641	424	1	907	250	12	1100	348	24
2-steps ro		1677	356	2	1034	232	10	1331	304	28
2-steps un		1529	712	1	853	404	8	932	644	24
1-step ro	128	4553	504	11	2809	300	26	3463	348	44
1-step un		4165	1052	10	2353	584	24	2784	884	40
2-steps ro		4345	720	11	2593	432	18	3399	620	40
2-steps un		3957	1820	10	2157	1004	16	2377	1692	36

"ro": rolled ; "un": unrolled.

Plan

Conclusion (1/2)

The SPARX ciphers are:

1. lightweight and SCA-secure as ARX-based ciphers,
2. provably secure against some attacks as SPNs (the first!),
3. flexible: different implementation trade-offs are possible.

Conclusion (2/2)

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