An Analysis of the Post Quantum and Classical Security of 4x4 and 16x4 S-Boxes and Their Implementations in Simplified-AES

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Abstract. Grover's algorithm is a quantum searching algorithm that poses a threat to symmetric cryptography. Due to their smaller key sizes, lightweight cryptographic algorithms such as Simplified-AES face a much more immediate threat from Grover's algorithm than traditional cryptographic algorithms. By analyzing different S-boxes, it was discovered that the S-box 946C753AE8FBD012 may be more quantum resistant than the S-box that Simplified-AES uses, 94ABD1856203CEF7. In addition to this, 16x4 S-boxes (or 4 4x4 S-boxes) showed to be significantly more quantum secure than 4x4 S-boxes. This is because the number of gates needed to model a 2^nx4 S-box increases at an exponential rate. It was also found that this property extends to 2^nx8 S-boxes, implying the existence of a more quantum secure 8x8 S-box that AES could use. However, an increase in quantum security does not equate to an increase in classical security, as some of the least quantum secure S-boxes analyzed displayed some of the best classical security. Finally, an alteration of Simplified-AES that used a 16x4 S-box was found that displayed better classical and quantum security than Simplified-AES and did not require an increase in key size.

Keywords: Grover's Algorithm, 16x4 S-box, Simplified-AES, Quantum Security

1 Introduction

Grover's algorithm is a quantum searching algorithm able to find values in $\sqrt{N}$ steps, where N is the amount of unstructured data being searched. This differs from classical algorithms which need to make an average of $\frac{N}{2}$ checks [20]. It can be used to perform brute force attacks to determine the key used in a symmetric encryption algorithm. To do this, one must implement the encryption algorithm used on a quantum computer. As such, the quantum cost of such an implementation directly impacts the cost of Grover's algorithm, wherein quantum cost refers to the number of gates needed to model said implementation.

This is especially true regarding lightweight cryptography. Lightweight cryptography is a branch of cryptography that aims at enabling devices with limited resources to perform cryptography. This is because many Internet of Things (IoT) devices have limited memory, power, and processing speed that can be dedicated to performing cryptographic algorithms [21]. Lightweight cryptography has become increasingly prevalent given the rise of IoT devices. In 2021 there were 11.28 billion IoT devices, and this figure is predicted to reach 29.42 billion by 2030 [22].

Given the limited resources, lightweight cryptography uses smaller keys than standard encryption algorithms. Not only does this reduce the security of lightweight cryptographic algorithms, but these algorithms will be the first algorithms that Grover's algorithm may pose a threat to. IonQ is currently working on IonQ Forte, a quantum computer with 32 quantum bits (qubits) [19], which is enough qubits to perform an attack via Grover's algorithm on Simplified-AES (S-AES). It is because of this that lightweight cryptographic algorithms should be limited to ephemeral data with a short lifespan. As such, even minor increases in the security of lightweight cryptographic algorithms are greatly beneficial.

One aspect of symmetric encryption algorithms that can be modified is the construction and implementation of substitution boxes (S-boxes). These are precomputed tables that map an input value to an output value. This paper analyzes how the construction of an S-box impacts its respective quantum cost, and if the use of multiple variably assigned S-boxes provides better quantum security against Grover's algorithm.

1.1 Methodology

The original plan was to modify the S-box used in S-AES and perform a brute force attack on this modified version of S-AES via Grover's algorithm. S-AES is a lightweight cryptographic algorithm whose structure is identical to AES. It has a key and block size of 16-bits and has two rounds [13].

This would be achieved by modifying the work done by Kyung-Bae Jang, Gyeong-Ju Song, Hyun-Ji Kim, and Hwa-Jeong Seo in a paper entitled "Grover on Simplified AES". This paper managed to create an efficient quantum implementation of S-AES that only used 32 qubits for a 16-bit plaintext and 16-bit key. A tool called LIGHTER-R was used to generate the quantum circuit for the S-box that did not require the use of any ancilla qubits [5].

LIGHTER-R was originally going to be used to generate the quantum circuits for the modified S-boxes which would then replace the substitution circuit and be run through Grover's algorithm. IBM Quantum (IBMQ) would be used in conjunction with Qiskit to model these results. However, LIGHTER-R produced inconsistent results that could not be replicated. In addition to this, memory constraints prevented the modified versions of S-AES from being run in Qiskit. As such, SageMath was used to generate the algebraic normal form (ANF) of various S-boxes which was then used to create a quantum circuit for said S-box. Grover's algorithm was then used to perform a known plaintext attack on a quantum circuit that XOR-ed a key with a plaintext before running said plaintext through the S-box. A known plaintext attack was performed instead of a brute force attack because it required less resources to simulate.

Afterwards, three possible full implementations of S-AES that use 16x4 S-boxes were tested. This was proceeded by classical analysis performed through the National Institute of Standards and Technology (NIST) statistical test suite on said algorithms and modified versions of S-AES that use different S-boxes. This process was then repeated on implementations using the three 16x4 randomly generated S-boxes that required the most quantum gates to model.

2 S-Box Construction

Four sets of four S-boxes were created. They were broken into these groups because a 16x4 S-box would also be tested that consisted of each S-box in the set. This S-box would use two bits from the provided key to determine which S-box would be used on the plaintext. The first set of S-boxes were created using the same methodology as the S-boxes from S-AES and AES. They served as the base set of S-boxes that the other sets would modify to meet various criteria.

The S-box that S-AES uses was generated by inverting values as an element of GF(2^4) using the prime polynomial $x^4 + x + 1$. These values were then multiplied by a matrix and had a vector added to them. This produces the equation below, wherein b_n is the nth bit of the inverted input [13].

$$\begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} b_0 \\ b_1 \\ b_2 \\ b_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

This process was used to create each of the S-boxes in the first set of S-boxes, with the prime polynomials used being $x^4 + x + 1$ (i.e., the S-box that S-AES uses), $x^4 + x^3 + 1$, and $x^4 + x^3 + x^2 + x + 1$. Since there are only three prime polynomials in GF(2^4), the fourth S-box was generated using a rotated matrix and the prime polynomial $x^4 + x + 1$. The 16x4 S-box formed from Set 1 can be seen in Table 2.

The second set that was created aimed at analyzing S-boxes that produced a unique output for any given input. This was achieved by progressively shifting each S-box in the first set of S-boxes to the left. Afterwards, repeat occurrences of an output for any given input were swapped with the next value in the S-box that would not cause a collision.

The third set aimed at analyzing S-boxes that had no collisions with the input, i.e., no output values are identical to the input values. This was done by taking the first set of S-boxes and swapping any values that resulted in a collision with the next value in the S-box that would not cause said collision. Finally, the fourth set of S-boxes aimed at analyzing S-boxes that had no collisions with each other or the plaintext. This was generated by repeating this process on the second set of S-boxes. The resulting set of S-boxes can be seen in Table 1.

Table 1: Sets 1-4

	S-Box 1	S-Box 2	S-Box 3	S-Box 4
Set 1	94ABD185 6203CEF7	940756EB FD1C2A83	946C753A E8FBD012	9E518BDA 67F3C402
Set 2	94ABD185 6203CEF7	40756EBF D1C2A839	6C573AE8 FBD01294	18BDA673 CF4920E5
Set 3	94ABD185 6203ECF7	940756EB FD1C2A83	946C735A E8FDB012	9E518BDA 67F34C02
Set 4	94ABD185 6203ECF7	40756EBF D1C2A839	6C573AE8 FBD01294	18BDA673 CF49205E

2.1 S-Box Quantum Circuit Construction

It is possible to express an S-box as a series of polynomials, or their ANF. This can be used to reduce the quantum cost needed to perform Boolean functions on a quantum computer [4]. SageMath was used to calculate the ANF of each S-box. The ANF of S-box 1 of Set 1 is depicted below, with y_n being the nth output bit and x_n being the nth input bit. The ANF of the other S-boxes can be found in Appendix A.

$$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3 \oplus 1$$
$$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3$$
$$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$$
$$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3 \oplus 1$$

This can be converted to a quantum circuit by using a multi-controlled X (MCX) gate whose target is the register y_n and whose controls are the registers in $\{x_0, \ldots, x_n\}$. The controls for each MCX gate are dictated by which x values are being multiplied together. Doing this for the equation above results in the quantum circuit depicted in Figure 1.

Table 2: 16x4 S-box formed by Set 1

	0b000000	0b000001	0b000010	0b000011
0b000000	0x9	0x4	0xA	0xB
0b000100	0xD	0x1	0x8	0x5
0b001000	0x6	0x2	0x0	0x3
0b001100	0xC	0xE	0xF	0x7
0b010000	0x9	0x4	0x0	0x7
0b010100	0x5	0x6	0xE	0xB
0b011000	0xF	0xD	0x1	0xC
0b011100	0x2	0xA	0x8	0x3
0b100000	0x9	0x4	0x6	0xC
0b100100	0x7	0x5	0x3	0xA
0b101000	0xE	0x8	0xF	0xB
0b101100	0xD	0x0	0x1	0x2
0b110000	0x9	0xE	0x5	0x1
0b110100	0x8	0xB	0xD	0xA
0b111000	0x6	0x7	0xF	0x3
0b111100	0xC	0x4	0x0	0x2

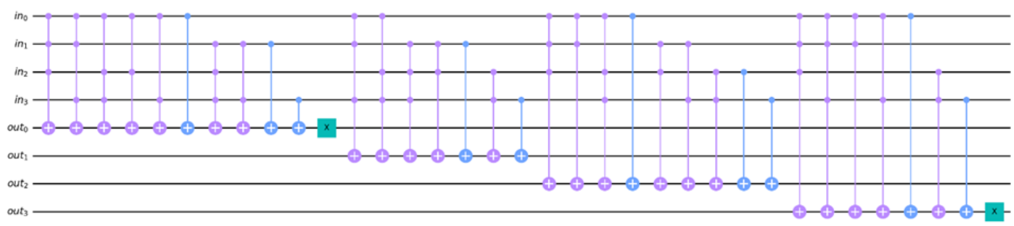

Figure 1: Quantum circuit for S-box 1 of Set 1 (94ABD1856203CEF7)

3 Quantum Cost of S-Boxes

Quantum particles must be trapped in a low energy state to allow the performance of meaningful operations. Reducing the number of gates needed for a quantum algorithm reduces the cost of performing said algorithm, as it reduces the number of necessary quantum computations and therefore the time atoms need to stay in a specific state. This is important as it reduces the likelihood of the occurrence of decoherence. Decoherence can cause a spin flip of quantum particle and can cause trapped atoms to be excited into higher vibrational modes [16].

Table 3 depicts the resulting cost of the quantum circuit for the ANF of each S-box. It lists the number of MCX gates with n controls. An MCX gate with 0 controls is equivalent to an X gate. Table 4 depicts the cost of a 16x4 S-box generated from each set. It should be noted that the quantum circuits depicted in Table 3 require 8 qubits, while the circuits in Table 4 require 10 qubits. This is because a 16x4 S-box requires 2 additional bits to determine what S-box should be used. It should also be noted that using a rotated matrix to generate S-box 4 in Set 1 had no impact on the cost of performing said S-box.

3.1 Analyzing Quantum Cost of Random S-Boxes

This process was repeated on a set of 1,500 randomly generated 4x4 S-boxes and a set of 800 randomly generated 16x4 S-boxes. Table 5 and Table 6 list the MCX gates needed

Table 3: Cost of each S-box in Sets 1 through 4

MCX Controls	Set 1 S-Box 1	Set 1 S-Box 2	Set 1 S-Box 3	Set 1 S-Box 4	Set 2 S-Box 1	Set 2 S-Box 2	Set 2 S-Box 3	Set 2 S-Box 4
0	2	2	2	2	2	1	2	1
1	10	9	13	10	10	6	8	10
2	12	14	19	12	12	11	13	14
3	11	7	7	11	11	6	6	7
Total Gates	35	32	41	35	35	24	29	32
MCX Controls	**Set 3 S-Box 1**	**Set 3 S-Box 2**	**Set 3 S-Box 3**	**Set 3 S-Box 4**	**Set 4 S-Box 1**	**Set 4 S-Box 2**	**Set 4 S-Box 3**	**Set 4 S-Box 4**
0	2	2	2	2	2	1	2	1
1	10	9	13	10	10	6	8	10
2	11	14	17	11	11	11	13	14
3	10	7	7	10	10	6	6	6
Total Gates	33	32	39	33	33	24	29	31

Table 4: Cost of each 16x4 S-box formed by Sets 1 through 4

MCX Controls	Set 1	Set 2	Set 3	Set 4
0	2	2	2	2
1	10	17	10	17
2	22	26	21	25
3	48	39	45	38
4	27	32	25	33
5	10	10	8	12
Total Gates	119	126	111	127

to run the 3 most costly randomly generated 4x4 and 16x4 S-boxes respectively. The 16x4 S-boxes were created by combining 4 randomly generated 4x4 S-boxes. A list of all the S-boxes generated and their associated costs can be found in Appendix B.

The most expensive randomly generated 4x4 S-box was 7FAC98B234516D0E, which required the same number of gates as the most expensive 4x4 S-box generated by hand (946C753AE8FBD012). The most expensive 16x4 S-box that was generated by hand was formed from Set 4, requiring 127 gates. However, the randomly generated S-box CB91D538E7A20F64A217C6534D8EBF09D14A58BF792C630E58B214C790E6DFA3 required 150 gates. This is approximately 3.659 times more gates than the most expensive 4x4 S-box found, and an increase of 23 gates compared to the 16x4 S-box generated from Set 4.

It should be noted that all the 16x4 S-boxes depicted in Table 6 were more expensive than the hand generated 16x4 S-boxes depicted in Table 4. This is even though each 16x4 S-box in Table 6 had at least one collision with the input, and at least one collision between the different 4x4 S-boxes used to generate the 16x4 S-box. This implies that reducing these collisions in 16x4 S-boxes does not increase said S-box's quantum security.

Table 5: Cost of the 3 most expensive randomly generated 4x4 S-boxes

	S-Box		
MCX Controls	7FAC98B234516D0E	FD8716ABCE459320	C2BA7FD51408E396
0	3	4	2
1	8	9	12
2	19	14	15
3	11	13	11
Total Gates	41	40	40

Table 6: Cost of the 3 most expensive randomly generated 16x4 S-boxes

	S-Box		
MCX Controls	CB91D538E7A20F64 A217C6534D8EBF09 D14A58BF792C630E 58B214C790E6DFA3	70812A3B496DCEF5 89C62357BA4ED01F 841CEAB73265DF09 0386F4127B95ECAD	6A543D18EC27F09B 9ADC7F3E502816B4 FC1BE0568A423D79 309C7BA2D8F4E651
0	2	3	2
1	10	19	13
2	42	38	38
3	48	44	52
4	36	37	34
5	12	8	8
Total Gates	150	149	147

4 Using Grover's Algorithm to Perform a Known Plaintext Attack

A known-plaintext attack is an attack wherein the attacker has access to both the ciphertext and plaintext of an encryption algorithm. Such an attack aims at figuring out the key used to encrypt the plaintext [15]. Performing a known plaintext attack with Grover's algorithm is cheaper than performing a brute force attack using Grover's algorithm. This is because Grover's algorithm will only need to search through the possible values of a key as opposed to the values for both the key and the plaintext.

Using Grover's algorithm, a known plaintext attack was performed on an algorithm that XOR-es a 4-bit key to a 4-bit plaintext that is then ran through an S-box (Algorithm 1). This performs the add round key and substitution steps of round 1 of S-AES on a 4-bit block. The shift rows, mix columns, and second add round key steps were excluded due to memory and time constraints. Two different implementations of a 16x4 S-box were tested. The first implementation (Algorithm 2) used the first and last bit of the key to determine what S-box to use (acting as x_4 and x_5) and the second implementation (Algorithm 3) appended two bits to the key that determined what S-box to use (once again acting as x_4 and x_5).

These algorithms serve as a simplified single round version of S-AES that requires fewer resources to model and operates on a single plaintext block. Below is the pseudocode for these algorithms, wherein BitToInt is a function that converts a bitstream to an integer value and *sbox* is a list of values between 0x0 and 0xF that represent the S-box being used.

Algorithm 1

```
Input: bitstream[4] pt, bitstream[4] key, list[16] sbox
bitstream[4] ct
i = 0
while i < 4 do
    ct[i] = pt[i] ⊕ key[i]
    i = i + 1
end while
ct = sbox[BitToInt(ct)]
```

Algorithm 2

```
Input: bitstream[4] pt, bitstream[4] key, list[64] sbox
bitstream[4] ct
i = 0
while i < 4 do
    ct[i] = pt[i] ⊕ key[i]
    i = i + 1
end while
bitstream[2] b
b = [key[0], key[3]]
box = BitToInt(b) * 2^4                ▷ Which 4x4 S-box to use
ct = sbox[box+BitToInt(ct)]
```

Algorithm 3

```
Input: bitstream[4] pt, bitstream[6] key, list[64] sbox
bitstream[4] ct
i = 0
while i < 4 do
    ct[i] = pt[i] ⊕ key[i]
    i = i + 1
end while
bitstream[2] b
b = [key[4], key[5]]
box = BitToInt(b) * 2^4                ▷ Which 4x4 S-box to use
ct = sbox[box+BitToInt(ct)]
```

5 Construction of Grover's Algorithm

5.1 Oracle Construction

To construct Grover's algorithm, one must create an oracle that is used to find a desired state [20]. The oracle for a known plaintext attack on a 4x4 S-box and a known ciphertext of 1100 is depicted in Figure 2 registers key, plaintext (pt), ciphertext (ct), expected, and passed. Had LIGHTER-R been used to generate the oracle, the ciphertext register would not be necessary. This is because LIGHTER-R is able to construct quantum circuits for reversible ANF representations of S-boxes that do not need an ancilla register and require fewer gates, significantly reducing the cost associated with an S-box's quantum circuit [7]. The first thing the oracle does is XOR the key register with the plaintext register. This is done by using a series of controlled-X gates on the key and plaintext registers. An S-box is then used on the plaintext and ciphertext registers, with the plaintext register acting as x_0 through x_3 and the ciphertext register acting as y_0 through y_3.

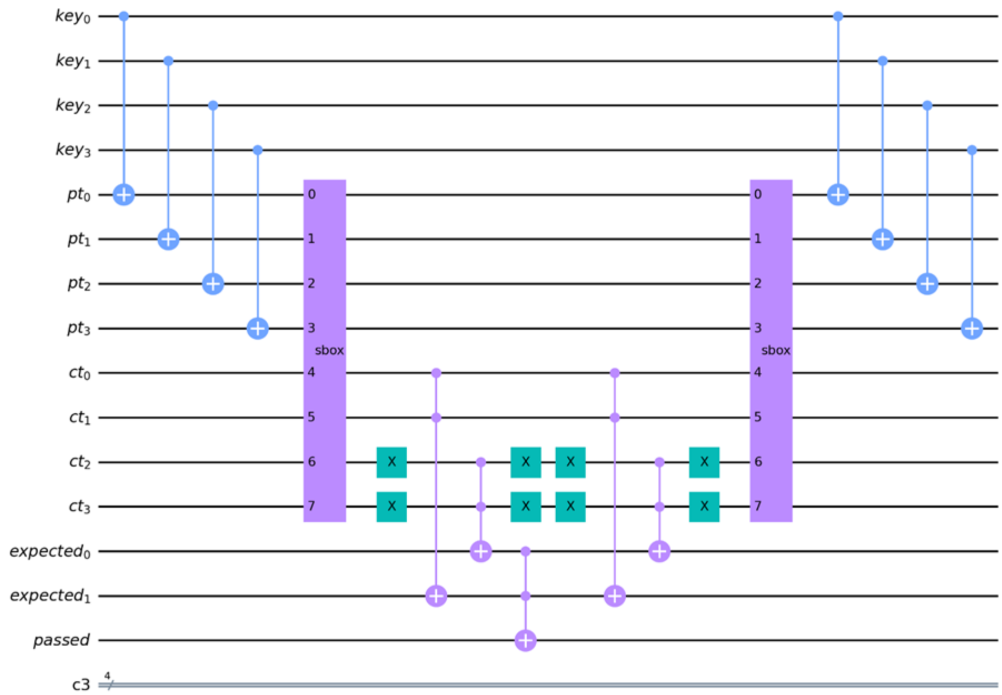

Figure 2: Quantum oracle for S-AES

The ciphertext register is then tested to see if it is in the randomly chosen state $|1100\rangle$. This is done using the 2-qubit expected register. The first qubit of this register is used to check the 0's of the ciphertext and the second qubit being used to check the 1's of the ciphertext. This is done by applying an X gate on qubits that should be in the state $|0\rangle$. A controlled-X gate is then applied, using these qubits as its control and the first qubit of the expected register as its target. It is then followed by another X gate on the ciphertext qubits in question. If the known ciphertext does not contain any zeroes, the first qubit of the expected register can either be removed or initialized to the state $|1\rangle$. Another controlled-X gate is then ran using the qubits that should be in the state $|1\rangle$ as the control, and the second qubit of the expected register being its target. If the known ciphertext does not contain any zeroes, the second qubit of the expected register can either be removed or initialized to the state $|1\rangle$.

A controlled-X gate is then run using the expected register as its control and the passed register as its target to determine if the ciphertext register is in the desired state. The process of checking the 1's and 0's of the ciphertext, running the S-box, and XORing the key with the plaintext is then repeated. Doing this sets everything back to the state they were in originally.

This process was repeated for 16x4 S-boxes. Figure 3 depicts the oracle for Algorithm 2, while Figure 4 depicts the oracle for Algorithm 3. Once again, a known ciphertext of 1100 is being looked for. As seen in Figure 4, the two additional bits of the key in Algorithm 3 are not XORed with the plaintext.

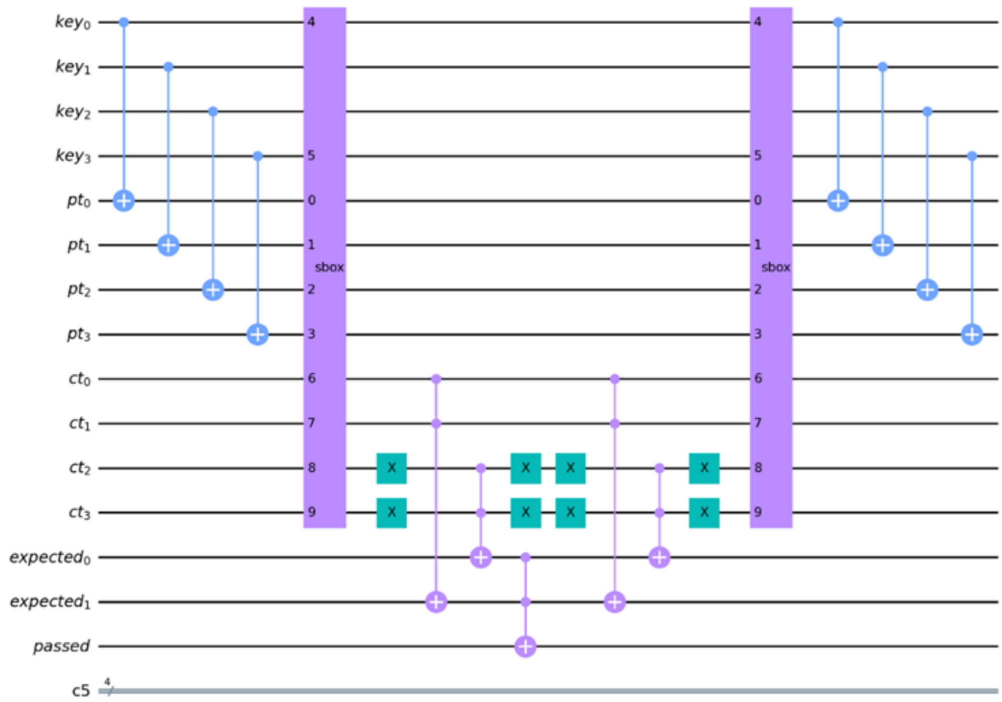

Figure 3: Quantum oracle for Algorithm 2

5.2 Assembling Grover's Algorithm

To find the 4 to 6-bit key used to generate the known ciphertext from a known plaintext, one must perform 2 searches. The plaintext register will also need to be initialized to its known value. This is done by applying a X gate on each plaintext qubit that is meant to be a $|1\rangle$. Finally, the passed register will need to be initialized to the state $|-\rangle$. An example of this is shown in Figure 5, wherein a known plaintext of 1101 is being looked for using a single 4x4 S-box. After the oracle is run, a diffuser is applied to the key register. The diffuser rotates the key register closer to the states that satisfy oracle [20].

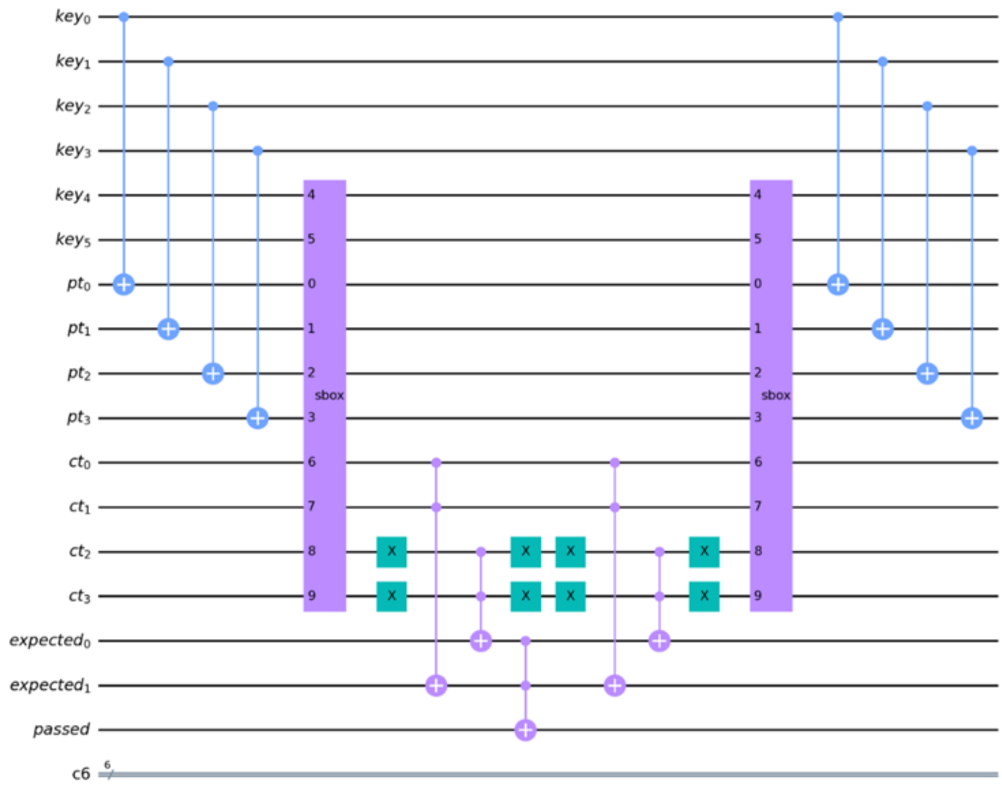

Figure 4: Oracle for Algorithm 3

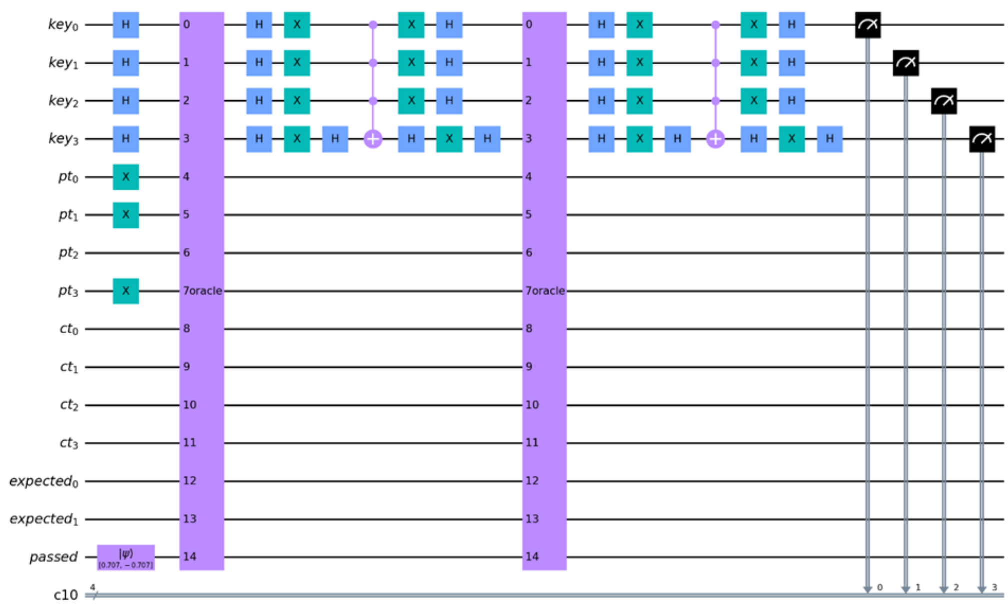

Figure 5: An example of Grover's algorithm that is looking through a 4x4 S-box to find what produces the plaintext 1101

6 Results

Table 7 lists 3 sets of randomly generated plaintext ciphertext pairs that were used to perform a known plaintext attack. Figures 6, 7, and 8 show the results of performing a known plaintext attack via Grover's algorithm on Algorithms 1, 2, and 3 respectively with the randomly generated plaintext 0110 and randomly generated ciphertext 0100. These tests were performed using Qiskit via IBMQ. These figures only depict the results of performing the attack on Set 1. The rest of the results of each of these attacks on 16x4 S-box algorithms can be seen in Appendix C. The results of a known plaintext attack on Algorithm 1 had an average of 932.146 out of 1024 shots being correct with a standard deviation of 8.636. Comparable results were present when performing this attack on Algorithm 2, having an average of 930.5 out of 1024 shots being correct with a standard deviation of 9.987. However, instead of finding only 1 valid key, it found 4. Such a result means that Algorithm 2 is unable to provide authentication.

Table 7: Randomly generated plaintext ciphertext pairs

Plaintext	Ciphertext
0000	0110
0011	1011
0110	0100

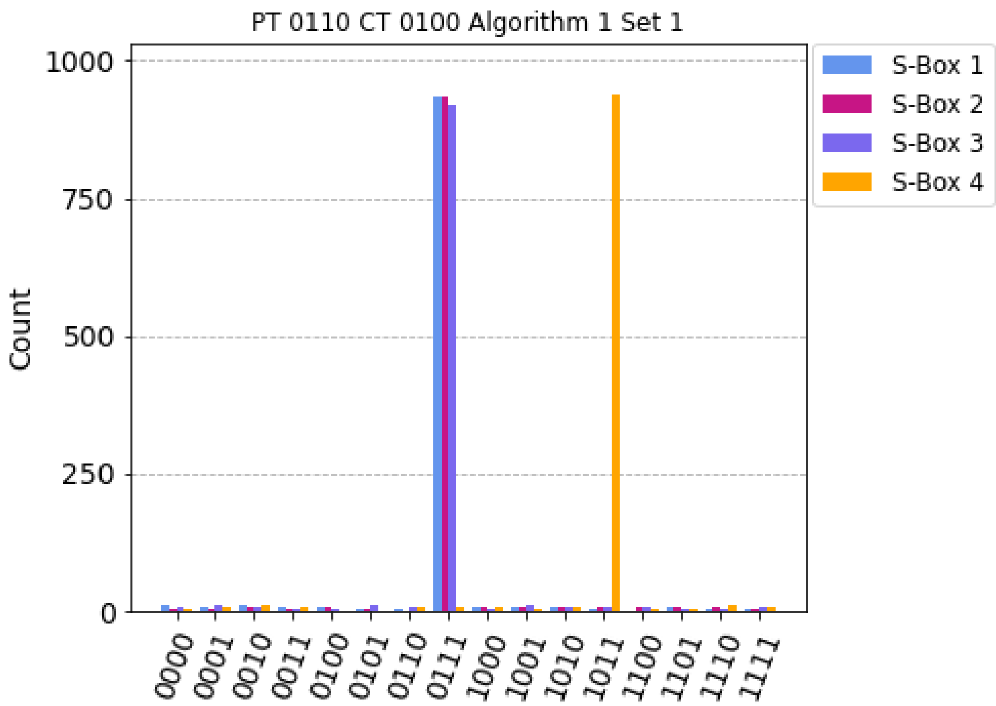

Figure 6: Results of performing a known plaintext via Grover's algorithm on Algorithm 1

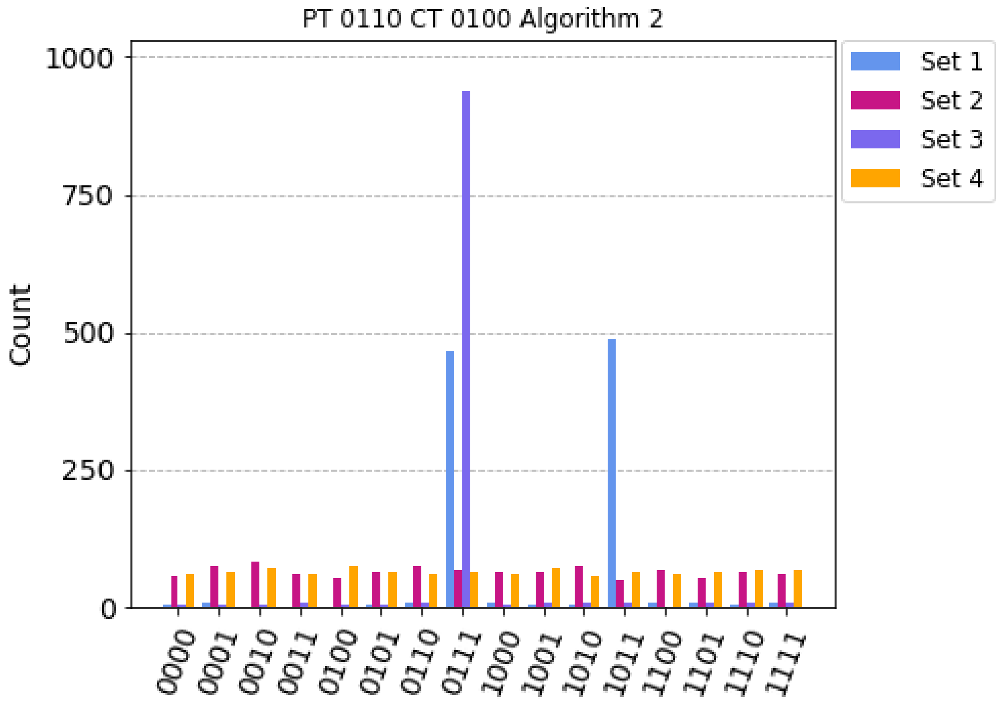

Figure 7: Results of performing a known plaintext via Grover's algorithm on Algorithm 2

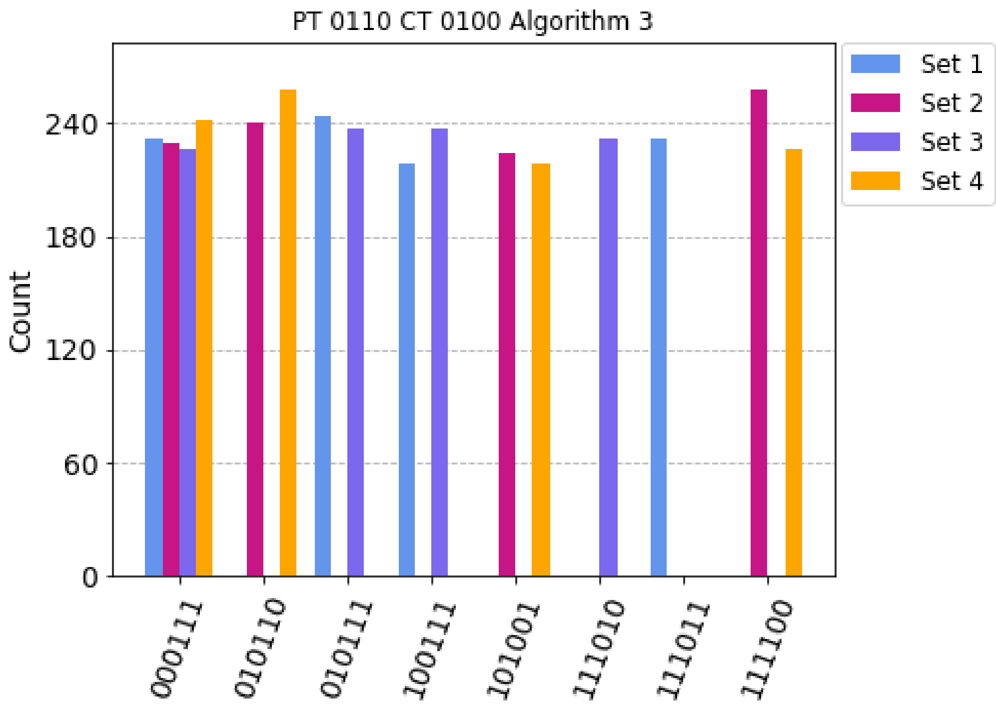

Figure 8: Results of performing a known plaintext via Grover's algorithm on Algorithm 3

6.1 Analyzing ALG 2

However, when Grover's algorithm was run on Algorithm 2, results were very inconsistent. Figure 7 best demonstrates this, as the attack only found a valid key when using the S-boxes in Set 1 and 3. Furthermore, Set 1 yielded two possible keys (0111 and 1011) while Set 3 only yielded one possible key (0111). Sets 2 and 4 did not find any valid keys because no keys exist that could produce the ciphertext 0100 from the plaintext 0110. Since the value that is XORed with the plaintext also decides which S-box to use, the plaintext will only be XORed with one of 4 values before being put through a specific S-box. Table 8 depicts what key values correlate to each S-box for any particular set.

XORing a plaintext before putting it through an S-box serves to create permutations that are computationally indistinguishable from a random permutation. To do this, a function must map each n-bit input to exactly one random n-bit output, with the input being the key XORed with a 4-bit plaintext block [23]. However, ALG 2 fails at doing this. Table 9 shows the output of Algorithm 2 using Set 1 for any given key and a plaintext of 0x0. One can see that a ciphertext of 0x4, 0x7, and 0xD are produced multiple times, while a ciphertext of 0x0, 0x5, and 0xC are never produced. As such, it fails at providing a computationally random permutation.

Table 8: Keys applicable to nth S-box in Algorithm 2

S-Box	Key			
S-Box 1	0 (0000)	2 (0010)	4 (0100)	6 (0100)
S-Box 2	1 (0001)	3 (0011)	5 (0101)	7 (0111)
S-Box 3	8 (1000)	A (1010)	C (1100)	E (1110)
S-Box 4	9 (1001)	B (1011)	D (1101)	F (1111)

Table 9: Output of Algorithm 2 when using Set 1 for any given key and a plaintext of 0x0

	S-Box 1				S-Box 2				S-Box 3				S-Box 4			
Key	0	2	4	6	1	3	5	7	8	A	C	E	9	B	D	F
CT	9	A	D	8	4	7	6	B	E	F	D	1	7	3	4	2

6.2 Analyzing Algorithm 3

In contrast, Algorithm 3 supplies a computationally random permutation since each n-bit plaintext input has an equally likely chance of being mapped to any other n-bit ciphertext. However, each ciphertext generated has 4 possible keys that could be used to decrypt it. Ideally, given a key size of n-bits, an attacker should have a $\frac{1}{2^n}$ chance of guessing the correct key. However, when Algorithm 3 is implemented, an attacker has a $\frac{4}{2^4}$ or $\frac{1}{16}$ probability of guessing the key instead of a $\frac{1}{2^8}$ or $\frac{1}{64}$ chance of guessing the key. While this does not provide ideal security, it provides the same amount of security as Algorithm 1, as an attacker would also have a $\frac{1}{16}$ chance of guessing the correct key.

It is because of this that Grover's algorithm must run the same number of times for all three algorithms evaluated. As such, the only benefit that Algorithm 3 provides is an increased cost of the oracle used to perform Grover's algorithm. As depicted in Tables 3 and 4, if Algorithm 3 was ran using Set 4, the S-box subcircuit would require 127 gates. Whereas if Algorithm 1 was ran using S-box 3 of Set 4, the S-box subcircuit would only require 24 gates.

Since each oracle subcircuit applies two S-box subcircuits, and since the oracle had to be run twice, this meant that the S-box subcircuit had to be run a total of 4 times for each known plaintext attack performed. Therefore, given the scenario outlined above, Algorithm 3 would require 412 more gates in total than Algorithm 1. In addition to this, Algorithm 3 requires 2 more qubits to perform a known plaintext attack than an attack performed on Algorithm 1. However, this increase in gates and qubits can be circumvented by just testing on a single specific S-box, i.e., by using Algorithm 1.

7 Implementation in S-AES

It might be possible to overcome the security holes present in Algorithms 2 and 3 by implementing them in the full S-AES algorithm. To do this for Algorithm 2, the S-AES algorithm was largely unmodified. The key expansion algorithm was left unchanged, using the first S-box from the set to perform the key expansion. The only step that was changed was the substitution step, wherein the previous round key was used to determine which S-box to use (i.e., W_0W_1 was used in round 1 and W_2W_3 was used in round 2 to determine which S-box to use). Figure 9 depicts this process. The high and low bits of K_0 are used to determine which S-box to use on Block 1, while the high and low bits of K_1 are used to determine which S-box to use on Block 0. This implementation will be referred to as ALG 2. It serves to perform a version of S-AES that uses a 16x4 S-box without increasing the key size.

7.1 Implementing Algorithm 3 in S-AES

Implementing Algorithm 3 in S-AES required a lot more changes to S-AES. The first thing that had to be modified was the key expansion algorithm. Key expansion in S-AES operates by breaking the 16-bit key into 4 4-bit nibbles (K_0 through K_3) that are then used to form 6 8-bit words (W_0 through W_5). These nibbles are then rotated and put through a S-box before adding the round constant g. The first round of this process is depicted in Figure 10.

To implement Algorithm 3, the key size needed to be increased to 24 bits, with these additional bits forming the nibbles K_4 and K_5. K_4 and K_5 are then used to form α_0, which determines which S-box to apply on each plaintext nibble in round 1. Before performing the key expansion, $K_0(\kappa_0\kappa_1)$ and $K_2(\kappa_2\kappa_3)$ are swapped with K_4 and K_5 to form α'_0. $\kappa_0\kappa_1$ are then used to determine which S-box to use on W_1.

α'_0 is then expanded using a process that mirrors the original key expansion algorithm used by S-AES. 2 2-bit words (ω) are formed from α'_0, with ω_0 being formed from $\kappa_0\kappa_1$ and ω_1 being formed from the rotated $\kappa_3\kappa_2$. The substitution step is skipped and ω_1 is XORed with the constant ρ (0b1000) before being XORed with ω_0 to form ω_2. ω_2 is then XORed with ω_1 to form ω_3, with $\omega_2\omega_3$ forming α_1. α_1 is then used to determine which S-box to use on each plaintext nibble in round 2. Figure 11 depicts this process.

To calculate W_5W_6, this process, excluding the key expansion of α_1, is repeated. This implementation is referred to as ALG 3 Double Swap. Another implementation was tested that did not swap K_4K_5 with K_0K_2 when calculating W_5W_6, with this implementation being referred to as ALG 3 Single Swap.

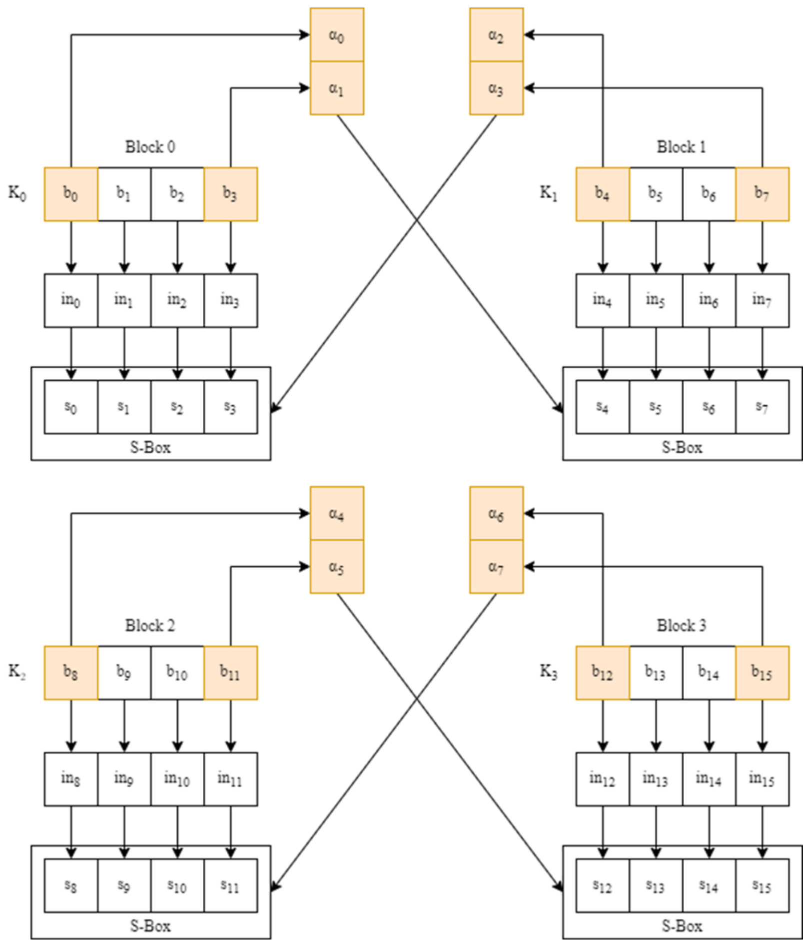

Figure 9: ALG 2

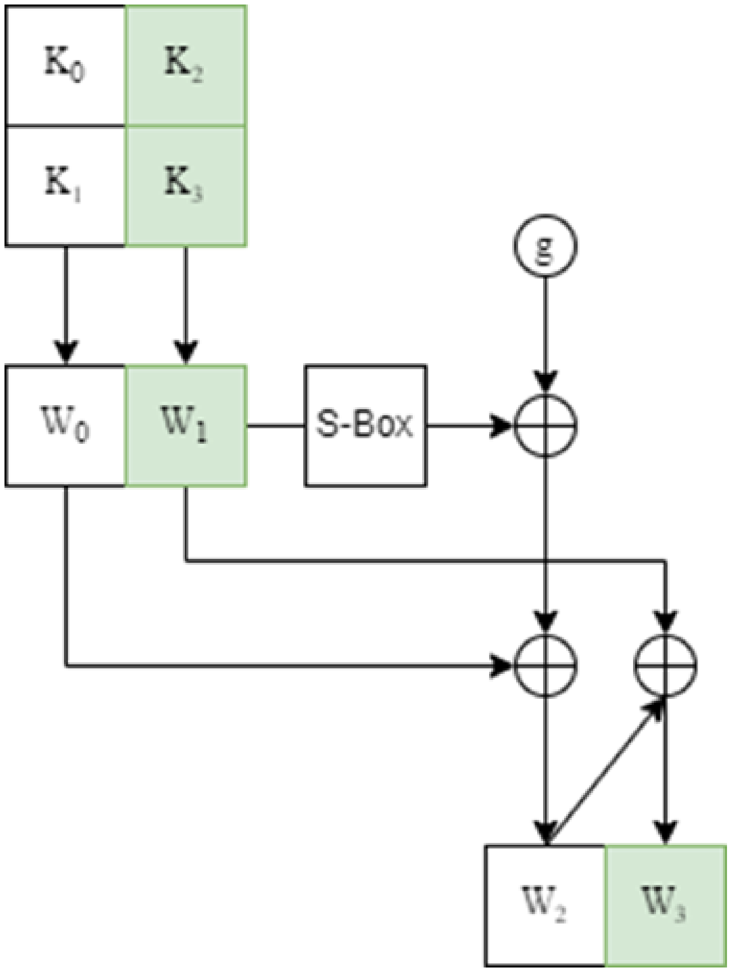

Figure 10: S-AES key expansion algorithm

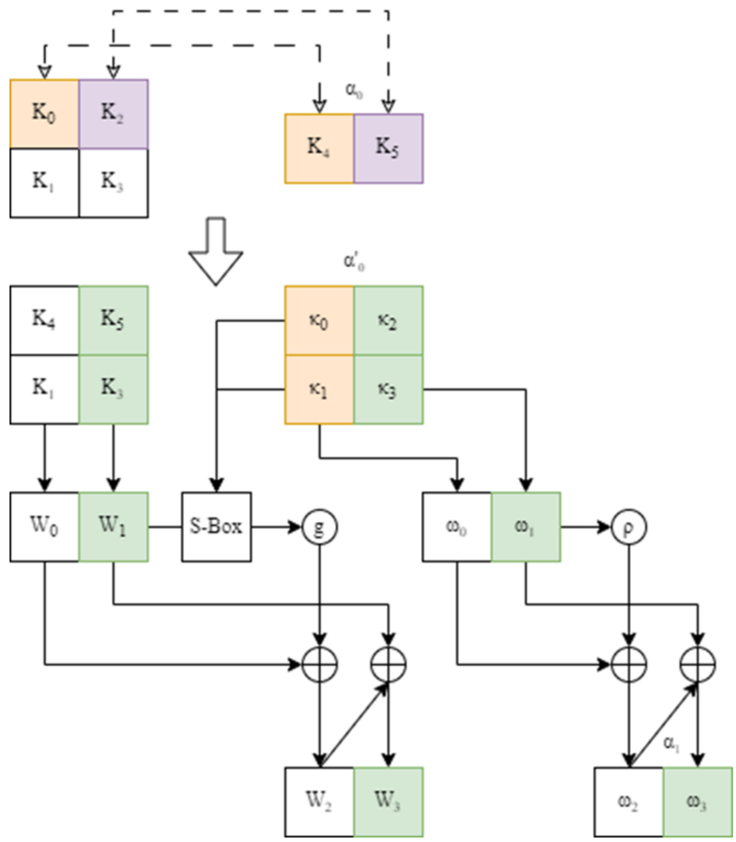

Figure 11: ALG 3

8 Analyzing Full S-AES Implementations of ALG 2 and 3

Running Grover's algorithm on these modified versions of S-AES was too resource intensive. As such, every possible key was used on 3 randomly generated plaintexts (as well as the plaintext 0x0000) to determine how many keys generated the same ciphertext given a specific plaintext. When doing this, the S-box S-AES used was always set to the first S-box of the set being tested. This was done to see how resistant each implementation was to a known plaintext attack of an unmodified version of S-AES that uses the first S-box of a 16x4 S-box.

The average results of performing this test on each set is depicted in Figures 12 and 13. Table 10 provides the average minimum, maximum, mean, median, variance, and standard deviation of these tests.

The distribution of keys that correlated to identical outputs is statistically identical between S-AES and ALG 2. They were also statistically identical between ALG 3 Double Swap and ALG 3 Single Swap. Roughly 36.76% of the possible 2^{16} 16-bit outputs (or around 24,094) could not be generated by S-AES or ALG 2. Another 36.85% of the possible outputs (or around 24,149) could only be generated with a single key. On average, each ciphertext produced by ALG 3 could be generated with 256 different keys. This is because a 24-bit key is being applied to a 16-bit plaintext block that will produce a 16-bit plaintext block.

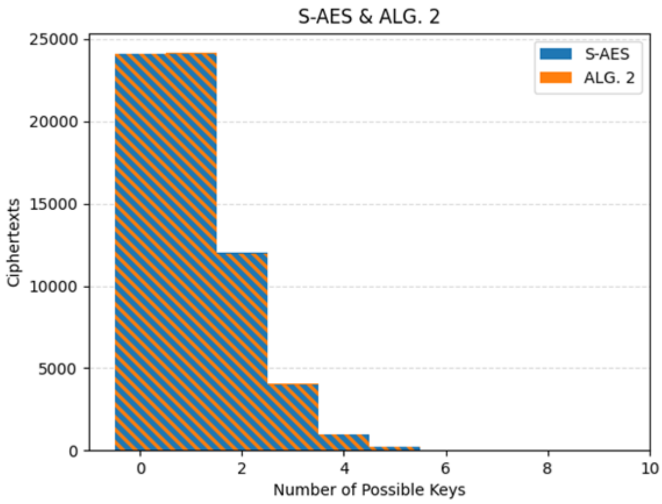

Figure 12: Key distribution of S-AES and ALG 2

8.1 Effectiveness of ALG 3 Double Swap & Alg 3 Single Swap

ALG 3 Double Swap and ALG 3 Single Swap were designed to prevent an attacker from being able to use any possible value for the additional 8 bits when attacking the algorithm. Five random ciphertexts that could be generated from the plaintext 0xD3AE with 256 possible keys were selected from ALG 3 Double Swap and ALG 3 Single Swap. Each key that could generate the ciphertext in question was then analyzed to see how many of the possible values for K_4K_5 generated said ciphertext. If all 2^8 of these values can be used, an attacker would be able to ignore these additional 8 bits.

Doing so revealed that ALG 3 Double Swap, on average, used 62.34% of the possible K_4K_5 values. Doing this on ALG 3 Single Swap had similar results, with it using an

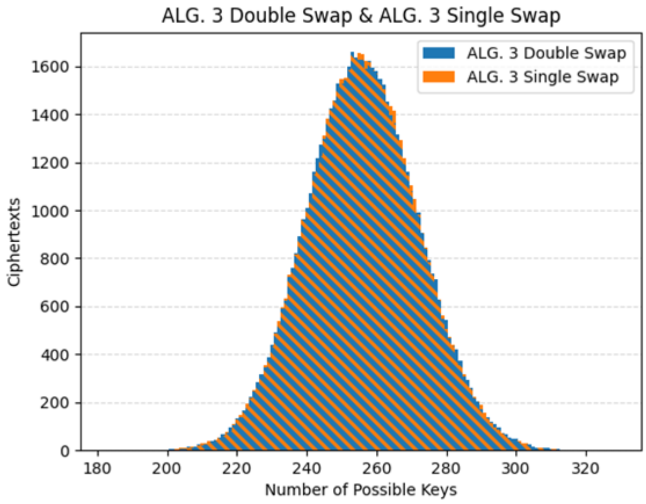

Figure 13: Key distribution of ALG 3 Double Swap and ALG 3 Single Swap

Table 10: Keys per ciphertext

	Average Minimum	Average Maximum	Average Mean	Average Median	Average Variance	Average Standard Deviation
S-AES	0	7.75	1	1	1	1
ALG 2	0	7.75	1	1	1	1
ALG 3 Double Swap	192.5	325.25	256	256	255.805	15.993
ALG 3 Single Swap	190	325	256	256	256.63	16.023

average of the 63.67% possible K_4K_5 values. This difference is most likely due to the small sample size. It is likely that repeating this test on all the ciphertexts that could be generated with 256 different keys would result in a near identical ratio between the two algorithms.

8.2 The Ability of S-AES, ALG 2, and ALG 3 to Provide Authentication

IoT devices are found in many settings such as the military, industrial, and healthcare fields. Many of these devices are required to provide confidentiality, integrity, and authentication of transmitted data. Authentication is provided using shared keys that transform a plaintext into a ciphertext, wherein the same key must be used to decrypt the ciphertext to a valid plaintext value [10]. This is especially true for IoT devices in the medical field, as the security of patient data is a top priority. Due to the various applications and benefits provided by IoT devices, the healthcare industry has been quick to adopt IoT devices [8].

Due to the distribution of keys, ALG 3 could never provide authentication. Since there will always be more keys than possible ciphertexts, there will always be more than one possible valid key that could be used to authenticate data. However, ALG 2 was equally as capable of providing authentication as S-AES was. This is because their key distributions were nearly identical.

To provide ideal authentication, each ciphertext should map to exactly one key given a specific plaintext. However, encryption algorithms can still provide authentication if they produce collisions such that it is difficult to find x values that compose of a key and plaintext that satisfy the equation $encryption(x_1) = encryption(x_n)$. This is best done with hashing algorithms but can still be performed through the use of encryption algorithms [9].

Due to the constraints of lightweight cryptographic algorithms (i.e., their limited computational costs and limited key space) any lightweight algorithm that has an x value that satisfies the above equation a collision in it would be easy to find. Seeing as there are only around 36.85% possible values of x that do not cause a collision in S-AES or ALG 2, both algorithms fail at providing adequate authentication. However, the lack of differentiation between the number of collisions amongst the two algorithms would imply that implementations of ALG 2 on algorithms such as AES would not impact their ability to provide authentication.

9 Statistical Analysis of These Implementations

One of the criteria that encryption algorithms must provide is their ability to act as random number generators [18]. NIST has provided a statistical test suite that can be used to analyze random number generators and cryptographic algorithms. It works under the null hypothesis that the sequence being analyzed is random. This test suite performs 15 tests that measure the randomness of an algorithm to produce a *P-value*. This is the probability that a test statistic will produce values that are equal to or worse than the test statistic value. A *P-value* of 1 indicates perfect randomness, while a *P-value* of 0 indicates that the sequence analyzed is completely non-random [1]. Information about each test can be seen in [1].

The implementations of ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap were analyzed using this test suite. In addition to this, versions of S-AES that used each S-box in each set of S-boxes were also analyzed. The algorithms generated 60 bitstreams of 100,000 bits each. This was done by generating 60 random 32-bit input values for the different versions of S-AES and ALG 2, as well as 60 random 40-bit input values for ALG 3 Double Swap and ALG 3 Single Swap. These values were then fed into their respective algorithms, being incremented by one until each bitstream had the necessary number of bits.

Appendix D lists the *P-value* associated with as well as the percentage of bitstreams that passed each test. Tables 11 lists the results for implementations of S-AES that use S-box 1 and 3 of Set 1. S-box 1 of Set 1 is the S-box that S-AES uses, and S-box 3 of Set 1 was the most expensive 4x4 S-box found. Table 12 lists the results of implementations of ALG 2, ALG 3 Single Swap, and ALG 3 Double Swap that use Set 4, as it composed the most expensive 16x4 handmade S-box.

9.1 Test Flaws

Fine tuning each test performed was infeasible, as 49 different algorithms ended up being tested. As such, several tests produced questionable results. This is most apparent in the various tests that had a *P-value* of 0 despite having a very high pass rate. Furthermore, only 3 Random Excursions and Random Excursions Variant tests could be performed on each algorithm. In addition to this, the only Discrete Fourier Transform (FFT) tests that did not result in a *P-value* of 0 were the ones ran on ALG 2. Finally, only one Muarer's "Universal Statistical" test could be performed on each algorithm tested.

Table 11: Statistical analysis results of S-AES using its default S-box (S-box 1 of Set 1) and the most quantum expensive 4x4 S-box found (S-box 3 of Set 1)

	S-Box 1		S-Box 3	
	P-val	Passed	P-val	Passed
Frequency	0	100%	0.299	100%
Block Frequency	0.178	93.33%	0.016	98.33%
Sums 1	0	100%	0.001	100%
Sums 2	0	100%	0.01	100%
Runs	0	100%	0.773	100%
Longest Run	0.324	98.33%	0.706	98.33%
Rank	0.437	100%	0.195	93.33%
FFT	0	16.66%	0	71.66%
Non-Overlapping	0.256	99.06%	0.247	98.96%
Overlapping	0.804	98.33%	0.195	98.33%
Universal	0.83	—	0.886	—
Entropy	0.407	100%	0.02	100%
Excursions	—	100%	—	96.87%
Excursion Variants	—	100%	—	93.05%
Serial 1	0.74	100%	0.148	100%
Serial 2	0.233	100%	0.773	100%
Linear Complexity	0.773	100%	0.054	100%
Average Pass Rate	94.0%		97.0%	
100% Pass Rate	11		10	

9.2 Analysis of Results

Apart from the Binary Matrix Rank and FFT tests, each algorithm passed each test more than 80% of the time. ALG 3 Double Swap and ALG 3 Single Swap tended to have low pass rates of the rank test, with ALG 3 Double Swap consistently having a significantly lower pass rate than ALG 3 Single Swap when performing this test. ALG 3 Double Swap also tended to have lower pass rates than ALG 3 Single Swap across every test performed, implying that ALG 3 Single Swap is more secure than ALG 3 Double Swap. Finally, the only algorithm that consistently passed every single test, including FFT, was ALG 2. Each test performed on this algorithm had a pass rate of 90% or more, implying that ALG 2 was the most classically secure algorithm tested.

The Binary Matrix Rank test is used to look for linear dependencies among fixed length substrings of a binary stream [1]. Failure of this test implies that the various values produced by an encryption algorithm are dependent on each other and are therefore not random. Such a dependence makes algorithms susceptible to linear cryptanalysis that can be used to perform key recovery attacks [14]. The FFT test is used to find repetitive patterns that are near each other [1]. These patterns can be exploited by cryptanalysts to recover the plaintext [3].

ALG 2 was also the algorithm that had the highest average pass rate of 99% of all tests performed passing when used in conjunction with Set 4. Despite this, the unmodified version of S-AES had the highest number of tests that had a 100% pass rate for each *P-value* generated, as 11 of the performed tests had a 100% pass rate. ALG 3 Double Swap using Set 4 performed the worst, having an average pass rate of 89% and with only 3 tests having a 100% pass rate.

Table 12: Statistical analysis results of implementations of ALG 2 and 3 using the most expensive handmade 16x4 S-box (Set 4)

	ALG 2		ALG 3 Double Swap		ALG 3 Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.378	98.33%	0.111	95.0%	0.195	100%
Block Frequency	0.001	98.33%	0.254	98.33%	0.233	98.33%
Sums 1	0.276	96.66%	0	91.66%	0.091	100%
Sums 2	0.888	100%	0	91.66%	0.025	100%
Runs	0.254	100%	0.834	98.33%	0.324	100%
Longest Run	0	96.66%	0.74	100%	0.067	98.33%
Rank	0.122	100%	0	58.33%	0.091	93.33%
FFT	0.804	96.66%	0	0.0%	0	71.66%
Non-Overlapping	0.303	98.99%	0.486	98.72%	0.498	98.96%
Overlapping	0.06	100%	0.135	98.33%	0.991	98.33%
Universal	0.461	—	0.713	—	0.621	—
Entropy	0.35	98.33%	0.028	98.33%	0.005	100%
Excursions	—	93.75%	—	98.61%	—	96.87%
Excursion Variants	—	100%	—	96.28%	—	93.05%
Serial 1	0.005	100%	0.534	100%	0.378	100%
Serial 2	0.834	100%	0.888	100%	0.437	100%
Linear Complexity	0.148	100%	0.35	95.0%	0.602	100%
Average Pass Rate	99.0%		89.0%		97.0%	
100% Pass Rate	8		3		8	

9.3 Avalanche Criterion

Another desirable property of encryption algorithms is their ability for small changes in an input to produce significant changes to the output. To achieve this effect, each output bit should have a 50% chance of changing when any individual bit of the input is flipped. This is known as the Strict Avalanche Criteria (SAC) [17]. While the SAC requires each bit to have an exactly 50% chance of changing, such a criterion is very hard to achieve, and it is more useful as a means of measuring a sample's divergence from the SAC. As such, algorithms are considered to meet the generalized SAC when each bit has a probability close to 50% of changing [12].

This was tested by generating 2,500 random plaintexts and keys for each implementation. Each bit in the input was then iterated through to measure the ciphertext produced when said bit was flipped. Furthermore, this test was also applied on a version of S-AES that used each S-box from each set of generated S-boxes. Table 13 lists the average chance that each bit had of changing, and Appendix E contains charts depicting the chance of each individual bit changing for each implementation tested.

Across all four sets analyzed, the bits when running ALG 2 ranged from having a 47.76% to a 51.14% chance of changing. Results were near identical with ALG 3 Double Swap and ALG 3 Single Swap, with bits ranging from having a 48.89% to 51.17% chance of changing. Similarly, each modified version of S-AES produced results that ranged from 48.35% to 53.21%.

Overall, each bit across all the algorithms tested in Table 13 ranged from having a 49.28% to a 50.63% average chance of changing when any given input bit is changed. As such, ALG 2, ALG 3 Double Swap, ALG 3 Single Swap, and each implementation of

S-AES tested met the generalized SAC.

Table 13: SAC test results of Sets 1 through 4

	Set 1						
	ALG 2	ALG 3 Double Swap	ALG 3 Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.65%	49.28%	49.98%	49.76%	50.52%	49.78%	49.87%
	Set 2						
	ALG 2	ALG 3 Double Swap	ALG 3 Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.60%	50.02%	50.04%	49.72%	50.02%	49.92%	50.23%
	Set 3						
	ALG 2	ALG 3 Double Swap	ALG 3 Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.83%	49.94%	49.93%	49.63%	50.55%	49.90%	50.01%
	Set 4						
	ALG 2	ALG 3 Double Swap	ALG 3 Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.65%	50.04%	49.87%	49.80%	49.89%	49.98%	50.63%

10 Analyzing Randomly Generated 16x4 S-Boxes

When analyzing the quantum cost of the ANF of the randomly generated 16x4 S-boxes, multiple S-boxes were found that were more expensive than the S-boxes analyzed in Sets 1 through 4. Table 6 lists the three most expensive randomly generated 16x4 S-boxes. The individual 4x4 S-boxes that produced the three most expensive 16x4 S-boxes were categorized into Sets 5 through 7, as depicted in Table 14. Table 15 depicts the cost of the quantum circuit for the ANF of each of these S-boxes. Appendix A lists the ANF of each of these S-boxes.

Table 14: Sets 5-7

	S-Box 1	S-Box 2	S-Box 3	S-Box 4
Set 5	CB91D538 E7A20F64	A217C653 4D8EBF09	D14A58BF 792C630E	58B214C7 90E6DFA3
Set 6	70812A3B 496DCEF5	89C62357 BA4ED01F	841CEAB7 3265DF09	0386F412 7B95ECAD
Set 7	6A543D18 EC27F09B	9ADC7F3E 502816B4	FC1BE056 8A423D79	309C7BA2 D8F4E651

Table 15: Quantum costs of Sets 5 through 7

	MCX Controls						Total
	0	1	2	3	4	5	Gates
Set 5							
S-Box 1	2	7	19	9	0	0	37
S-Box 2	2	9	11	8	0	0	30
S-Box 3	3	7	10	7	0	0	27
S-Box 4	2	9	7	8	0	0	26
16x4 S-Box	2	10	42	48	36	12	150
Set 6							
S-Box 1	3	11	18	8	0	0	40
S-Box 2	1	6	10	3	0	0	20
S-Box 3	1	9	10	8	0	0	28
S-Box 4	0	10	14	9	0	0	33
16x4 S-Box	3	19	38	44	37	8	149
Set 7							
S-Box 1	2	7	13	11	0	0	33
S-Box 2	2	8	10	11	0	0	31
S-Box 3	4	9	11	8	0	0	32
S-Box 4	2	8	15	6	0	0	31
16x4 S-Box	2	13	38	52	34	8	147

11 Statistical Analysis of Randomly Generated 16x4 S-Boxes

To see if Sets 5 through 7 also provided classical security, each of these S-boxes were analyzed using the NIST statistical test suite and tested to see if they met the generalized SAC. The same procedure used when analyzing Sets 1 through 4 was once again used on Sets 5 through 7. The NIST statistical test suite was ran on versions of S-AES that use S-box 1 of each set, ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap. These algorithms (as well as versions of S-AES that use each S-box in Sets 5 through 7) were then analyzed to measure the likelihood of each bit changing in accordance to a single bit flip in the input to measure their compliance with the SAC. Table 16 and Table 17 contains the results of performing the NIST statistical test suite on Set 5, and Table 18 contains the results for the SAC tests. Appendix D lists the results of running the NIST statistical test suite on each implementation tested, and Appendix E lists charts depicting the chance of each individual bit changing for each implementation tested.

11.1 Analysis of Statistical Tests

Table 19 depicts the results of running implementations of ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap using Set 5, the most expensive 16x4 S-box analyzed in terms of quantum gates. Table 20 depicts the algorithms that performed the best and worst when running statistical tests using Sets 5 through 7. These results were generated using ALG 2 and ALG 3 Double Swap respectively, with both algorithms using Set 6.

Despite requiring the most gates, implementations of ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap that used Set 5 tended to perform worse than implementations that used Sets 6 or 7. Using Set 6 in conjunction with ALG 3 Double Swap resulted in the worst performance with an average pass rate of 86% and only 3 *P-values* that had a

Table 16: Statistical analysis results of implementations of S-AES using each S-box from Set 5.

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.074	100%	0	100%	0.378	100%	0.534	100%
Block Frequency	0.001	100%	0	100%	0.602	100%	0	96.66%
Sums 1	0.001	100%	0	100%	0.233	100%	0.672	100%
Sums 2	0.018	100%	0	100%	0.637	100%	0.637	100%
Runs	0.039	100%	0.534	100%	0.672	100%	0.233	100%
Longest Run	0.501	100%	0.672	100%	0.233	100%	0.254	100%
Rank	0.407	98.33%	0.862	96.66%	0.706	100%	0.672	98.33%
FFT	0	16.66%	0	21.66%	0	30.0%	0	8.33%
Non-Overlapping	0.303	99.15%	0.333	99.03%	0.314	99.14%	0.305	98.86%
Overlapping	0.74	98.33%	0.95	98.33%	0.932	100%	0.911	98.33%
Universal	0.53	—	0.3	—	0.338	—	0.898	—
Entropy	0.025	100%	0.001	100%	0.035	100%	0.501	100%
Excursions	0.361	100%	0.016	97.36%	—	100%	—	100%
Excursion Variants	0.293	100%	0.009	99.7%	—	100%	—	100%
Serial 1	0.862	96.66%	0.213	100%	0.469	100%	0	100%
Serial 2	0.834	100%	0.195	100%	0.407	100%	0.862	100%
Linear Complexity	0.911	98.33%	0.991	98.33%	0.672	100%	0.602	98.33%
Average Pass Rate	94.21%		94.44%		95.57%		93.67%	
100% Pass Rate	10		9		14		10	

100% pass rate. In contrast, using Set 6 in conjunction with ALG 2 resulted in the best performance. These results had an average pass rate of 99%, with 11 *P-values* that had a 100% pass rate.

11.1.1 Analysis of S-Box 3 of Set 5

When the NIST statistical test suite was ran on implementations of S-AES that used S-boxes from Sets 5 through 7, there was a massive outlier when S-box 3 of Set 5 was tested. The results of this test are depicted in Table 21. This test produced 14 *P-values* that had a 100% pass rate. This was the highest number of *P-values* out of the 49 different algorithms tested. It also had an average *P-value* of 0.442, which is the 4th highest average *P-value*.

This could be due to a poor choice of parameters, or it could be due to an anomaly from the inputs fed into the algorithm. However, if it is not, this would imply that the S-box D14A58BF792C630E was the most classically secure 4x4 S-box tested. This is even though this S-box only required 27 gates to create its quantum oracle. The ANF of this S-box is listed below, and Figure 14 depicts what its quantum oracle would look like.

$$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_1 \oplus x_3$$
$$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_2 \oplus x_3$$
$$y_2 = x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2$$
$$y_3 = x_0x_1x_2 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$$

Table 17: Statistical analysis results of implementations of ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap using Set 5

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.254	100%	0.009	91.66%	0.706	100%
Block Frequency	0.568	100%	0	91.66%	0.031	100%
Sums 1	0.299	100%	0	90.0%	0.437	100%
Sums 2	0.01	100%	0	86.66%	0.299	100%
Runs	0.011	100%	0.122	95.0%	0.834	98.33%
Longest Run	0.035	100%	0.254	95.0%	0.195	98.33%
Rank	0.74	98.33%	0	28.33%	0	73.33%
FFT	0.009	90.0%	0	0.0%	0	45.0%
Non-Overlapping	0.303	98.94%	0.462	98.59%	0.462	98.91%
Overlapping	0.602	96.66%	0.672	100%	0.534	98.33%
Universal	0.79	—	0.021	—	0.956	—
Entropy	0.011	100%	0.834	100%	0.888	100%
Excursions	—	94.64%	—	98.42%	—	97.91%
Excursion Variants	—	98.41%	—	100%	—	99.07%
Serial 1	0.082	100%	0.407	96.66%	0.888	100%
Serial 2	0.74	100%	0.568	100%	0.602	100%
Linear Complexity	0.163	96.66%	0.568	98.33%	0.74	100%
Average Pass Rate	98.35%		85.64%		94.32%	
100% Pass Rate	9		4		8	

Table 18: SAC test results of Sets 5 through 7

	Set 5						
	ALG 2	Double Swap	Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.78%	49.86%	49.88%	50.19%	49.87%	49.94%	49.55%
	Set 6						
	ALG 2	Double Swap	Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.48%	50.06%	50.12%	50.07%	49.48%	50.36%	50.10%
	Set 7						
	ALG 2	Double Swap	Single Swap	S-AES (S-Box 1)	S-AES (S-Box 2)	S-AES (S-Box 3)	S-AES (S-Box 4)
Average	49.49%	49.48%	49.95%	49.83%	49.12%	50.26%	50.04%

11.2 Analysis of SAC Tests

While each bit had an average chance of changing that is close to 50% when using Sets 5 through 7, each individual bit did not have a near 50% chance of changing. This is best shown in Figure 15. When using S-AES with S-box 2 of Set 7, bits b_7 and b_{11} only had a 44.76% and 44.93% chance of changing respectively. This is the lowest probability that a single bit had of changing across all the tests performed on implementations of S-AES with different S-boxes. When using ALG 2 with Set 6, bit b_5 only has a 46.61% chance

Table 19: Statistical analysis results of ALG 2 and ALG 3 implementations using Set 5

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.254	100%	0.009	91.66%	0.706	100%
Block Frequency	0.568	100%	0	91.66%	0.031	100%
Sums 1	0.299	100%	0	90.0%	0.437	100%
Sums 2	0.01	100%	0	86.66%	0.299	100%
Runs	0.011	100%	0.122	95.0%	0.834	98.33%
Longest Run	0.035	100%	0.254	95.0%	0.195	98.33%
Rank	0.74	98.33%	0	28.33%	0	73.33%
FFT	0.009	90.0%	0	0.0%	0	45.0%
Non-Overlapping	0.303	98.94%	0.462	98.59%	0.462	98.91%
Overlapping	0.602	96.66%	0.672	100%	0.534	98.33%
Universal	0.79	—	0.021	—	0.956	—
Entropy	0.011	100%	0.834	100%	0.888	100%
Excursions	—	94.64%	—	98.42%	—	97.91%
Excursion Variants	—	98.41%	—	100%	—	99.07%
Serial 1	0.082	100%	0.407	96.66%	0.888	100%
Serial 2	0.74	100%	0.568	100%	0.602	100%
Linear Complexity	0.163	96.66%	0.568	98.33%	0.74	100%
Average Pass Rate	98.35%		85.64%		94.32%	
100% Pass Rate	9		4		8	

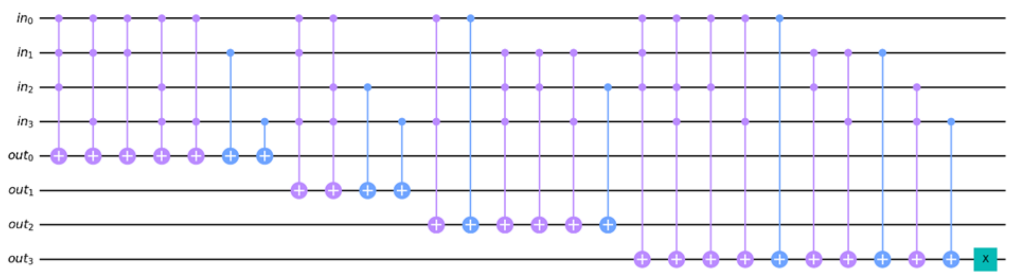

Figure 14: Quantum oracle of the ANF of S-box 3 of Set 5

of changing. This is the lowest probability that a single bit had of changing throughout all the tests performed on ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap. The individual bits that had the highest chance of changing are not of concern, as across all 49 different algorithms analyzed the highest chance any single bit had of changing was only 51.28% (specifically bit b_1 of ALG 2 when using Set 7).

S-box 2 of Set 7 performed the worst in this test, which is not surprising as it was a randomly generated S-box. Furthermore, this S-box had the lowest quantum cost out of all 28 4x4 S-boxes analyzed, with it only needing 20 quantum gates for a quantum circuit of its ANF.

Table 20: The best and worst performing algorithms across Sets 5 through 7, both of which are from Set 6

	ALG 2		Double Swap	
	P-val	Passed	P-val	Passed
Frequency	0.054	100%	0.378	96.66%
Block Frequency	0.672	100%	0	100%
Sums 1	0.031	100%	0.437	95.00%
Sums 2	0.007	96.66%	0.135	95.00%
Runs	0.706	100%	0.005	93.33%
Longest Run	0.049	98.33%	0.672	98.33%
Rank	0.082	100%	0	25.00%
FFT	0.122	100%	0	0.00%
Non-Overlapping	0.271	99.21%	0.522	98.79%
Overlapping	0.054	100%	0.637	100%
Universal	0.213	—	0.076	—
Entropy	0	96.66%	0.091	98.33%
Excursions	—	100%	—	100%
Excursion Variants	—	100%	—	93.05%
Serial 1	0.074	100%	0.568	95.00%
Serial 2	0.233	100%	0.932	96.66%
Linear Complexity	0.276	98.33%	0.932	98.33%
Average Pass Rate	99.0%		86.0%	
100% Pass Rate	11		3	

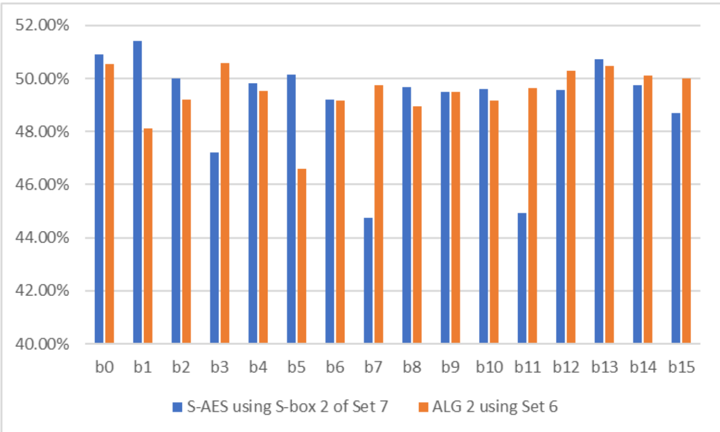

Figure 15: SAC test results of S-AES using S-box 2 of Set 7 and ALG 2 using Set 6

12 Overall Observations and the Correlation Between Quantum and Classical Security

Table 22 lists the range of average pass rates amongst the different implementations of S-AES, ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap. Based on these results, it is clear that ALG 2 performed better than any of the other algorithms tested.

The most quantum secure 4x4 S-box found (S-box 3 of Set 1, or 946C753AE8FBD012) only had an average pass rate of 94%. The 4x4 S-box that produced the highest average pass rate, S-box 4 of Set 4, or 18BDA673CF49205E, was also the 4x4 S-box that had the

Table 21: Statistical analysis results of an implementation of S-AES using S-box 3 of Set 5 (D14A58BF792C630E)

	P-val	Passed
Frequency	0.378	100%
Block Frequency	0.602	100%
Sums 1	0.233	100%
Sums 2	0.637	100%
Runs	0.672	100%
Longest Run	0.233	100%
Rank	0.706	100%
FFT	0	30.00%
Non-Overlapping	0.314	99.14%
Overlapping	0.932	100%
Universal	0.338	—
Entropy	0.035	100%
Excursions	—	100%
Excursion Variants	—	100%
Serial 1	0.469	100%
Serial 2	0.407	100%
Linear Complexity	0.672	100%
Average Pass Rate	96.0%	
100% Pass Rate	14	

highest FFT pass rate of 80%. This is abnormally high, as the average FFT pass rate of S-AES was only 25.35%. S-box 3 of Set 5, or D14A58BF792C630E, had the highest number of *P-values* with a 100% pass rate. As such, these two 4x4 S-boxes were some of the most secure 4x4 S-boxes analyzed. This is even though they only required 27 to 31 gates to model their ANF. The 4x4 S-box that required the most quantum gates to model its ANF, S-box 3 of Set 1 (or 946C753AE8FBD012) only had an average pass rate of 94%.

Table 22: Range of average pass rates for each implementation of each algorithm tested

Algorithm	Range of Average Pass Rates
S-AES	93 – 97%
ALG 2	98 – 99%
ALG 3 Single Swap	94 – 97%
ALG 3 Double Swap	86 – 89%

The most quantum secure 16x4 S-box, or Set 5, had one of the worst performances when ran through the NIST statistical test suite when implemented in ALG 2. It was the only 16x4 S-box that had an average pass rate of 98%, as all the other 16x4 S-boxes had an average pass rate of 99% when implemented in ALG 2. Furthermore, Set 5 produced the worst results when implemented in ALG 3 Single Swap, but one of the best results when implemented in ALG 3 Double Swap.

This implies a lack of correlation between quantum security and classical security, i.e., better quantum security does not necessarily equate to better classical security. This is further supported by what happened to the Supersingular Isogeny Key Encapsulation (SIKE) algorithm. This was an algorithm that was believed to be quantum secure but was cracked in about an hour using a nine-year-old Intel Xeon process [11].

13 Analysis of n-Length S-Boxes

13.1 Analysis of 2^nx4 S-Boxes

To see how increasing the number of 4x4 S-boxes used to construct variably assigned S-boxes impacts the quantum security of an algorithm, S-boxes with the dimensions 2^nx4 were tested to see how increasing n impacted the quantum security of said S-box. Doing so enabled the analysis of S-boxes with dimensions ranging from 4x4 ($n = 2$) to 1024x4 ($n = 10$). Each S-box required $n - 2$ bits to determine which 4x4 S-box to use. Figure 16 depicts the average number of gates needed to model each 2^nx4 S-box and Figure 17 depicts the number of 4x4 S-boxes are needed to construct each 2^nx4 S-box.

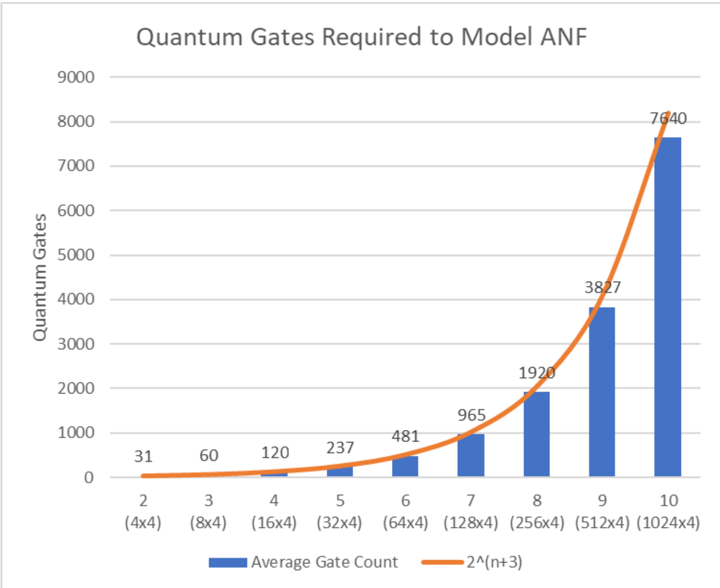

Figure 16: Number of gates needed to model the ANF of a 2^nx4 S-box

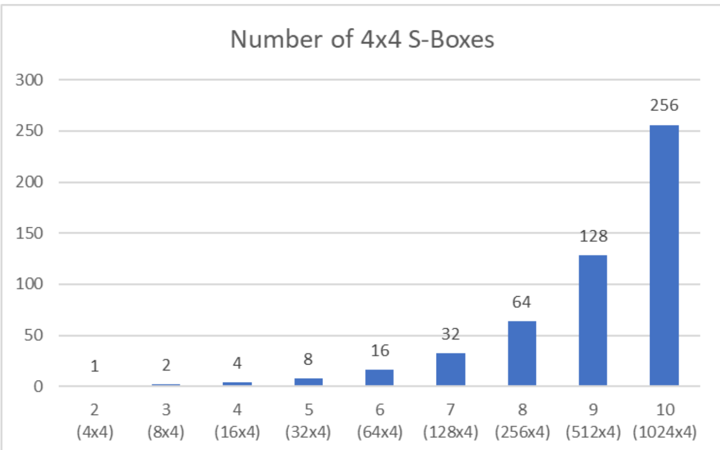

Figure 17: Number of 4x4 S-boxes required for a 2^nx4 S-box

As n increased, both the number of S-boxes and the number of gates required increased at an exponential rate, while the number of additional bits needed increased at a linear rate. The average number of necessary gates increased at a rate of approximately 2^{n+3}, while the number of necessary S-boxes increased at a rate of 2^{n-2}.

A regular 4x4 S-box maps a single input to one of 16 (N) values. As such, a classical device will need to perform an average of 8, or $N/2$, searches each time it runs something through an S-box during the encryption or decryption process. The value of N in a variably assigned S-box is equal to 2^{n+2}. Therefore, the average number of searches a classical device will need to make when performing said S-box will be 2^{n+1}.

13.2 Analysis of 2^nx8 S-Boxes

AES uses an 8x8 S-box. As such, this test was repeated on 2^nx8 S-boxes. This was performed on 3 randomly generated S-boxes. The results of doing so are depicted in Figure 18. Due to computational costs, only 3 different values of n could be analyzed. Similar to 2^nx4 S-boxes, the number of gates required to model the ANF of an 2^nx8 S-box also increased at an exponential rate. This rate of increase was approximately equal to 2^{n+7}.

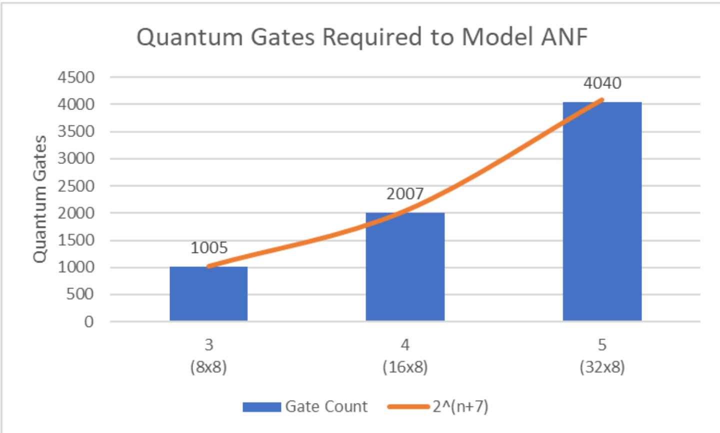

Figure 18: Number of gates needed to model the ANF of 2^nx8 S-boxes

13.2.1 AES S-Box Implications

The ANF of AES' S-box is depicted in Appendix F, and the necessary gates required to model said S-box's ANF in a quantum environment is depicted in Table 23. Based on this, the S-box that AES uses requires slightly less than 1024 gates, which is the expected average number of gates necessary to model an 8x8 S-box. This implies that there is a more quantum secure 8x8 S-box that AES could use.

14 Conclusion

Throughout this paper, an alteration to S-AES was tested that provided better classical and better quantum security. This algorithm, ALG 2, used a 16x4 S-box instead of a 4x4 S-box, using bits in the key to determine which S-box to use. While ALG 2 provided better classical and quantum security, quantum security does not necessarily result in classical security. This was demonstrated by how the most quantum secure 4x4 S-box (946C753AE8FBD012), as well as the most quantum secure 16x4 S-boxes tended to result in comparatively poor performances when analyzed with the NIST statistical test suite. The

Table 23: MCX gates needed to model the ANF of AES' S-box

MCX Controls	Amount
0	4
1	35
2	97
3	245
4	268
5	236
6	107
7	25
Total Gates	1017

two S-boxes that displayed the best classical security were the S-boxes 18BDA673CF49205E and D14A58BF792C630E. These S-boxes required 31 and 27 gates respectively to model their ANF in a quantum environment. Both values are less than the expected average of 32 gates needed to model a 4x4 S-box.

When trying to optimize the quantum security of an S-box, it is important to select the S-box whose ANF requires the most XOR operations. Doing so will maximize the cost necessary to run Grover's algorithm on said S-box. This suggests that an S-box that uses the prime polynomial $x^4 + x^3 + x^2 + x + 1$ (specifically the S-box 946C753AE8FBD012) is more quantum secure than the prime polynomial that S-AES currently uses ($x^4 + x + 1$). This is because an ANF implementation of said S-box requires 41 quantum gates, whereas an ANF implementation of the S-box that S-AES uses only requires 35 quantum gates. While this is only a minor increase in security, it could be very beneficial in protecting ephemeral data with a short lifespan. This is especially true of lightweight cryptography, wherein security is compromised to allow devices with limited resources to provide partial protection to data [2].

It was also demonstrated that the number of gates needed to model the ANF of variably assigned S-boxes increases at an exponential rate, as does the number of searches that need to be performed during the encryption and decryption process. Specifically, the rate of increase in the number of required quantum gates to model a 2^nx4 S-box increases at a rate approximately equal to 2^{n+3} while the number of required quantum gates to model a 2^nx8 S-box increases at a rate approximately equal to 2^{n+7}. This implies that AES could use a more quantum secure S-box, as the S-box that it currently uses only requires 1017 gates to model instead of the expected 1024 gates. However, the methods used to construct the quantum circuits for the S-boxes analyzed throughout this paper could be greatly improved. Tools such as LIGHTER-R can generate quantum circuits of S-boxes that do not require additional qubits and use fewer gates. It does this by generating a reversible ANF [6]. As such, this expected rate of growth in quantum cost could probably be significantly reduced.

When designing these larger S-boxes, it is important to analyze the ANF of the S-box as a whole instead of the ANF of each individual 4x4 S-box composing said larger S-box. Furthermore, reducing the collisions between an S-box and the plaintext or amongst the other S-boxes in a 16x4 S-box does not increase the quantum security of said S-box. The most quantum secure 16x4 S-box was found to be the randomly generated S-box CB91D538E7A20F64A217C6534D8EBF09D14A58BF792C630E58B214C790E6DFA3, requiring a total of 150 quantum gates to model. Since 16x4 S-boxes have an n value of 4, they are expected to require an average of 128 quantum gates to model in a quantum environment. As such, this randomly generated 16x4 S-box is in the upper bounds of the possible 16x4 S-boxes. Despite this, there could be an even more secure 16x4 S-box, as this S-box was found from a small sample size of only 800 randomly generated 16x4 S-boxes.

15 Further Work

15.1 Improved Quantum Circuit Construction

While the ANF of an S-box was used to generate their respective quantum circuit, there are alternative and more efficient methods of doing so. Tools such as LIGHTER use a graph-based meet-in-the-middle approach to calculate the smallest implementation needed to implement an S-box. It then computes good implementations of the smaller functions to reduce the time and memory requirements of said implementation [7]. This approach has been built on through LIGHTER-R, which uses this approach to generate reversible ANF representations that do not need extra qubits and require fewer gates [6]. The S-boxes assessed throughout this paper should be analyzed to see if the strengths and weaknesses discovered still hold true when using this alternate approach. This alternate approach should also be analyzed to see how it impacts the rate of growth of the number of required gates needed to model 2^nx4 and 2^nx8 S-boxes in a quantum environment.

15.2 Improved & Alternate ALG 2 Implementations

It might be possible to further increase the quantum security of ALG 2 by using the 16x4 S-box in the key expansion algorithm. Alternatively, instead of just using the first 4x4 S-box in ALG 2's 16x4 S-box, one could use the most expensive 4x4 S-box that composes said S-box. Doing so should increase its quantum security without increasing the cost associated with performing encryption and decryption. Finally, an implementation of ALG 2 on AES should be tested. Since S-AES and AES share the same structure, this should require minimal alterations to ALG 2.

15.3 Analysis of Algorithms in a Quantum Environment

The full S-AES, ALG 2, ALG 3 Double Swap, and ALG 3 Single Swap algorithms could not be implemented in a quantum environment due to computational and time constraints. Further analysis of the ALG 3 implementations is probably unnecessary as ALG 2 outperformed said algorithm and ALG 3 provided lackluster classical security. However, analyzing S-AES and ALG 2 in a quantum environment still holds merit and should be further investigated.

A ANF of Each Set and Their Corresponding 4x4 S-Boxes

Algebraic Normal Form of 4x4 S-Boxes

Set 1 S-Box 1 (94ABD1856203CEF7)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 1 S-Box 2 (940756EBFD1C2A83)

$y_0 = x_0x_1x_3 \oplus x_0x_3 \oplus x_0 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus 1$
$y_1 = x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_3$

$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1 \oplus x_2 \oplus 1$

Set 1 S-Box 3 (946C753AE8FBD012)

$y_0 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$
$y_1 = x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus 1$

Set 1 S-Box 4 (9E518BDA67F3C402)

$y_0 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3$
$y_3 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 2 S-Box 1 (94ABD1856203CEF7)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 2 S-Box 2 (940756EBFD1C2A83)

$y_0 = x_0x_1x_3 \oplus x_0x_3 \oplus x_0 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus 1$
$y_1 = x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1 \oplus x_2 \oplus 1$

Set 2 S-Box 3 (946C753AE8FBD012)

$y_0 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$
$y_1 = x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus 1$

Set 2 S-Box 4 (9E518BDA67F3C402)

$y_0 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3$
$y_3 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 3 S-Box 1 (94ABD1856203ECF7)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 3 S-Box 2 (940756EBFD1C2A83)

$y_0 = x_0x_1x_3 \oplus x_0x_3 \oplus x_0 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus 1$
$y_1 = x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1 \oplus x_2 \oplus 1$

Set 3 S-Box 3 (946C735AE8FDB012)

$y_0 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus 1$

Set 3 S-Box 4 (9E518BDA67F34C02)

$y_0 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3$
$y_3 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_3 \oplus 1$

Set 4 S-Box 1 (94ABD1856203ECF7)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 4 S-Box 2 (40756EBFD1C2A839)

$y_0 = x_1 \oplus x_2x_3 \oplus x_3$
$y_1 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2$
$y_2 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_2x_3 \oplus 1$
$y_3 = x_0x_1x_2 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2 \oplus x_3$

Set 4 S-Box 3 (6C573AE8FBD01294)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_1 = x_0x_1x_2 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus 1$
$y_2 = x_0x_1x_2 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_2 \oplus 1$
$y_3 = x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_2x_3 \oplus x_3$

Set 4 S-Box 4 (18BDA673CF49205E)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_1x_2 \oplus x_2x_3 \oplus x_3$
$y_3 = x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1 \oplus x_2 \oplus x_3$

Set 5 S-Box 1 (CB91D538E7A20F64)

$y_0 = x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2$
$y_1 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_2x_3 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1 \oplus x_2x_3 \oplus 1$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_2x_3 \oplus 1$

Set 5 S-Box 2 (A217C6534D8EBF09)

$y_0 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3$
$y_1 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2 \oplus x_3 \oplus 1$
$y_2 = x_0x_1 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 5 S-Box 3 (D14A58BF792C630E)

$y_0 = x_0x_1x_2 \oplus x_0x_2 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_1x_2 \oplus x_3$
$y_2 = x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus 1$
$y_3 = x_0x_1x_2 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$

Set 5 S-Box 4 (58B214C790E6DFA3)

$y_0 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1$
$y_2 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_1 \oplus x_2 \oplus x_3 \oplus 1$
$y_3 = x_0x_1x_2 \oplus x_0x_2 \oplus x_0 \oplus x_1x_3 \oplus x_1 \oplus x_3$

Set 6 S-Box 1 (70812A3B496DCEF5)

$y_0 = x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_3 \oplus 1$
$y_2 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_2 \oplus 1$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3$

Set 6 S-Box 2 (89C62357BA4ED01F)

$y_0 = x_0x_1 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_3$
$y_1 = x_0x_1 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2 \oplus x_3$
$y_2 = x_0x_2x_3 \oplus x_1 \oplus x_2x_3$
$y_3 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus 1$

Set 6 S-Box 3 (841CEAB73265DF09)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_1 \oplus x_3$
$y_1 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_2 \oplus x_3$
$y_2 = x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2$
$y_3 = x_0x_1x_2 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$

Set 6 S-Box 4 (0386F4127B95ECAD)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_3 \oplus x_0 \oplus x_2 \oplus x_3$
$y_1 = x_0x_2x_3 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1 \oplus x_2$

Set 7 S-Box 1 (6A543D18EC27F09B)

$y_0 = x_0x_1 \oplus x_0x_2x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1 \oplus x_2$
$y_1 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus 1$
$y_2 = x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_0 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2 \oplus 1$
$y_3 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_3$

Set 7 S-Box 2 (9ADC7F3E502816B4)

$y_0 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_3 \oplus x_2x_3 \oplus x_2$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_3 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_1x_2x_3 \oplus x_2x_3 \oplus x_2 \oplus x_3 \oplus 1$

Set 7 S-Box 3 (FC1BE0568A423D79)

$y_0 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_2 \oplus x_3 \oplus 1$
$y_1 = x_0 \oplus x_1x_3 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$
$y_2 = x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_2 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_3 \oplus 1$
$y_3 = x_0x_1x_3 \oplus x_0x_1 \oplus x_0x_2 \oplus x_1x_2x_3 \oplus x_1 \oplus x_2x_3 \oplus 1$

Set 7 S-Box 4 (309C7BA2D8F4E651)

$y_0 = x_0x_2 \oplus x_0 \oplus x_1x_2 \oplus x_2x_3 \oplus 1$
$y_1 = x_0x_1x_2 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_1 \oplus x_2x_3 \oplus x_3 \oplus 1$
$y_2 = x_0x_1 \oplus x_0x_2 \oplus x_0x_3 \oplus x_1x_2x_3 \oplus x_1x_2 \oplus x_2x_3 \oplus x_2 \oplus x_3$
$y_3 = x_0x_1x_3 \oplus x_0x_2 \oplus x_1x_2x_3 \oplus x_1x_3 \oplus x_1 \oplus x_3$

Algebraic Normal Form of 16x4 S-Boxes

Set 1

$y_0 = x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_4x_5 \oplus x_3x_4x_5 \oplus x_3x_4 \oplus x_3 \oplus 1$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_4x_5 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_4 \oplus x_1 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_5 \oplus x_3$

$y_2 = x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_4 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2x_5 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1x_5 \oplus x_2x_3x_4 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2 \oplus x_3$

$y_3 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3 \oplus x_2x_4 \oplus x_2x_5 \oplus x_3x_4 \oplus x_3x_5 \oplus x_3 \oplus 1$

Set 2

$y_0 = x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_4x_5 \oplus x_3x_4x_5 \oplus x_3x_4 \oplus x_3 \oplus 1$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_4x_5 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_4 \oplus x_1 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_5 \oplus x_3$

$y_2 = x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_4 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2x_5 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1x_5 \oplus x_2x_3x_4 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2 \oplus x_3$

$y_3 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3 \oplus x_2x_4 \oplus x_2x_5 \oplus x_3x_4 \oplus x_3x_5 \oplus x_3 \oplus 1$

Set 3

$y_0 = x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_4x_5 \oplus x_3x_4x_5 \oplus x_3x_4 \oplus x_3 \oplus 1$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_5 \oplus x_1x_2 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_4 \oplus x_1 \oplus x_2x_3x_5 \oplus x_2x_4x_5 \oplus x_2x_5 \oplus x_3$

$y_2 = x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_4 \oplus x_0x_1 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_3x_4 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_4 \oplus x_1x_2 \oplus x_1x_3 \oplus x_1x_5 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2 \oplus x_3$

$y_3 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_2x_3x_4 \oplus x_2x_3 \oplus x_2x_4 \oplus x_2x_5 \oplus x_3x_4 \oplus x_3x_5 \oplus x_3 \oplus 1$

Set 4

$y_0 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_3x_4 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_5 \oplus x_3 \oplus x_4 \oplus x_5 \oplus 1$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_5 \oplus x_0x_3x_5 \oplus x_0x_4x_5 \oplus x_0x_5 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2 \oplus x_1x_3x_4 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_5 \oplus x_2x_4 \oplus x_3x_4x_5 \oplus x_3x_4 \oplus x_3x_5 \oplus x_3 \oplus x_4x_5 \oplus x_5$

$y_2 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_5 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4 \oplus x_2 \oplus x_3x_4 \oplus x_3x_5 \oplus x_3 \oplus x_4 \oplus x_5$

$y_3 = x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2x_5 \oplus x_1x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_3 \oplus x_4x_5 \oplus x_4 \oplus x_5 \oplus 1$

Set 5

$y_0 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus$

$x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_4 \oplus x_2x_5 \oplus x_2 \oplus x_5$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_4 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4 \oplus x_1x_4 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_4 \oplus x_3x_4x_5 \oplus x_3 \oplus x_4x_5 \oplus x_4$

$y_2 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_5 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4 \oplus x_3x_4 \oplus x_4x_5 \oplus x_4 \oplus 1$

$y_3 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0x_5 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2x_5 \oplus x_1x_2 \oplus x_1x_3x_5 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_2x_3x_4x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_5 \oplus x_3x_4x_5 \oplus x_3x_4 \oplus x_3x_5 \oplus x_4x_5 \oplus 1$

Set 6

$y_0 = x_0x_1x_2x_5 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_5 \oplus x_0x_4x_5 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4 \oplus x_2x_5 \oplus x_2 \oplus x_3 \oplus x_4x_5 \oplus x_4 \oplus x_5 \oplus 1$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_5 \oplus x_1x_2 \oplus x_1x_3x_4 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_4x_5 \oplus x_2x_4 \oplus x_2x_5 \oplus x_3 \oplus x_4x_5 \oplus x_4 \oplus x_5 \oplus 1$

$y_2 = x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_5 \oplus x_0x_4 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4 \oplus x_1x_3 \oplus x_1x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_4 \oplus x_2 \oplus x_3x_4x_5 \oplus x_4x_5 \oplus x_4 \oplus x_5 \oplus 1$

$y_3 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4 \oplus x_1x_2 \oplus x_1x_3x_4x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3 \oplus x_2x_4 \oplus x_3x_4x_5 \oplus x_3x_5 \oplus x_4 \oplus x_5$

Set 7

$y_0 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_4 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_5 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0x_5 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4 \oplus x_1x_2 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_4 \oplus x_2 \oplus x_3x_4x_5 \oplus x_3x_5 \oplus x_4x_5 \oplus x_4 \oplus x_5$

$y_1 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3 \oplus x_0x_1x_4 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_5 \oplus x_0x_2 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_4x_5 \oplus x_2x_4 \oplus x_3x_5 \oplus x_4x_5 \oplus x_4 \oplus 1$

$y_2 = x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_4 \oplus x_0x_1x_5 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_5 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_4 \oplus x_1x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3 \oplus x_2x_4x_5 \oplus x_2x_5 \oplus x_2 \oplus x_3x_4x_5 \oplus x_3x_4 \oplus x_3x_5 \oplus x_4 \oplus 1$

$y_3 = x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2 \oplus x_0x_1x_3 \oplus x_0x_1x_4 \oplus x_0x_1 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_5 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4x_5 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0 \oplus x_1x_2x_3 \oplus x_1x_3x_4 \oplus x_1x_3x_5 \oplus x_1x_3 \oplus x_1x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_4x_5 \oplus x_2x_4 \oplus x_3x_4x_5 \oplus x_3x_5 \oplus x_3 \oplus x_4 \oplus x_5$

B Randomly Generated 4x4 & 16x4 S-Boxes

Randomly Generated 4x4 S-Boxes

S-Box	Total Gates	S-Box	Total Gates	S-Box	Total Gates	S-Box	Total Gates
B9A53E18D2CF4706	28	7F143A20B698E5CD	29	9EBC678415DAF032	31	92570F4E13D86BCA	30
EA86DC91B04732F5	32	43A5B7DF6E2108C9	32	DB93F210A8EC6745	26	645D9F73A0EBC182	31
F24B731DC9658E0A	32	0B74D58E92613CFA	26	15B3FEC8907D6A42	27	EB37094621FAD58C	30
E9D4A180B763C5F2	37	258C9EB0F146AD73	34	FD501B48C7963E2A	36	3956D018EA2F47BC	30
B358FA7ED12690C4	27	25EDF68174CB90A3	28	A7960FBE2C31845D	21	5AEBD63C2081F794	33
DE2C0F7B9156A834	37	0D5A7E29FC8134B6	26	AD6901C34B7285FE	27	29DAB7F6C40E1358	35
D6310A495FB2EC78	31	C064B9135A2DF7E8	35	23F0A1E4B6C859D7	33	57FD810CE269AB34	29
E1C34B0765F928AD	29	714C29853FDA6B0E	29	AD9C35284BE076F1	29	9FE6C2758D431AB0	30
DA31C8F067EB2954	33	689FB0DE2A1745C3	30	B3E81495A62D7FC0	36	642BAC810DF573E9	30
FD2345CA98E60B71	31	9B41DCE052FA7386	30	04DB62C9AE7531F8	23	ED6F9814B7A0325C	36
57D01BC864A29FE3	26	2A9DF5EB374018C6	30	FD9A1CB604E52873	34	68735F2DCB4AE910	28
E1DFA06CB7824539	36	568CB94327EDA1F0	32	401B7FEC5DA69238	31	32807A4D69CF1EB5	28
A7D4E98B23C510F6	26	37F2809DBA6E1C45	24	19E48D0F23C57B6A	26	B3C28190F5DA467E	29
CA196D7B05F48E23	30	5260C78B9A14FE3D	35	D0A3E4FC86B91257	31	60C93B71FEA482D5	36
18DA6BE23FC47095	32	2CA71B0465D9FE38	29	D648AC2953107EFB	33	0F78E54AB126D9C3	32
B687F0C9D412A53E	25	A4D1806C9E32B57F	30	68B091E45F3A7C2D	37	BE6CA19F70D45382	35
15F260AE9B743DC8	27	CE1538926704BDFA	34	425BDE09A37186CF	30	D7EA61280B45C3F9	34
2CADF5E06193B847	25	F78A30DE24BC1695	38	89DCB435A71F206E	27	48CDA09F625E7B13	32
1C9A3D60BF8E4572	33	E0F95872D63A4B1C	30	6BA9E051C7D8F432	31	9E403C2D71865ABF	30
836CE49057D2ABF1	27	CE732804D915AB6F	30	74B1FC860AD293E5	24	3A9DB56417FEC802	31
E53D9A867BC1240F	30	31589AC46F2EB70D	29	68FDC132E0A79B45	34	46F7BA98E13C502D	31
DF91045CEAB62387	29	42F5BC31D96A8E07	25	CE3987621F40B5AD	31	A43D7B109CF8256E	33
D45BC96E38A7F012	27	065A289C4DFE3B71	29	47EADF92386B1C50	36	AD0479E63B8C2F51	37
490DFC7AB16832E5	32	1628DB4E7F0A53C9	34	67F2548A9DBE130C	34	A2EF6D5193CB4078	25
0589CA1DB37E24F6	28	D326C0A9FE5B4817	35	EA0CF25341D7B968	29	FD8716ABCE459320	40
E0AD4762F13C85B9	30	3DBC275A04F91E68	31	E1CBF96DA3458720	32	C4A0782963B1FDE5	32
68BCA945307ED2F1	33	A0D74C581EB6329F	30	E4B62073C159DFA8	31	9E8631F274DBA50C	34
C4169528FD3EAB70	28	1DCA7B84E65F2039	26	7FAC98B234516D0E	41	48CA5F37E0912D6B	31
02AE869B143F7D5C	30	ADBF0354E6C19287	31	E06FBC91AD238547	29	970E26A53FDB14C8	29
04F8273DC916E5AB	25	7F30B564E1C829DA	26	A813FB645C92ED70	32	C31E84AD0F26579B	33
D314F9C82B76EA50	36	C2BA7FD51408E396	40	F72A690B84DE1C53	30	391BA7E82064CDF5	24
D3791FBAC652408E	27	A8F25197E6CD043B	31	2CBA67081FED4539	30	54B0AE789D26CF31	31
609F7DBC24A183E5	30	4A05BE2F1D9863C7	33	29AF7EC041D63B58	29	F21536A078BDEC94	29
5E46FC2018A793DB	27	4FD2510AE396B87C	30	87B5AF0D92E136C4	23	1BD264CA78950FE3	24
2BD946158F0AE3C7	29	A5096842F1B7C3DE	31	67DE9B42C305F1A8	33	13F0A6EBD94257C8	33
3E69015F7A48D2CB	25	B3E92405FD8A61C7	33	328E51C406D79FBA	36	6DEA8534170CF92B	35
38A19546FD2BE7C0	32	DB96E8A0215734CF	24	5B03A872C96E4DF1	33	BA3CDF2E96704158	29
EC6B3A24897DF051	31	EBC13674A28590DF	26	2A41C63FE98D70B5	32	65F8730B2A9CD4E1	31
B702149D53AF8CE6	38	E4C5B0D6327A891F	32	BA2E3C41F685097D	35	378E0A49C2FB51D6	30
4862D5BF7C1AE903	20	C8D9612A0F3EB547	25	C69F5348EB072D1A	32	AE3017F9B85D64C2	33
5DFB28C30A91764E	27	3CFDA107964528BE	25	9D8B35C217EA04F6	30	F9D10274BCEA6385	32
B07AD491CF5E8236	32	F702B3C61D4A598E	21	D21EF3954B8A607C	24	D3140FE56C9BA872	31
DFC0284BE573916A	30	DBEC37654A2F9108	29	EF4B216A7D09C835	34	8405DAB9FE1267C3	34
6853DF09C42E17BA	32	9D8CF4A2B0E15763	24	635DB1EC972A084F	36	4586B0739F2DCEA1	33
CAE4798625D30BF1	31	E3D2061A8F5BC497	35	59184E0CB673D2AF	26	84329E01CBA7D56F	32
DB7081AC3F29E654	33	A7E8C60D45F9B321	35	62C0E1FB549D83A7	29	17C620D5AF8E4B93	36
8E75BF2694130DAC	28	4F3B7920156EDCA8	33	F9CEA1B80D274563	30	514F278ABCE906D3	30
B827EF01D659C34A	28	FD0423B91CA7586E	37	251DF04397E68BAC	32	E29D1A567C084FB3	34
8AE761F2D0B5C439	30	5AD48E06713BFC92	27	FB74038916C5DE2A	32	F7AB459180E62D3C	30
39D0F26E417CBA58	37	80CDF2613459BE7A	34	F396EA4207D5C1B8	33	02E7536C48FA1BD9	26
E86F9B75C430D21A	34	29ED0C87F6134BA5	26	593F7AC01BDE4268	27	B197EFC43680D52A	30
15948F6ED7BAC203	28	DF50671AC4E9328B	31	643E0F87DBC15A92	31	8A71D0435CE2B9F6	32
8AF379D1C4B260E5	30	6BD875943CEA201F	30	4C39B78D50F12AE6	28	97FBC1A62D5083E4	29
64B903187CEDF2A5	24	C28A314D9E5F760B	29	6D3CB0174859EF2A	30	D053F8A4B91672EC	36
83109725BCADE46F	26	87AEC2DF354B1609	28	D7E24C965B038A1F	28	9CB72A8140F3D56E	25
DA9185F42CE63B70	34	517894DABF2C360E	25	13BD64E789F0C2A5	30	69FB7D03C154EA28	31
493EA0572DB8F1C6	28	68DA9FB2731E40C5	32	DAB34CE6912785F0	36	680917EB4D3F2C5A	30
F7C149E5D3B0A286	30	B527FD6C81094E3A	34	14D5CBE82309A7F6	32	203BC57AD689E4F1	31
7BCDEA6358021F49	32	89A56DE12CB73F40	32	B25A849EC76D130F	34	90AF68C512E47B3D	31
9658FD43BC12A70E	35	C70D519B86F423AE	29	2AB47F36ED1C8590	30	2D985067EBA31FC4	31
B839DF0526EA41C7	25	54D9361FE7B2A80C	30	BF29C13ADE650478	37	723DF860CAEB9145	30
8A476ED0913BC52F	28	F160D7A48EC5B392	31	79AC138BDF65E204	29	72964EB3805CFDA1	35
C205361E8DA794BF	38	B576AFED841092C3	28	70CDA483256FE9B1	31	3580E6DAF179C42B	33
1DC805F39476EB2A	20	95AB76321FECD084	33	78FA941C20BD563E	33	BC7F06A32951DE48	29
D0EFA59C3B714268	29	3C145609287DABFE	33	16BD025F7EA8349C	32	C1DF3AB59E048672	35
F51CE2038B79DA64	27	05E6C9A3BF8D7142	23	3B71F62C40AED598	31	62F07D5C19EA834B	31
0C4D3F896E7A25B1	27	7F048CBD1E39256A	32	7C6035F94A18D2EB	35	42A05961BE7FDC83	32
36792B4E018DCAF5	30	74C3526D0EAF891B	31	FCA8467E30D5291B	31	418EAD7025C6FB39	26
AF5BE872C1D43906	32	8ED34F76B5A2C190	28	436589AF1E7D2BC0	20	A9851E7BCD2F6043	28
D0284E6BA7C3F591	33	9064A17DBF35EC82	31	14CEAFBD73568902	27	D597A0FC3E21846B	31
9CB84F23A156D7E0	34	FD14A09EB657C283	32	0C678DF9342EA51B	29	3947F2AC0B5D681E	25
7D4FEB26CA085139	36	18F9AB724E5C036D	35	CE6580B4DA19F327	25	A48921BD7FC3065E	35
5EA83B769CD40F21	37	85D7294B1F6AC3E0	32	9FC850172DBE6A43	24	2176DB5F93E840AC	32
60F8D2E53791BA4C	32	AD632E798FC1045B	19	18CF942375E06ABD	27	8AEC2F0369754B1D	31
D1A47293BE68FC05	36	92451EC7680FA3DB	31	EAD108946532CBF7	29	186E309C4BFD25A7	29
F9A84B3CE7D15062	27	B41A2586C937F0ED	31	47369051B2DAEFC8	33	D019752B48AE63FC	34
A7491B3E506C82FD	35	7CA34E2105BD689F	36	A5B813EC94D76F02	33	15CDB9F826A734E0	26
4A93B7EDC8F10562	33	C63E14F09582BDA7	37	8F05E2D6B934C17A	26	9E78C21F350AB46D	29
62347FDBA5198EC0	30	E71A3598FBC0624D	35	18BFDC3A2754069E	31	CA5BD2E348061F97	27
3652E1A8C07F4D9B	35	236FB8ADC740E519	26	B0CE51A9F67324D8	35	9021ACB75F643D8E	29
72CB01E843F56DA9	28	95F8027B16E4AC3D	33	056E398A4FBC271D	29	5DEC403B62FA7819	28
47CF62E839D105BA	22	1D0AB9547386FC2E	31	4E7952683FC0AB1D	23	70C68B13FEDA5942	33
86EC1FA29537DB40	28	731D2A48E069CB5F	28	09426CDF78351BAE	27	847ED2F0C9A6315B	31
2B6E95D8401AC73F	26	C139A528F46D0BE7	31	91C430B56827DAFE	31	0672B5D8341CA9EF	26
5EF8170A93CD42B6	30	DA145372C68B9EF0	30	85C7F46D21A0B93E	37	9AEB7D04163582CF	28
75BCA30186942FED	37	F98130C25E6D7B4A	34	E8A3416C2D5B07F9	32	F01A4568DB92EC73	34
3FA618527BD0C49E	23	0651A24BDF893EC7	23	D91A7BC082E546F3	34	7514C29DB86A30EF	32
85641F2EAC307D9B	37	01F2973A84BC5D6E	33	54FE91A7C6308BD2	25	80AE65FB179D324C	32
5719A2364FB8C0ED	31	4B072CF18395A6DE	29	031CBAE468D7F952	27	814E9D30AF62B75C	20
1F05968BA72C3D4E	27	023517CBF8D6EA94	25	35A8406ECB7D2F19	28	4ACE6B3591870F2D	33
0937DF82BE541AC6	34	718D3AC246B5E9F0	32	8CF5D1AB76E40923	28	B65F7AE014283CD9	32
4916ECD8A0FB2537	29	13ADC56B748F02E9	24	86B1593472FA0DEC	34	56E74B01832D9FCA	26
0F5B7A8C346ED921	23	0F25AE3BD79184C6	34	38C6529A17D0BEF4	35	D9B6FE5830417CA2	33

61D38542B7F09CEA	36	18075EDBFC96A423	30	0BC294DF71638A5E	29	90475A136C8FB2DE	33
E2CAB638105F4D97	29	FA90347852DEB6C1	27	859742ED3AF6BC01	31	8CBE546137092ADF	24
03B856F147E2ACD9	24	F04159E7DA8C362B	31	40D9BA815C276E3F	26	396FBCD4015278AE	33
8DCB71A42E9605F3	32	94D71E2F3068B5CA	30	728E05F16ADB9C43	26	536E98204ACFDB71	33
23E7546BC0D1AF98	29	78394FD0AB5E62C1	37	A4605DF8739E21CB	33	16A794CF25ED38B0	30
67D043FE9CB1852A	28	5DE61CB427A9F380	28	8E021C9743ADB5F6	24	137E4BF529086DAC	30
BFCDA60E39258417	31	ABD045E6F978213C	32	9CB81256D0AE4F37	25	8CD791B620F35AE4	25
9F6AE014BDC35287	25	9264FD105A837CBE	29	BDAF1590C46E7238	35	6834F702ECBD159A	28
A4279FCE513860DB	31	0FACE61978B523D4	31	1FB3AD0846E5279C	30	B0C73E659D284F1A	32
AB7F48C539ED2061	31	7AB1D40F5E3692C8	27	74D0263A8F9B1C5E	39	14D29FC5B360EA78	31
D0F583CE14AB7629	30	B4FD20E83A96517C	32	08153DA49F62E7CB	27	B0CD579A3F8E4261	33
9A614E2D5830F7CB	33	EA318D7C2B64F950	32	95E4278A610C3DBF	34	984DA675F23E01CB	23
3A745DB2FE0C6981	35	03AEC76F84B521D9	28	ABF2193ED807645C	30	728ED6FB1A54930C	36
1A094FCD352EB786	24	6A47CFB82D50391E	33	5E7B6093DF281CA4	37	BD21C6FA0394E758	31
6012D5F834AB9EC7	33	382C1D0ABF954E67	29	48CD36215FBA9E07	31	3659124EF0ABD7C8	27
B75EAC380261F9D4	35	50234A8FD9B71CE6	28	E39D6250AB1F874C	30	D75E016A9C48FB23	34
2AC1E0BD6F598437	27	C12E76839DB04F5A	32	768ADB320FC594E1	33	415BC9EA3D7628F0	26
01438C257BEA9DF6	30	A7234C0B856DE9F1	31	4136BDEF972C5A08	29	A3F5B6148D902CE7	33
83AFB4E52967DC10	30	8325AD106CFB74E9	26	39E480C65AF7DB21	31	6201FA5C398EDB74	33
A79CF801B64532DE	29	D57E3A2694C8FB10	26	F0C7952D1A863EB4	31	92E37F4CD01B8A65	32
274EC30B51A68FD9	32	C9BD78A1EF340625	32	91874F6023BD5ACE	29	D392A7C158640EBF	28
A840FD2B651379CE	31	567FB4E8A139DC02	33	34AD291E0C6FB578	29	6B035A1D294F78EC	30
6D503AF9E8B4271C	32	8347C0A92B65DF1E	27	E2D41038B6CA7F95	32	269C03874F5B1DEA	30
F29E5B04137D86AC	34	6D1EAF84C29703B5	30	86753F9B40C2EA1D	29	8A4502F9E6C73DB1	25
502A6734B9DC18FE	35	60AE5B317842F9CD	31	1F98B4D732065EAC	32	4BC72DAF3695E180	28
6AC807BF214E9D35	32	37FED105289BCA46	26	B2C50167FED943A8	25	128653C9BDFEA704	31
A301D287C4B96FE5	30	DC69BA7142E05F83	30	FC3D95B1678A402E	35	502AB4F791C38ED6	34
78FDE4CB5A613092	31	2B536D7FAE4109C8	33	5C34D7601AEFB892	25	10DC4E26AB8F3795	28
C5490FB716E3AD28	33	C6BE5719024DAF83	32	DE6A209CB3815F47	31	7F24C981D605A3BE	31
4EDF0A8BC2561379	20	0476A2381CF59BED	27	01ADE958C6B423F7	29	2416DAEF9BC58073	30
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Randomly Generated 16x4 S-Boxes

S-Box	Total Gates	S-Box	Total Gates	S-Box	Total Gates	S-Box	Total Gates
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38D6E4B02C9A751F 0A57B3DE19FC4628 5D9B4078621CA3EF 24F5E1D6073A8B9C	126	EBDC26A45803197F 4ED0CFA7395B2186 108D3E62CB7A594F 64E829FDC5A1B730	124	0B728F3CA5D41E96 B3285D76E41AC9F0 9087F15A3E2DB46C 1EBCDA7F29403568	115	90CF1DE2847635AB 426F7ECA91053DB8 4F9D586A7C23B1E0 12BFD98673EA54C0	118
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14703258BC9ADF6E		6D507491FAE38C2B		092BF5DAC8E43176		B5687E12F4AC39D0	

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18B74AC2D3E96F05 E7405268BF9CA3D1 7C84FBD9605123EA A1C6842BF3E9D705	108	FAC4E329BD710685 BDC23169E045AF87 4982D160F5BC3AE7 3DA8C7FB0164295E	127	83941F6CE0B5A27D A67FBE08429D3C51 1F2C8DBE34A60579 C7B69F58E203D4A1	111	B8A0C41DF567E932 72D46EA10C39F85B 40E159B8CD3F7A26 3FE6C7AD4250B891	115
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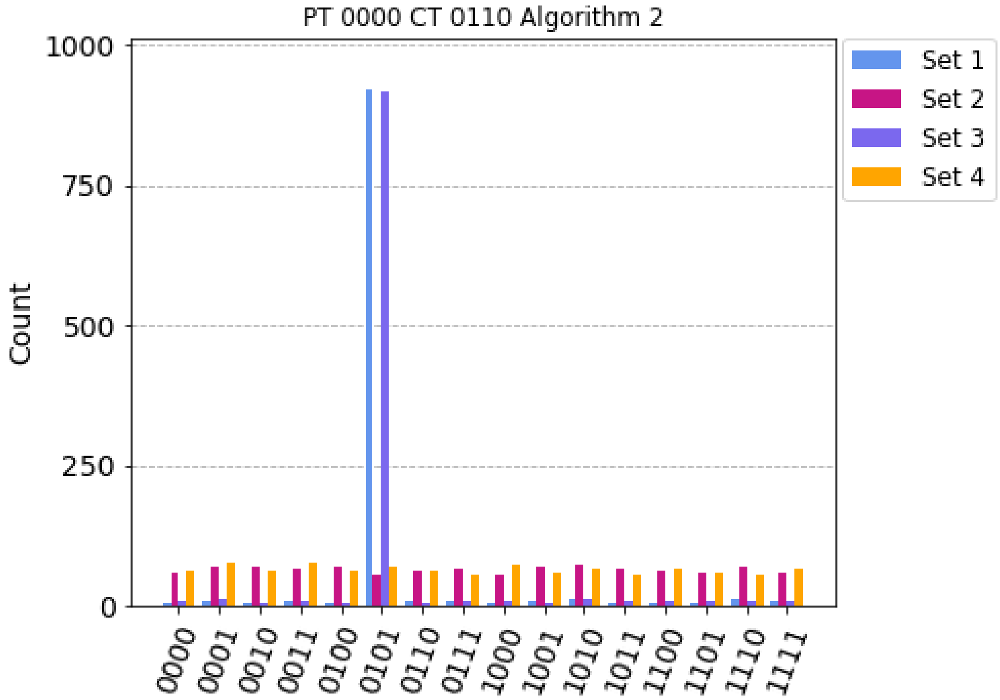
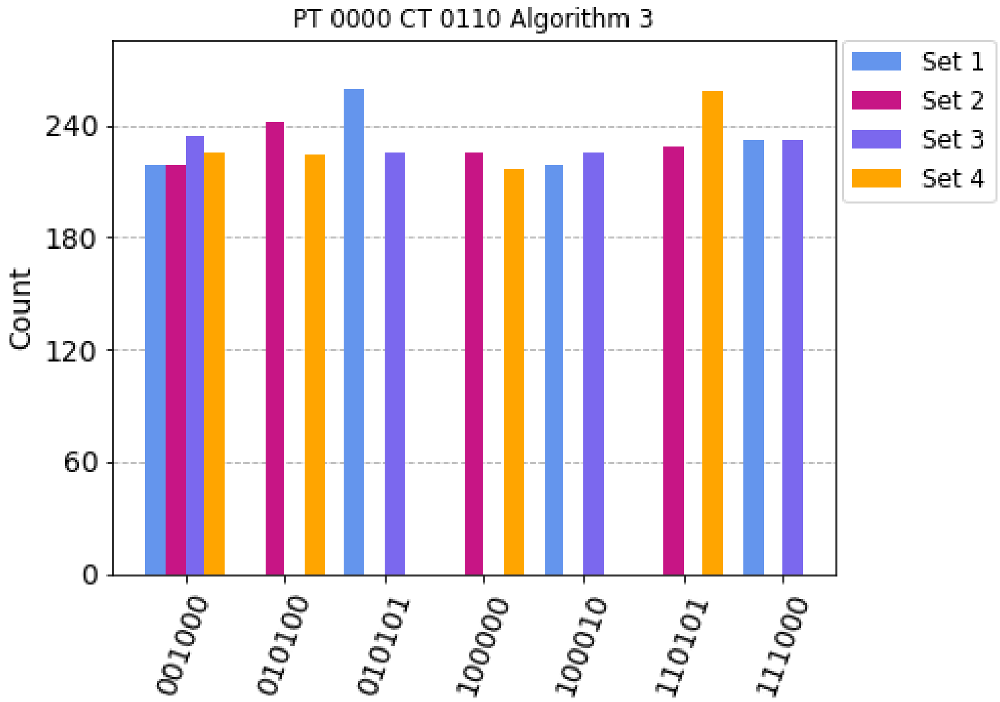
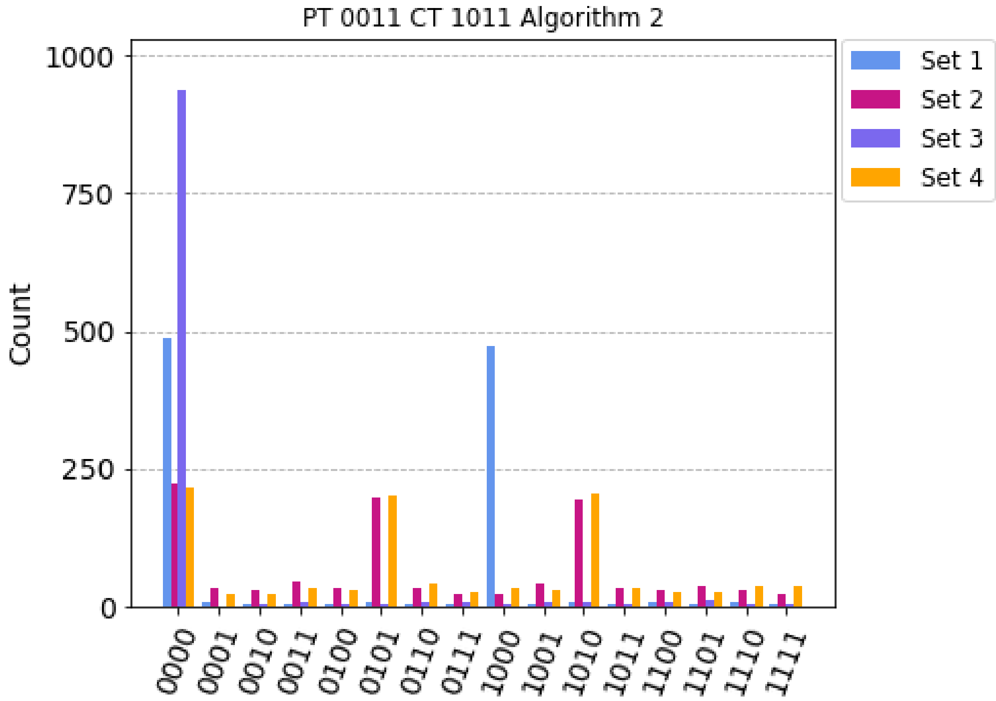
C Results of Using Grover's Algorithm to Perform a Known Plaintext Attack on Implementations of S-AES That Use a 16x4 S-Box



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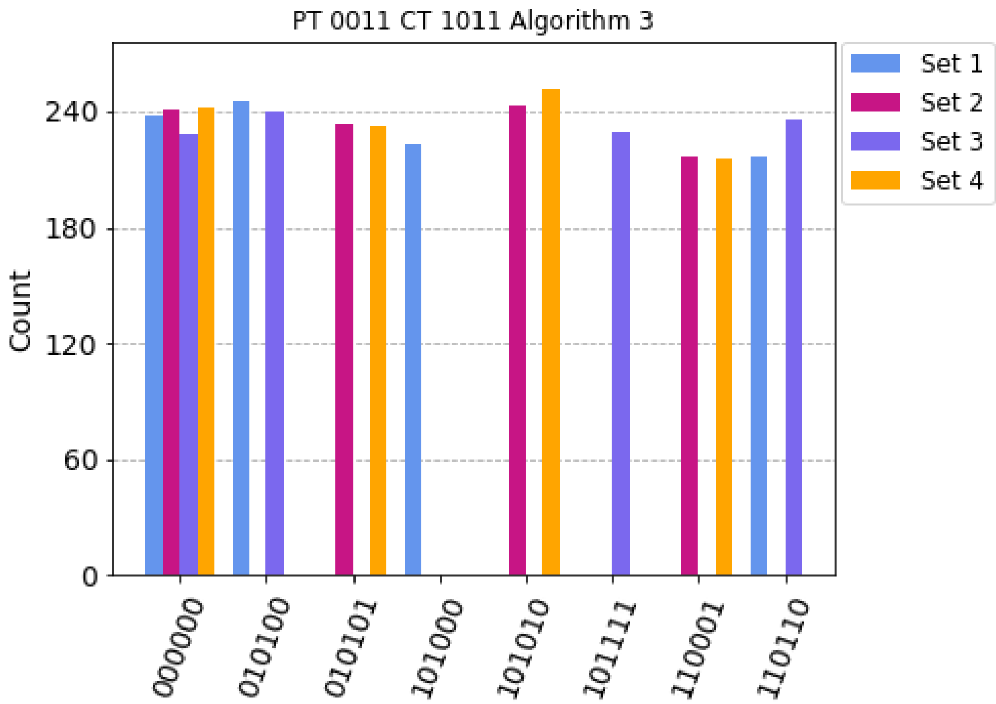
1000
750
500
250
0
Set 1
Set 2
Set 3
Set 4
0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1100
1101
1110
1111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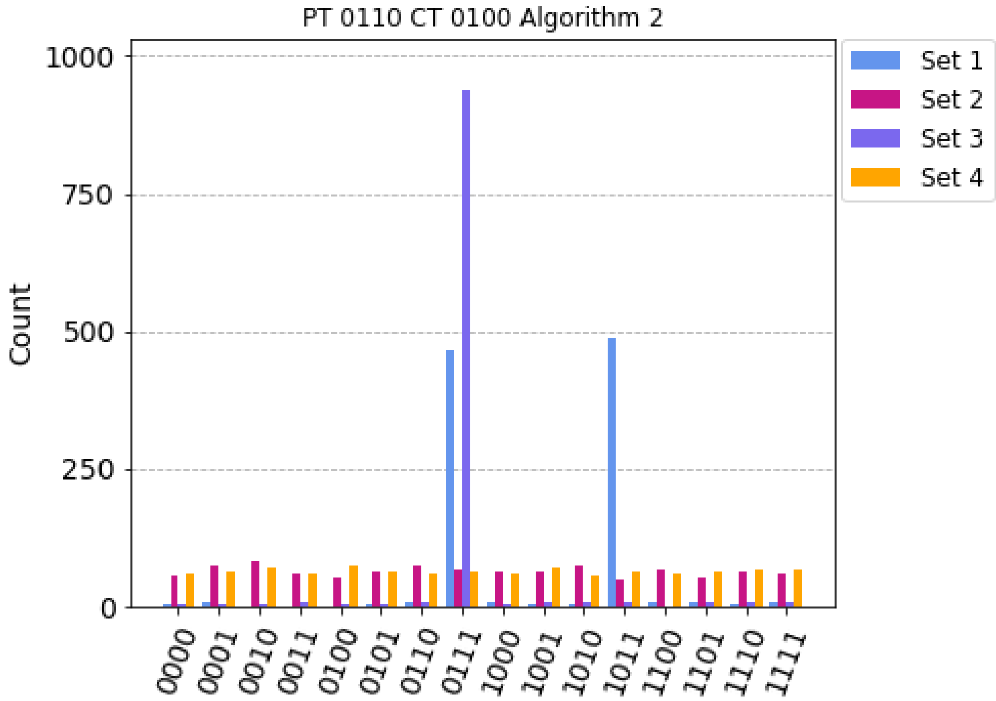
Count
240
180
120
60
0
Set 1
Set 2
Set 3
Set 4
000000
010100
010101
101000
101010
101111
110001
110110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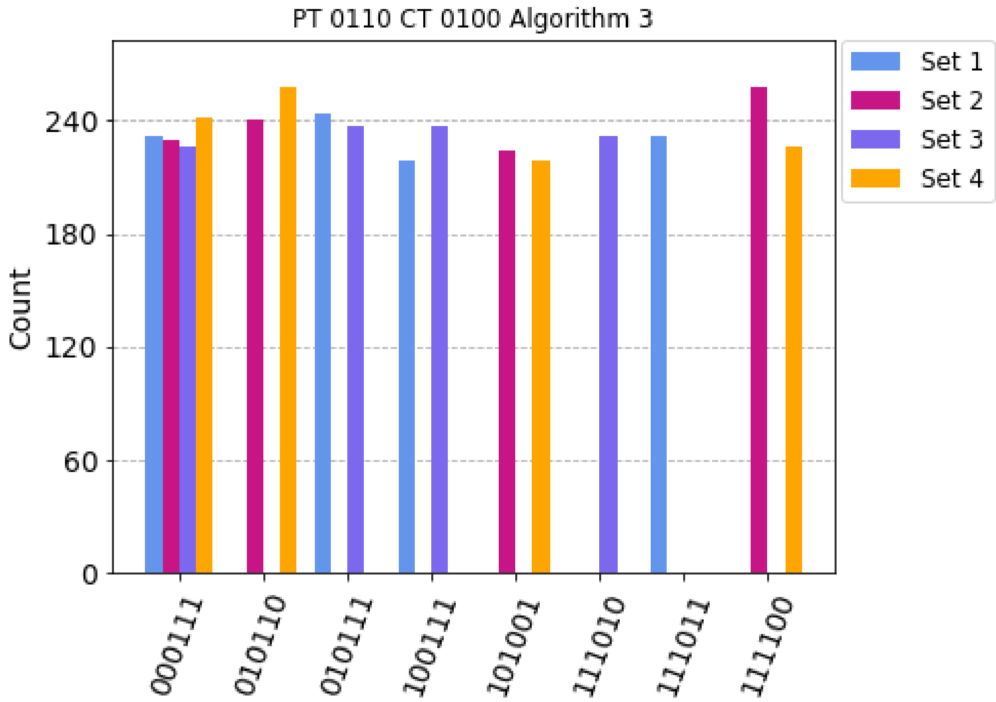
750
500
250
0
0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1100
1101
1110
1111
Set 1
Set 2
Set 3
Set 4


PT 0110 CT 0100 Algorithm 3
Count
240
180
120
60
0
000111
010110
010111
100111
101001
111010
111011
111100
Set 1
Set 2
Set 3
Set 4

D Statistical Analysis Results

Set 1

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.276	100%	0	93.33%	0.254	100%
Block Frequency	0.378	98.33%	0	98.33%	0.299	100%
Sums 1	0.672	100%	0	90.0%	0.437	98.33%
Sums 2	0.111	100%	0	88.33%	0.254	100%
Runs	0.006	95.0%	0.501	96.66%	0.773	98.33%
Longest Run	0.082	100%	0.276	95.0%	0.213	98.33%
Rank	0.091	96.66%	0	35.0%	0	78.33%
FFT	0.888	100%	0	0.0%	0	70.0%
Non-Overlapping	0.304	99.32%	0.445	98.36%	0.499	98.98%
Overlapping	0.035	100%	0.74	100%	0.804	100%
Universal	0.041	—	0.054	—	0.001	—
Entropy	0.005	98.33%	0	86.66%	0.976	98.33%
Excursions	—	100%	—	100%	—	98.61%
Excursion Variants	—	100%	—	96.28%	—	98.76%
Serial 1	0.054	98.33%	0.091	98.33%	0.637	100%
Serial 2	0.834	100%	0.706	100%	0.534	100%
Linear Complexity	0.324	98.33%	0.74	100%	0.862	100%
Average	0.273	99.01%	0.237	86.01%	0.436	96.12%
100% Pass Rate	9		4		7	

S-AES (Set 1)

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0	100%	0.324	100%	0.299	100%	0.082	100%
Block Frequency	0.178	93.33%	0.276	98.33%	0.016	96.66%	0.01	98.33%
Sums 1	0	100%	0.111	100%	0.001	100%	0.091	100%
Sums 2	0	100%	0.35	100%	0.01	100%	0.091	100%
Runs	0	100%	0.213	100%	0.773	100%	0.004	100%
Longest Run	0.324	98.33%	0.163	100%	0.706	100%	0.324	100%
Rank	0.437	100%	0.804	100%	0.195	98.33%	0.025	100%
FFT	0	16.66%	0	33.33%	0	20.0%	0	23.33%
Non-Overlapping	0.256	99.06%	0.342	99.06%	0.247	98.88%	0.269	99.07%
Overlapping	0.804	98.33%	0.028	91.66%	0.195	98.33%	0.135	100%
Universal	0.83	—	0.826	—	0.886	—	0.98	—
Entropy	0.407	100%	0	98.33%	0.02	100%	0.001	100%
Excursions	—	100%	—	98.21%	—	100%	0.35	98.86%
Excursion Variants	—	100%	—	100%	—	97.22%	0.46	100%
Serial 1	0.74	100%	0.834	100%	0.148	100%	0.135	100%
Serial 2	0.233	100%	0.672	100%	0.773	100%	0	100%
Linear Complexity	0.773	100%	0.602	98.33%	0.054	100%	0.407	100%
Average	0.332	94.10%	0.37	94.82%	0.288	94.33%	0.198	94.97%
100% Pass Rate	11		9		10		12	

Set 2

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.95	100%	0.067	96.66%	0.568	100%
Block Frequency	0.002	98.33%	0.437	98.33%	0.74	98.33%
Sums 1	0.031	100%	0	95.0%	0.163	100%
Sums 2	0.437	100%	0	96.66%	0.074	100%
Runs	0.378	96.66%	0.911	98.33%	0.122	100%
Longest Run	0.018	96.66%	0.568	100%	0.233	100%
Rank	0.378	100%	0	53.33%	0.044	86.66%
FFT	0.067	98.33%	0	0.0%	0	73.33%
Non-Overlapping	0.306	98.59%	0.529	98.82%	0.515	98.95%
Overlapping	0.004	98.33%	0.35	100%	0.437	96.66%
Universal	0.66	—	0.404	—	0.222	—
Entropy	0.534	100%	0.195	95.0%	0.95	98.33%
Excursions	—	100%	—	100%	0.382	98.86%
Excursion Variants	—	100%	—	100%	0.43	98.14%
Serial 1	0.003	96.66%	0.378	100%	0.773	100%
Serial 2	0.101	100%	0.276	98.33%	0.233	100%
Linear Complexity	0.195	100%	0.378	100%	0.834	100%
Average	0.271	98.97%	0.3	89.40%	0.395	96.82%
100% Pass Rate	9		6		8	

S-AES (Set 2)

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0	100%	0.111	100%	0.013	100%	0.163	100%
Block Frequency	0.178	93.33%	0.002	98.33%	0.111	96.66%	0.001	91.66%
Sums 1	0	100%	0.002	100%	0	100%	0.06	100%
Sums 2	0	100%	0.018	100%	0	100%	0.007	100%
Runs	0	100%	0.135	95.0%	0.054	100%	0.082	100%
Longest Run	0.324	98.33%	0.178	100%	0.672	98.33%	0.049	100%
Rank	0.437	100%	0.74	98.33%	0.773	98.33%	0.233	98.33%
FFT	0	16.66%	0	10.0%	0	41.66%	0	43.33%
Non-Overlapping	0.256	99.06%	0.269	99.2%	0.231	99.0%	0.251	99.03%
Overlapping	0.804	98.33%	0.602	98.33%	0.437	100%	0.049	100%
Universal	0.83	—	0.131	—	0.768	—	0.413	—
Entropy	0.407	100%	0.074	100%	0.035	100%	0.039	100%
Excursions	—	100%	0.364	98.75%	—	98.42%	0.231	99.1%
Excursion Variants	—	100%	0.398	99.44%	—	100%	0.204	100%
Serial 1	0.74	100%	0.001	98.33%	0.407	96.66%	0.031	100%
Serial 2	0.233	100%	0.469	100%	0.469	96.66%	0.254	100%
Linear Complexity	0.773	100%	0.148	98.33%	0.998	98.33%	0.804	98.33%
Average	0.332	94.10%	0.214	93.37%	0.331	95.25%	0.169	95.61%
100% Pass Rate	11		6		7		10	

Set 3

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.437	100%	0.035	90.0%	0.637	100%
Block Frequency	0.773	100%	0	98.33%	0.637	100%
Sums 1	0.74	100%	0.067	83.33%	0.016	100%
Sums 2	0.233	100%	0.006	88.33%	0.111	100%
Runs	0.299	100%	0.637	98.33%	0.178	100%
Longest Run	0.005	96.66%	0.773	100%	0.534	100%
Rank	0.602	100%	0	38.33%	0	71.66%
FFT	0.407	96.66%	0	0.0%	0	60.0%
Non-Overlapping	0.265	99.05%	0.443	98.22%	0.531	98.87%
Overlapping	0.213	100%	0.501	100%	0.148	100%
Universal	0.074	—	0.433	—	0.584	—
Entropy	0.001	95.0%	0	90.0%	0.324	96.66%
Excursions	—	100%	—	100%	0.532	97.72%
Excursion Variants	—	100%	—	100%	0.531	100%
Serial 1	0.049	100%	0.378	91.66%	0.276	100%
Serial 2	0.091	95.0%	0.178	95.0%	0.534	100%
Linear Complexity	0.299	95.0%	0.834	100%	0.932	96.66%
Average	0.299	98.58%	0.286	85.72%	0.383	95.09%
100% Pass Rate	10		5		10	

S-AES (Set 3)

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0	100%	0.111	100%	0.035	100%	0.254	100%
Block Frequency	0.804	93.33%	0.276	98.33%	0.054	98.33%	0	98.33%
Sums 1	0	100%	0.148	100%	0.067	100%	0.178	100%
Sums 2	0	100%	0.299	100%	0.009	100%	0.163	100%
Runs	0.101	100%	0.804	100%	0.002	98.33%	0.568	100%
Longest Run	0.534	96.66%	0.233	100%	0.672	100%	0.054	98.33%
Rank	0.602	100%	0.534	100%	0.122	100%	0.135	100%
FFT	0	20.0%	0	40.0%	0	45.0%	0	13.33%
Non-Overlapping	0.296	99.02%	0.343	99.05%	0.27	99.14%	0.285	99.13%
Overlapping	0.025	100%	0.254	95.0%	0.028	100%	0	100%
Universal	0.085	—	0.118	—	0.041	—	0.222	—
Entropy	0.039	100%	0	100%	0.932	100%	0.501	100%
Excursions	—	100%	—	98.21%	—	100%	—	100%
Excursion Variants	—	100%	—	100%	—	100%	—	99.38%
Serial 1	0.003	96.66%	0.074	96.66%	0.008	100%	0.407	100%
Serial 2	0	100%	0.049	100%	0.804	96.66%	0.407	100%
Linear Complexity	0.501	95.0%	0.911	100%	0.706	96.66%	0.862	100%
Average	0.199	93.79%	0.277	95.45%	0.25	95.88%	0.269	94.28%
100% Pass Rate	10		10		10		11	

Set 4

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.378	98.33%	0.111	95.0%	0.195	100%
Block Frequency	0.001	98.33%	0.254	98.33%	0.233	98.33%
Sums 1	0.276	96.66%	0	91.66%	0.091	100%
Sums 2	0.888	100%	0	91.66%	0.025	100%
Runs	0.254	100%	0.834	98.33%	0.324	100%
Longest Run	0	96.66%	0.74	100%	0.067	98.33%
Rank	0.122	100%	0	58.33%	0.091	93.33%
FFT	0.804	96.66%	0	0.0%	0	71.66%
Non-Overlapping	0.303	98.99%	0.486	98.72%	0.498	98.96%
Overlapping	0.06	100%	0.135	98.33%	0.991	98.33%
Universal	0.461	—	0.713	—	0.621	—
Entropy	0.35	98.33%	0.028	98.33%	0.005	100%
Excursions	—	93.75%	—	98.61%	—	96.87%
Excursion Variants	—	100%	—	96.28%	—	93.05%
Serial 1	0.005	100%	0.534	100%	0.378	100%
Serial 2	0.834	100%	0.888	100%	0.437	100%
Linear Complexity	0.148	100%	0.35	95.0%	0.602	100%
Average	0.326	98.60%	0.338	88.66%	0.304	96.80%
100% Pass Rate	8		3		8	

S-AES (Set 4)

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0	100%	0.005	100%	0.035	100%	0.276	100%
Block Frequency	0.804	93.33%	0	98.33%	0.501	100%	0.054	95.0%
Sums 1	0	100%	0	100%	0	100%	0.888	100%
Sums 2	0	100%	0	100%	0.004	100%	0.74	100%
Runs	0.101	100%	0.135	100%	0.122	100%	0.049	100%
Longest Run	0.534	96.66%	0.501	100%	0.602	98.33%	0	96.66%
Rank	0.602	100%	0.95	100%	0.028	98.33%	0.002	100%
FFT	0	20.0%	0	5.0%	0	55.00%	0	80.0%
Non-Overlapping	0.296	99.02%	0.259	99.09%	0.269	99.26%	0.32	98.92%
Overlapping	0.025	100%	0.378	100%	0.501	98.33%	0.01	100%
Universal	0.085	—	0.028	—	0.971	—	0.583	—
Entropy	0.039	100%	0.378	100%	0.932	100%	0.082	100%
Excursions	—	100%	0.546	100%	0.311	100%	—	92.85%
Excursion Variants	—	100%	0.23	100%	0.574	98.98%	—	98.41%
Serial 1	0.003	96.66%	0.023	100%	0.082	100%	0	100%
Serial 2	0	100%	0.101	100%	0.501	100%	0	100%
Linear Complexity	0.501	95.0%	0.378	95.0%	0.082	98.33%	0.469	96.66%
Average	0.199	93.79%	0.23	93.58%	0.324	96.66%	0.232	97.40%
100% Pass Rate	10		12		9		9	

Set 5

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.254	100%	0.009	91.66%	0.706	100%
Block Frequency	0.568	100%	0	91.66%	0.031	100%
Sums 1	0.299	100%	0	90.0%	0.437	100%
Sums 2	0.01	100%	0	86.66%	0.299	100%
Runs	0.011	100%	0.122	95.0%	0.834	98.33%
Longest Run	0.035	100%	0.254	95.0%	0.195	98.33%
Rank	0.74	98.33%	0	28.33%	0	73.33%
FFT	0.009	90.0%	0	0.0%	0	45.0%
Non-Overlapping	0.303	98.94%	0.462	98.59%	0.462	98.91%
Overlapping	0.602	96.66%	0.672	100%	0.534	98.33%
Universal	0.79	—	0.021	—	0.956	—
Entropy	0.011	100%	0.834	100%	0.888	100%
Excursions	—	94.64%	—	98.42%	—	97.91%
Excursion Variants	—	98.41%	—	100%	—	99.07%
Serial 1	0.082	100%	0.407	96.66%	0.888	100%
Serial 2	0.74	100%	0.568	100%	0.602	100%
Linear Complexity	0.163	96.66%	0.568	98.33%	0.74	100%
Average	0.308	98.35%	0.261	85.64%	0.505	94.32%
100% Pass Rate	9		4		8	

S-AES (Set 5)

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.074	100%	0	100%	0.378	100%	0.534	100%
Block Frequency	0.001	100%	0	100%	0.602	100%	0	96.66%
Sums 1	0.001	100%	0	100%	0.233	100%	0.672	100%
Sums 2	0.018	100%	0	100%	0.637	100%	0.637	100%
Runs	0.039	100%	0.534	100%	0.672	100%	0.233	100%
Longest Run	0.501	100%	0.672	100%	0.233	100%	0.254	100%
Rank	0.407	98.33%	0.862	96.66%	0.706	100%	0.672	98.33%
FFT	0	16.66%	0	21.66%	0	30.0%	0	8.33%
Non-Overlapping	0.303	99.15%	0.333	99.03%	0.314	99.14%	0.305	98.86%
Overlapping	0.74	98.33%	0.95	98.33%	0.932	100%	0.911	98.33%
Universal	0.53	—	0.3	—	0.338	—	0.898	—
Entropy	0.025	100%	0.001	100%	0.035	100%	0.501	100%
Excursions	0.361	100%	0.016	97.36%	—	100%	—	100%
Excursion Variants	0.293	100%	0.009	99.7%	—	100%	—	100%
Serial 1	0.862	96.66%	0.213	100%	0.469	100%	0	100%
Serial 2	0.834	100%	0.195	100%	0.407	100%	0.862	100%
Linear Complexity	0.911	98.33%	0.991	98.33%	0.672	100%	0.602	98.33%
Average	0.347	94.21%	0.299	94.44%	0.442	95.57%	0.472	93.67%
100% Pass Rate	10		9		14		10	

Set 6

	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.054	100%	0.378	96.66%	0.054	100%
Block Frequency	0.672	100%	0	100%	0.911	100%
Sums 1	0.031	100%	0.437	95.0%	0.378	100%
Sums 2	0.007	96.66%	0.135	95.0%	0.067	100%
Runs	0.706	100%	0.005	93.33%	0.862	100%
Longest Run	0.049	98.33%	0.672	98.33%	0.932	98.33%
Rank	0.082	100%	0	25.0%	0	68.33%
FFT	0.122	100%	0	0.0%	0	56.66%
Non-Overlapping	0.271	99.21%	0.522	98.79%	0.508	98.94%
Overlapping	0.054	100%	0.637	100%	0.299	100%
Universal	0.213	—	0.076	—	0.031	—
Entropy	0	96.66%	0.091	98.33%	0.074	98.33%
Excursions	—	100%	—	100%	—	98.21%
Excursion Variants	—	100%	—	93.05%	—	100%
Serial 1	0.074	100%	0.568	95.0%	0.501	100%
Serial 2	0.233	100%	0.932	96.66%	0.06	96.66%
Linear Complexity	0.276	98.33%	0.932	98.33%	0.324	98.33%
Average	0.19	99.32%	0.359	86.46%	0.333	94.61%
100% Pass Rate	11		3		8	

S-AES (Set 6)

	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.031	100%	0	100%	0.025	100%	0.011	100%
Block Frequency	0.054	95.0%	0	90.0%	0.003	100%	0.091	100%
Sums 1	0	100%	0	100%	0.003	100%	0.122	100%
Sums 2	0	100%	0	100%	0.005	100%	0	100%
Runs	0.06	100%	0.407	100%	0.163	100%	0.044	100%
Longest Run	0.049	95.0%	0.233	98.33%	0.091	100%	0.233	100%
Rank	0.888	100%	0.534	100%	0.773	100%	0.706	100%
FFT	0	0.0%	0	5.0%	0	25.0%	0	36.66%
Non-Overlapping	0.292	99.21%	0.295	99.03%	0.29	99.17%	0.331	99.13%
Overlapping	0.049	95.0%	0.672	100%	0.299	100%	0.195	100%
Universal	0	—	0.098	—	0.593	—	0.012	—
Entropy	0.254	100%	0.101	100%	0.049	98.33%	0.035	100%
Excursions	0.168	98.07%	—	100%	—	100%	—	100%
Excursion Variants	0.247	99.2%	—	100%	—	100%	—	98.88%
Serial 1	0.049	100%	0.016	100%	0.035	96.66%	0.101	100%
Serial 2	0.111	100%	0.178	96.66%	0.005	100%	0.74	100%
Linear Complexity	0.014	100%	0.324	100%	0.082	100%	0.706	100%
Average	0.133	92.59%	0.191	93.06%	0.161	94.94%	0.222	95.91%
100% Pass Rate	9		11		12		13	

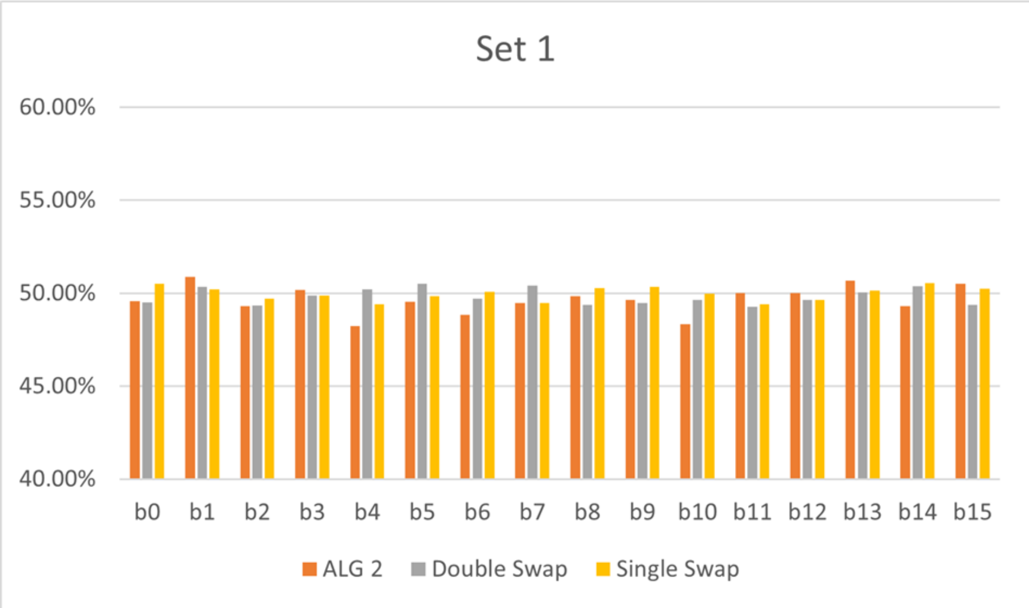
Set 7

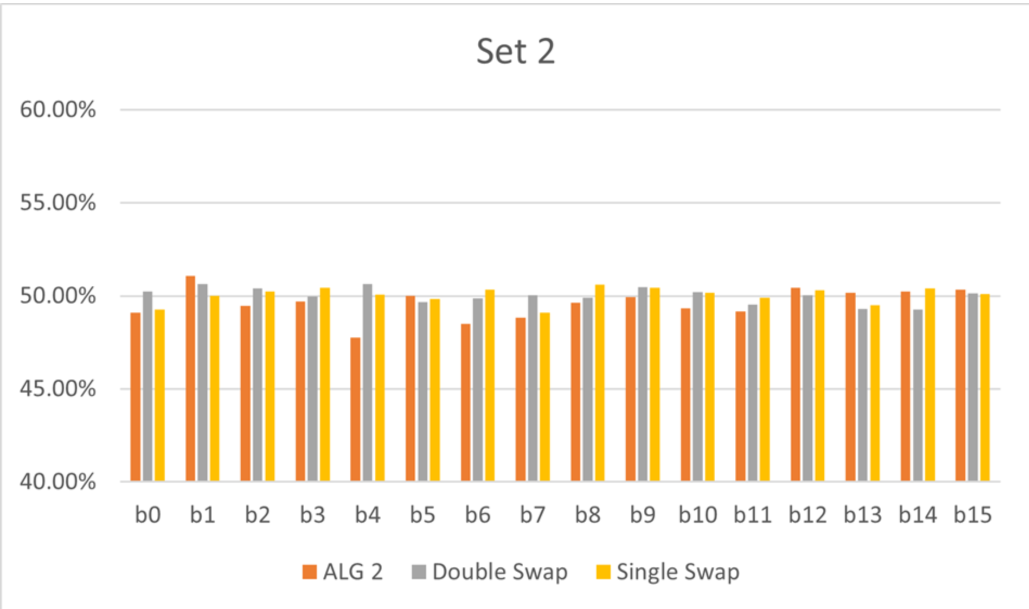
	ALG 2		Double Swap		Single Swap	
	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.74	98.33%	0.911	95.0%	0.706	98.33%
Block Frequency	0.082	100%	0	86.66%	0.195	98.33%
Sums 1	0.035	96.66%	0.008	93.33%	0.834	100%
Sums 2	0.74	96.66%	0.016	91.66%	0.602	100%
Runs	0.018	100%	0.834	98.33%	0.082	100%
Longest Run	0.178	98.33%	0.985	100%	0.602	100%
Rank	0.672	98.33%	0	31.66%	0	75.0%
FFT	0.534	98.33%	0	0.0%	0	73.33%
Non-Overlapping	0.313	99.0%	0.471	98.65%	0.469	98.98%
Overlapping	0.501	100%	0.35	96.66%	0.324	96.66%
Universal	0.279		0.937		0.224	
Entropy	0.122	100%	0.178	98.33%	0.804	100%
Excursions	—	100%	—	100%	—	100%
Excursion Variants	—	100%	—	100%	—	100%
Serial 1	0.023	98.33%	0.568	100%	0.35	100%
Serial 2	0.324	100%	0.862	100%	0.324	100%
Linear Complexity	0.407	100%	0.672	98.33%	0.233	100%
Average	0.331	98.99%	0.453	86.78%	0.383	96.28%
100% Pass Rate	8		5		10	

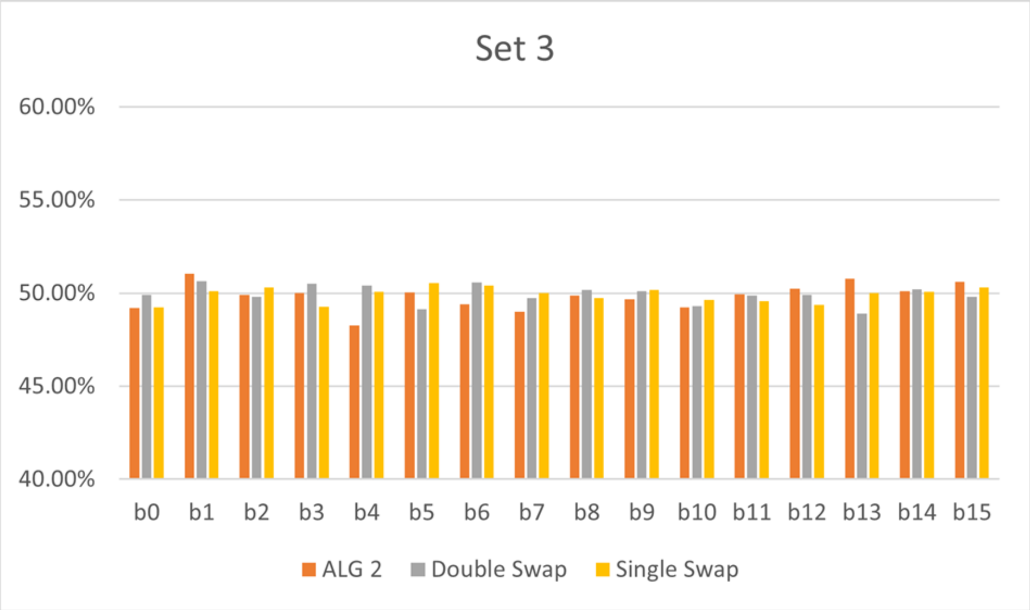
S-AES (Set 7)

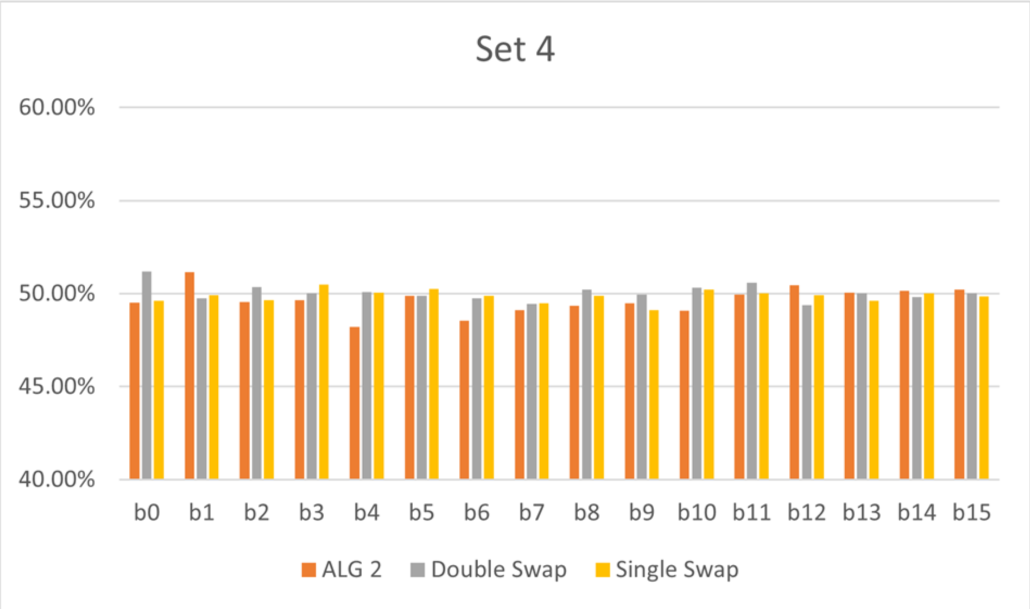
	S-Box 1		S-Box 2		S-Box 3		S-Box 4	
	P-val	Passed	P-val	Passed	P-val	Passed	P-val	Passed
Frequency	0.773	100%	0.018	100%	0.074	100%	0.082	100%
Block Frequency	0	93.33%	0.213	100%	0	98.33%	0.005	96.66%
Sums 1	0.834	100%	0	100%	0.067	100%	0.001	100%
Sums 2	0.862	100%	0.004	100%	0	100%	0.002	100%
Runs	0.007	100%	0.35	100%	0.018	100%	0.013	100%
Longest Run	0.195	100%	0.35	100%	0.534	100%	0.35	98.33%
Rank	0.213	100%	0.122	100%	0.008	100%	0.637	100%
FFT	0	11.66%	0	28.33%	0	13.33%	0	30.0%
Non-Overlapping	0.321	98.99%	0.312	98.98%	0.248	98.98%	0.297	99.22%
Overlapping	0.101	100%	0.163	100%	0.95	100%	0.378	95.0%
Universal	0.103	—	0.669	—	0.807	—	0.832	—
Entropy	0.013	100%	0	96.66%	0.002	100%	0.888	100%
Excursions	—	100%	0.337	98.86%	—	97.91%	0.558	98.95%
Excursion Variants	—	100%	0.427	100%	—	100%	0.478	99.53%
Serial 1	0	100%	0.002	100%	0.008	100%	0.35	100%
Serial 2	0.06	100%	0.568	100%	0.163	100%	0.195	100%
Linear Complexity	0.637	96.66%	0.706	100%	0.706	96.66%	0.637	100%
Average	0.275	93.78%	0.249	95.17%	0.239	94.07%	0.335	94.85%
100% Pass Rate	12		12		11		9	

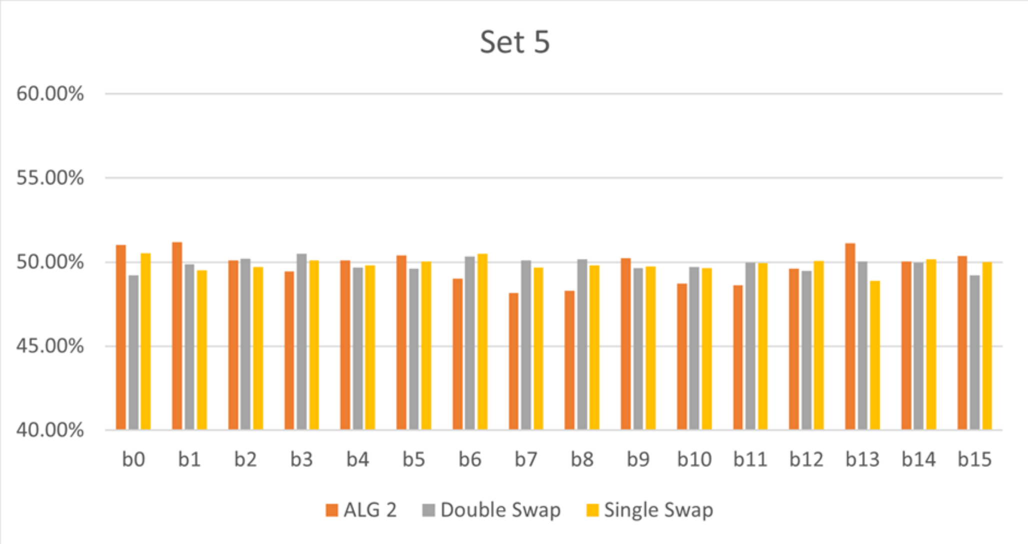
E Avalanche Criterion Analysis Results

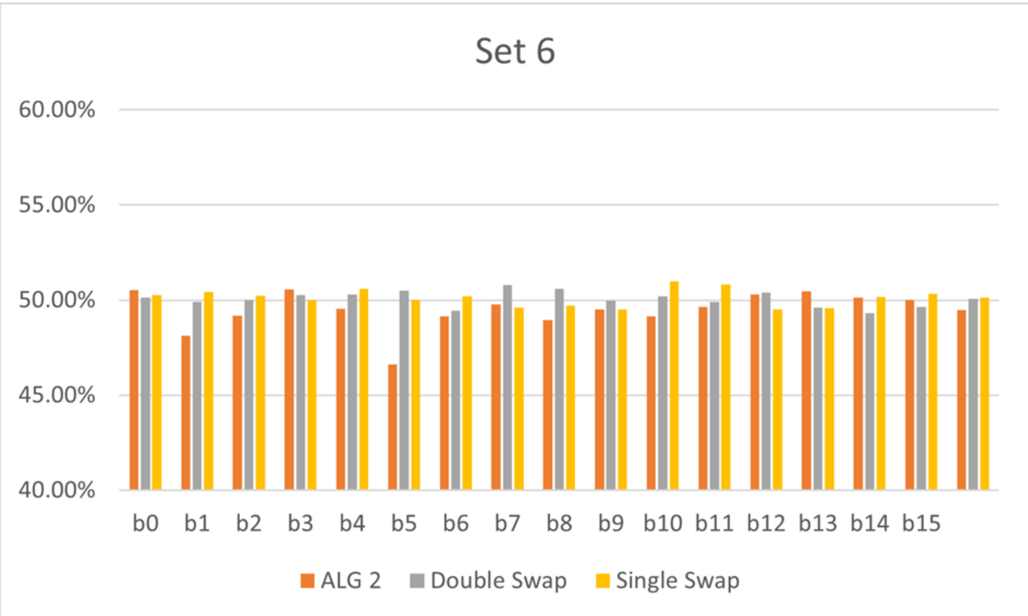


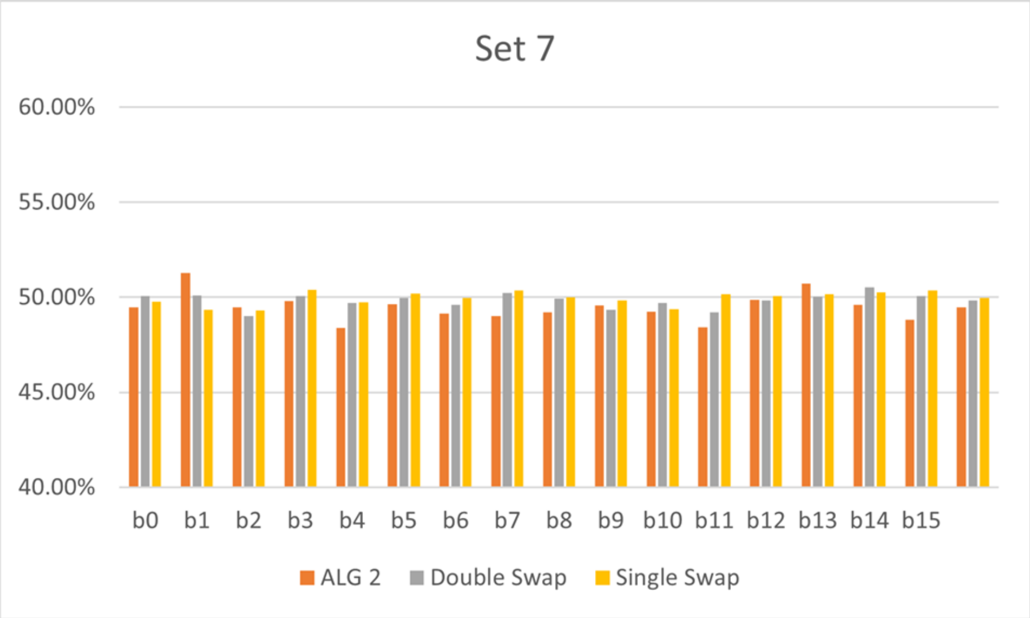


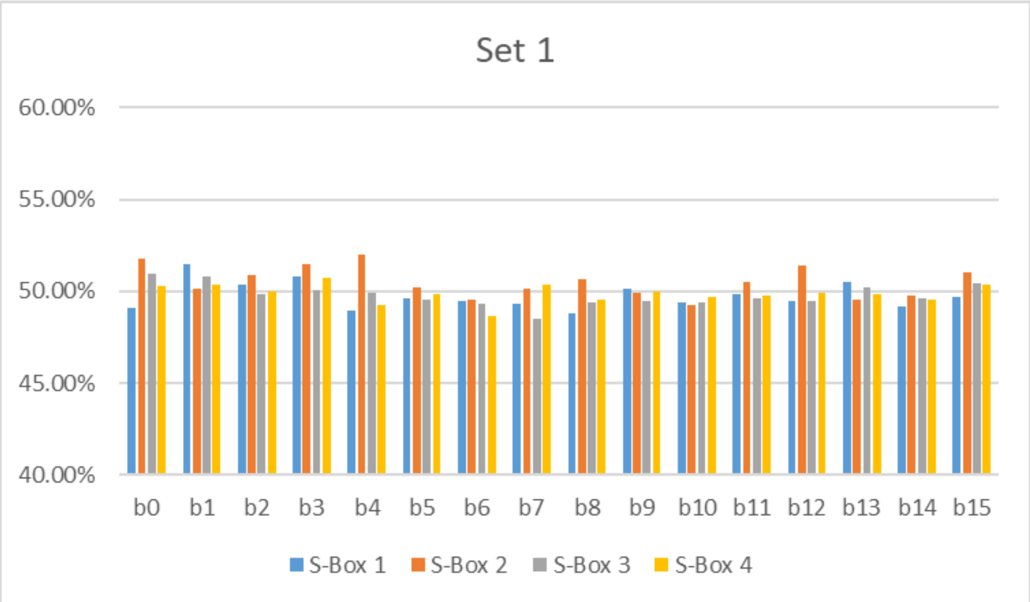

Set 3
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
ALG 2
Double Swap
Single Swap

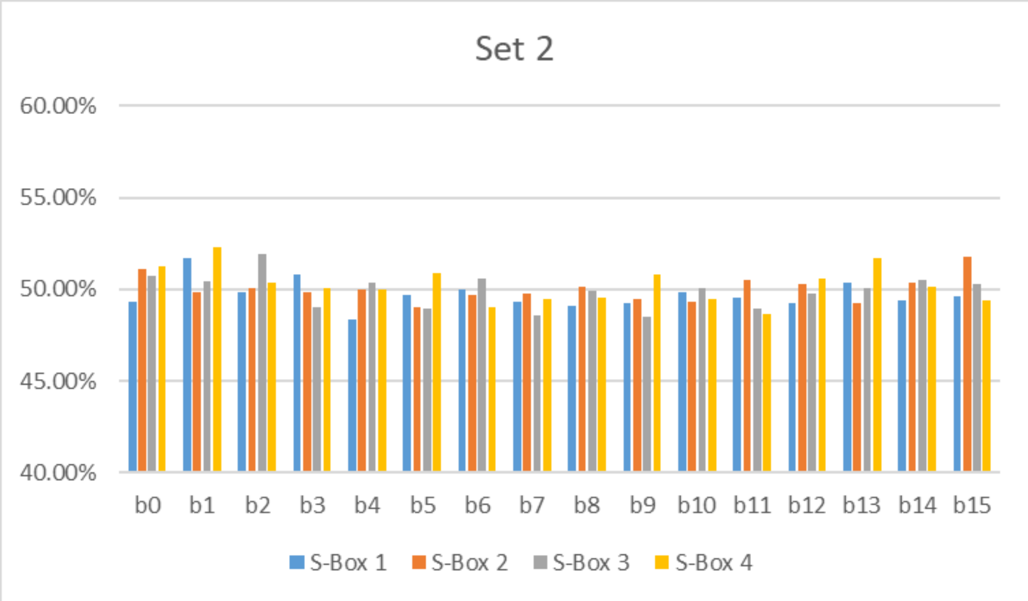

Set 4
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
ALG 2
Double Swap
Single Swap

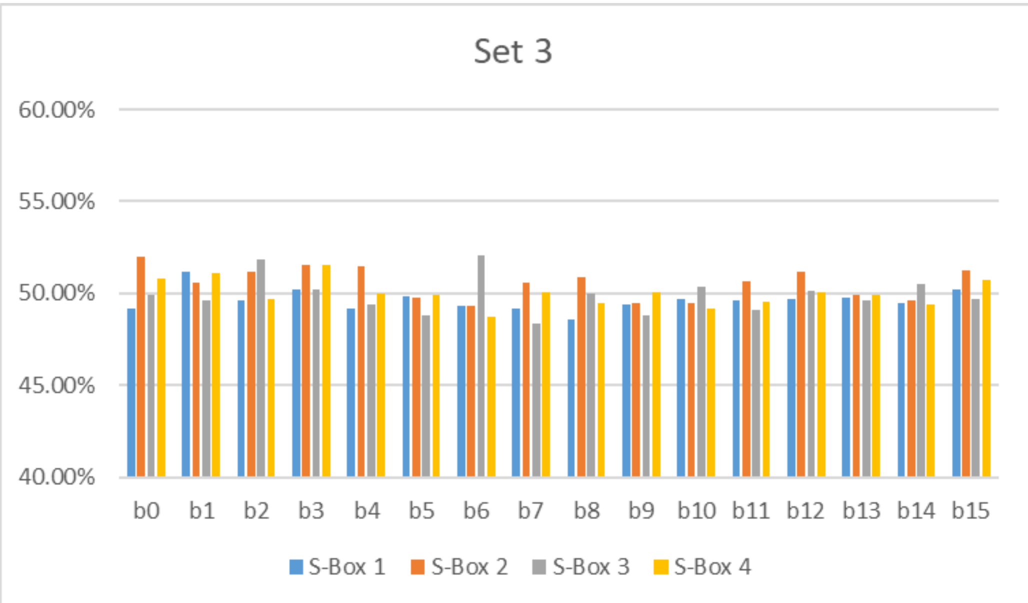

Set 5
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
ALG 2
Double Swap
Single Swap

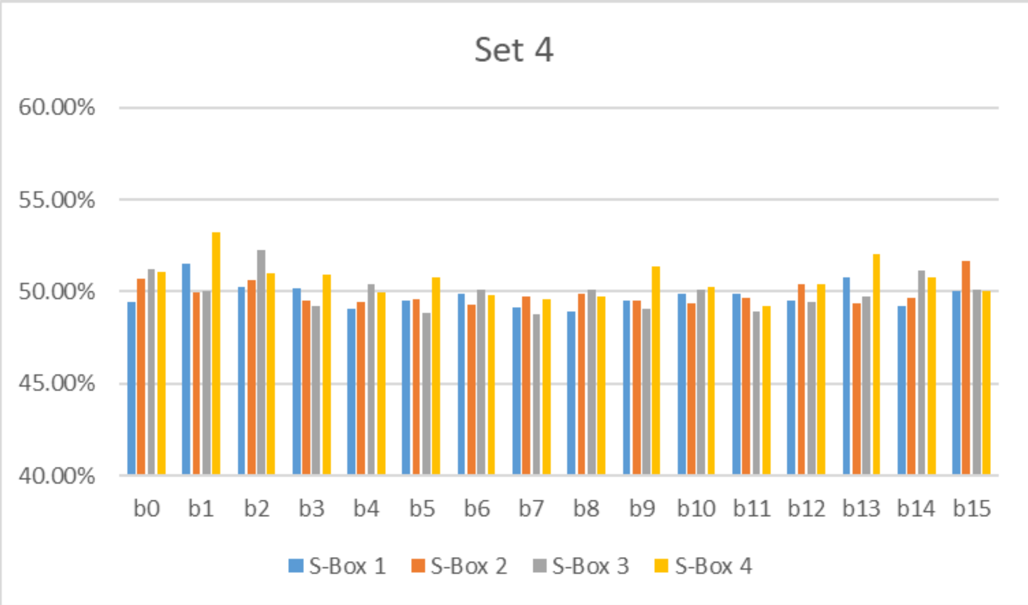

Set 6
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
ALG 2
Double Swap
Single Swap

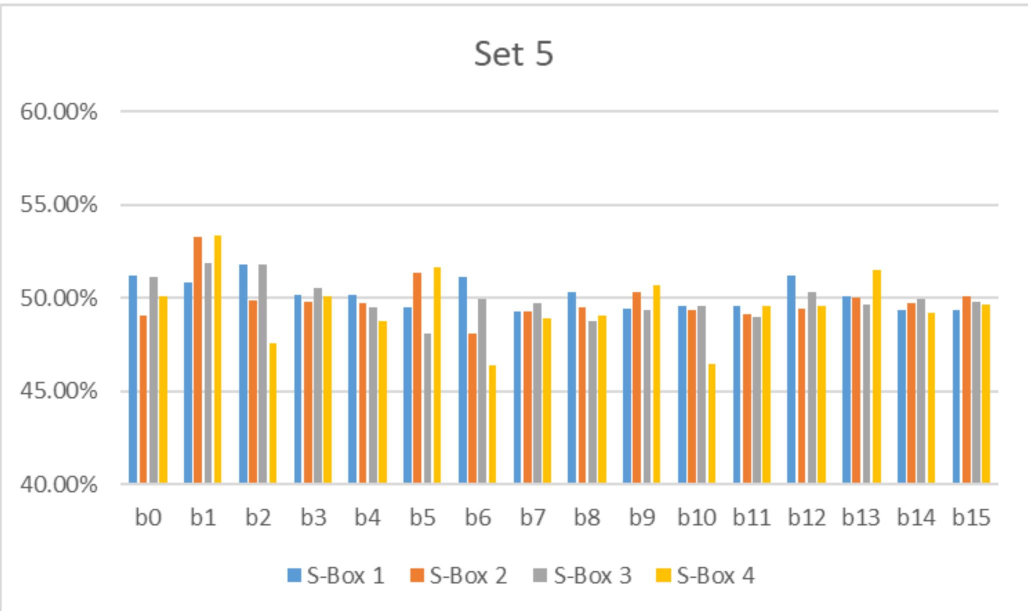

Set 7
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
ALG 2
Double Swap
Single Swap

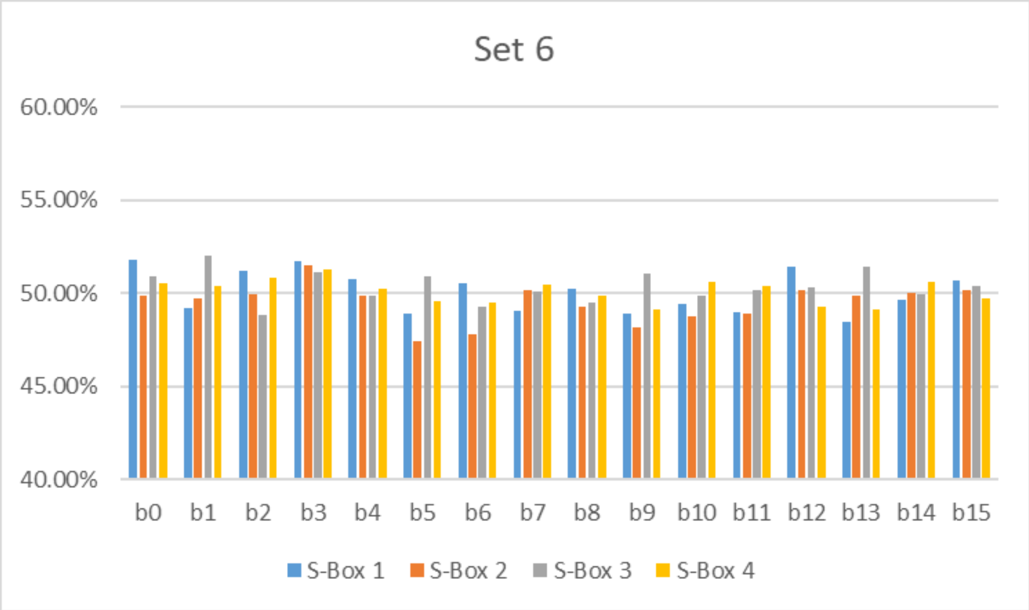

Set 1
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1
S-Box 2
S-Box 3
S-Box 4

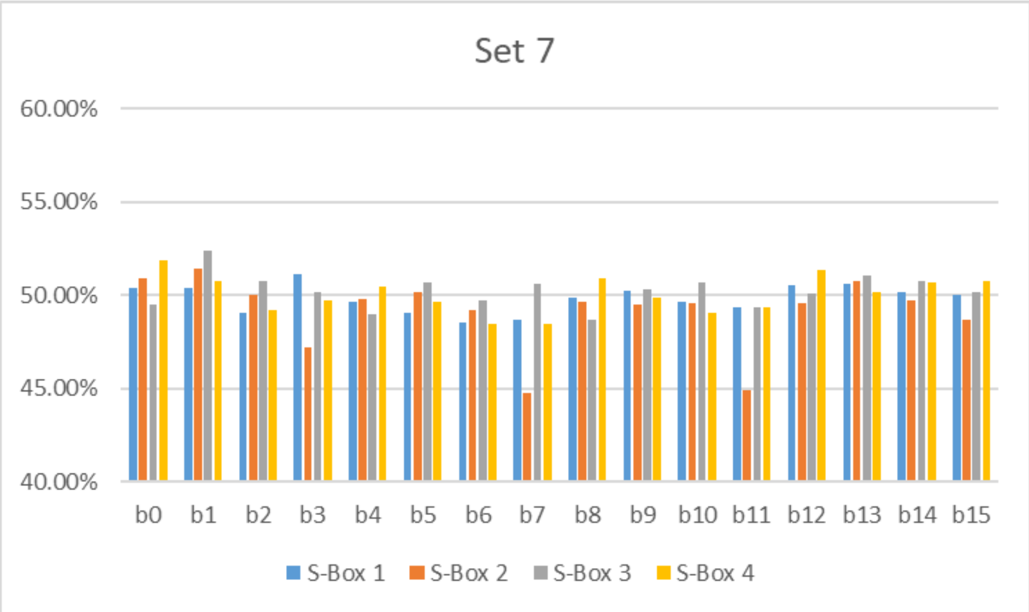

Set 2
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1 S-Box 2 S-Box 3 S-Box 4


Set 3
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1 S-Box 2 S-Box 3 S-Box 4


Set 4
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1 S-Box 2 S-Box 3 S-Box 4


Set 5
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1 S-Box 2 S-Box 3 S-Box 4


Set 6
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1 S-Box 2 S-Box 3 S-Box 4


Set 7
60.00%
55.00%
50.00%
45.00%
40.00%
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
S-Box 1 S-Box 2 S-Box 3 S-Box 4

F ANF of AES

$$
y_0 = x_0x_1x_2x_3x_4x_6x_7 \oplus x_0x_1x_2x_3x_4x_6 \oplus x_0x_1x_2x_3x_4x_7 \oplus x_0x_1x_2x_3x_4 \oplus x_0x_1x_2x_3x_5x_7 \oplus
x_0x_1x_2x_3x_6x_7 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_3 \oplus x_0x_1x_2x_4x_5x_6x_7 \oplus x_0x_1x_2x_4x_5x_7 \oplus
x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4x_7 \oplus x_0x_1x_2x_5x_6x_7 \oplus x_0x_1x_2x_5x_7 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2x_6x_7 \oplus
x_0x_1x_2x_6 \oplus x_0x_1x_2x_7 \oplus x_0x_1x_3x_4x_6x_7 \oplus x_0x_1x_3x_4x_6 \oplus x_0x_1x_3x_5x_6 \oplus x_0x_1x_3x_5x_7 \oplus x_0x_1x_3x_6x_7 \oplus
x_0x_1x_4x_5x_6x_7 \oplus x_0x_1x_4x_5x_6 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4x_7 \oplus x_0x_1x_4 \oplus x_0x_1x_5x_6x_7 \oplus x_0x_1x_6 \oplus
x_0x_1x_7 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5x_6x_7 \oplus x_0x_2x_3x_4x_5x_6 \oplus x_0x_2x_3x_4x_5x_7 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4x_6 \oplus
x_0x_2x_3x_5x_6x_7 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3x_7 \oplus x_0x_2x_4x_5x_7 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4x_6x_7 \oplus x_0x_2x_4x_7 \oplus
x_0x_2x_4 \oplus x_0x_2x_5x_6 \oplus x_0x_2x_5x_7 \oplus x_0x_2x_5 \oplus x_0x_2x_6 \oplus x_0x_2x_7 \oplus x_0x_3x_4x_5x_6 \oplus x_0x_3x_4x_5x_7 \oplus
x_0x_3x_4x_6x_7 \oplus x_0x_3x_4x_6 \oplus x_0x_3x_4 \oplus x_0x_3x_5x_6x_7 \oplus x_0x_3x_5x_6 \oplus x_0x_3x_5 \oplus x_0x_3x_6 \oplus x_0x_4x_5x_6 \oplus
x_0x_4x_5x_7 \oplus x_0x_4x_6x_7 \oplus x_0x_4x_6 \oplus x_0x_4x_7 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0x_6 \oplus x_0 \oplus x_1x_2x_3x_4x_6x_7 \oplus
x_1x_2x_3x_5x_6 \oplus x_1x_2x_3x_5x_7 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3x_6 \oplus x_1x_2x_3x_7 \oplus x_1x_2x_3 \oplus x_1x_2x_4x_5x_6x_7 \oplus
x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_6x_7 \oplus x_1x_2x_4x_6 \oplus x_1x_2x_4x_7 \oplus x_1x_2x_4 \oplus x_1x_2x_5x_6x_7 \oplus x_1x_2x_6x_7 \oplus
x_1x_2x_6 \oplus x_1x_2 \oplus x_1x_3x_4x_5x_6x_7 \oplus x_1x_3x_4x_5x_7 \oplus x_1x_3x_4x_6 \oplus x_1x_3x_4 \oplus x_1x_3x_6x_7 \oplus x_1x_3x_7 \oplus
x_1x_3 \oplus x_1x_4x_5x_6 \oplus x_1x_4x_5x_7 \oplus x_1x_4x_6 \oplus x_1x_4 \oplus x_1x_5x_6x_7 \oplus x_1x_5x_6 \oplus x_1x_6 \oplus x_2x_3x_4x_5x_6x_7 \oplus
x_2x_3x_4x_5x_6 \oplus x_2x_3x_4x_5x_7 \oplus x_2x_3x_5x_7 \oplus x_2x_3x_5 \oplus x_2x_3x_6x_7 \oplus x_2x_3x_7 \oplus x_2x_3 \oplus x_2x_4x_5x_6x_7 \oplus
x_2x_4x_5x_6 \oplus x_2x_4x_5x_7 \oplus x_2x_4x_7 \oplus x_2x_4 \oplus x_2x_5x_6 \oplus x_2x_5x_7 \oplus x_2x_6x_7 \oplus x_2x_6 \oplus x_2x_7 \oplus x_2 \oplus
x_3x_4x_7 \oplus x_3x_5x_6x_7 \oplus x_3x_5x_7 \oplus x_3x_6x_7 \oplus x_3 \oplus x_4x_5x_6 \oplus x_4x_6 \oplus x_4 \oplus x_5x_6x_7 \oplus x_5x_6 \oplus x_5x_7 \oplus
x_6x_7 \oplus 1
$$

$$
y_1 = x_0x_1x_2x_3x_4x_6x_7 \oplus x_0x_1x_2x_3x_4x_6 \oplus x_0x_1x_2x_3x_4x_7 \oplus x_0x_1x_2x_3x_4 \oplus x_0x_1x_2x_3x_5x_6x_7 \oplus
x_0x_1x_2x_3x_5x_6 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_4x_5x_6x_7 \oplus x_0x_1x_2x_4x_5x_7 \oplus x_0x_1x_2x_4x_5 \oplus
x_0x_1x_2x_4x_6x_7 \oplus x_0x_1x_2x_4x_6 \oplus x_0x_1x_2x_4x_7 \oplus x_0x_1x_2x_5x_6x_7 \oplus x_0x_1x_2x_6x_7 \oplus x_0x_1x_2x_6 \oplus
x_0x_1x_3x_4x_5x_6x_7 \oplus x_0x_1x_3x_4x_5x_6 \oplus x_0x_1x_3x_4x_6x_7 \oplus x_0x_1x_3x_4x_6 \oplus x_0x_1x_3x_4x_7 \oplus x_0x_1x_3x_4 \oplus
x_0x_1x_3x_5x_6 \oplus x_0x_1x_3x_5x_7 \oplus x_0x_1x_3x_6x_7 \oplus x_0x_1x_3x_6 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5x_6 \oplus x_0x_1x_4x_5 \oplus
x_0x_1x_4x_7 \oplus x_0x_1x_4 \oplus x_0x_1x_5x_6x_7 \oplus x_0x_1x_5x_6 \oplus x_0x_1x_6 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5x_6 \oplus x_0x_2x_3x_4x_5x_7 \oplus
x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4x_6x_7 \oplus x_0x_2x_3x_4x_7 \oplus x_0x_2x_3x_5x_6x_7 \oplus x_0x_2x_3x_5x_7 \oplus x_0x_2x_3x_6x_7 \oplus
x_0x_2x_3x_6 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5x_6 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_5x_6x_7 \oplus x_0x_2x_5x_6 \oplus x_0x_2x_7 \oplus x_0x_2 \oplus
x_0x_3x_4x_5x_7 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4x_6 \oplus x_0x_3x_4 \oplus x_0x_3x_5x_6x_7 \oplus x_0x_3 \oplus x_0x_4x_5x_6x_7 \oplus x_0x_4x_5x_6 \oplus
x_0x_4x_5x_7 \oplus x_0x_4x_5 \oplus x_0x_4x_6x_7 \oplus x_0x_4x_6 \oplus x_0x_4x_7 \oplus x_0x_4 \oplus x_0x_5x_7 \oplus x_0x_6x_7 \oplus x_0x_7 \oplus x_0 \oplus
x_1x_2x_3x_4x_5x_6 \oplus x_1x_2x_3x_4x_6x_7 \oplus x_1x_2x_3x_4x_6 \oplus x_1x_2x_3x_5x_6x_7 \oplus x_1x_2x_3x_5x_6 \oplus x_1x_2x_3x_5 \oplus
x_1x_2x_3 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_7 \oplus x_1x_2x_4 \oplus x_1x_2x_5x_6 \oplus x_1x_2x_5x_7 \oplus x_1x_2x_6x_7 \oplus x_1x_3x_4x_5x_6x_7 \oplus
x_1x_3x_4x_5x_6 \oplus x_1x_3x_4x_5x_7 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4x_7 \oplus x_1x_3x_4 \oplus x_1x_3x_5x_6 \oplus x_1x_3x_5x_7 \oplus
x_1x_3x_5 \oplus x_1x_3x_6 \oplus x_1x_3x_7 \oplus x_1x_3 \oplus x_1x_4x_5x_7 \oplus x_1x_4x_6x_7 \oplus x_1x_4x_7 \oplus x_1x_4 \oplus x_1x_5x_6 \oplus
x_1x_7 \oplus x_2x_3x_4x_5x_7 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4x_6x_7 \oplus x_2x_3x_4x_7 \oplus x_2x_3x_4 \oplus x_2x_3x_5x_7 \oplus x_2x_3x_5 \oplus
x_2x_3x_6 \oplus x_2x_3 \oplus x_2x_4x_5x_6x_7 \oplus x_2x_4x_5x_7 \oplus x_2x_4x_6x_7 \oplus x_2x_5x_7 \oplus x_2x_6x_7 \oplus x_2x_6 \oplus x_2x_7 \oplus
x_3x_4x_5x_6 \oplus x_3x_4x_5x_7 \oplus x_3x_4x_6x_7 \oplus x_3x_4x_6 \oplus x_3x_4x_7 \oplus x_3x_5x_6 \oplus x_3x_5x_7 \oplus x_3x_6x_7 \oplus x_3x_7 \oplus
x_3 \oplus x_4x_5 \oplus x_4x_6 \oplus x_5x_6x_7 \oplus x_6 \oplus x_7 \oplus 1
$$

$$
y_2 = x_0x_1x_2x_3x_4x_5 \oplus x_0x_1x_2x_3x_4x_6x_7 \oplus x_0x_1x_2x_3x_4x_6 \oplus x_0x_1x_2x_3x_4x_7 \oplus x_0x_1x_2x_3x_4 \oplus
x_0x_1x_2x_3x_5x_6x_7 \oplus x_0x_1x_2x_3x_5x_6 \oplus x_0x_1x_2x_3x_5 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_4x_5x_6 \oplus
x_0x_1x_2x_4x_5x_7 \oplus x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4x_7 \oplus x_0x_1x_2x_5x_7 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2x_6x_7 \oplus
x_0x_1x_2x_7 \oplus x_0x_1x_3x_4x_5x_6x_7 \oplus x_0x_1x_3x_4x_5x_7 \oplus x_0x_1x_3x_4x_6x_7 \oplus x_0x_1x_3x_4x_6 \oplus x_0x_1x_3x_4x_7 \oplus
x_0x_1x_3x_4 \oplus x_0x_1x_3x_5x_6x_7 \oplus x_0x_1x_3x_5x_7 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3x_6x_7 \oplus x_0x_1x_3x_6 \oplus x_0x_1x_3 \oplus
x_0x_1x_4x_5x_6x_7 \oplus x_0x_1x_4x_6x_7 \oplus x_0x_1x_4x_6 \oplus x_0x_1x_4 \oplus x_0x_1x_5x_6 \oplus x_0x_1x_5 \oplus x_0x_1x_6 \oplus x_0x_1x_7 \oplus
x_0x_2x_3x_4x_5x_6x_7 \oplus x_0x_2x_3x_4x_5x_6 \oplus x_0x_2x_3x_4x_6x_7 \oplus x_0x_2x_3x_4x_7 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5x_6x_7 \oplus
x_0x_2x_3x_5x_7 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3x_7 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5x_6x_7 \oplus x_0x_2x_4x_5x_6 \oplus x_0x_2x_4x_6 \oplus
x_0x_2x_4x_7 \oplus x_0x_2x_4 \oplus x_0x_2x_5x_6x_7 \oplus x_0x_2x_5 \oplus x_0x_2x_7 \oplus x_0x_2 \oplus x_0x_3x_4x_5x_7 \oplus x_0x_3x_4x_6 \oplus
x_0x_3x_4x_7 \oplus x_0x_3x_4 \oplus x_0x_3x_5x_6x_7 \oplus x_0x_3x_5x_6 \oplus x_0x_3x_5x_7 \oplus x_0x_3x_5 \oplus x_0x_3x_6 \oplus x_0x_3x_7 \oplus x_0x_3 \oplus
x_0x_4x_5x_6x_7 \oplus x_0x_4x_5 \oplus x_0x_4x_6 \oplus x_0x_4x_7 \oplus x_0x_4 \oplus x_0x_5x_7 \oplus x_0x_5 \oplus x_0x_6x_7 \oplus x_0x_6 \oplus x_0x_7 \oplus x_0 \oplus
x_1x_2x_3x_4x_5x_6x_7 \oplus x_1x_2x_3x_4x_5x_7 \oplus x_1x_2x_3x_4x_5 \oplus x_1x_2x_3x_4x_6x_7 \oplus x_1x_2x_3x_4x_6 \oplus x_1x_2x_3x_4 \oplus
x_1x_2x_3x_5 \oplus x_1x_2x_3x_6x_7 \oplus x_1x_2x_3x_6 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_5x_7 \oplus x_1x_2x_4x_6x_7 \oplus x_1x_2x_4x_7 \oplus
$$

$x_1x_2x_4 \oplus x_1x_2x_5x_7 \oplus x_1x_2x_5 \oplus x_1x_2x_6x_7 \oplus x_1x_2x_6 \oplus x_1x_2x_7 \oplus x_1x_3x_4x_5x_6 \oplus x_1x_3x_4x_6x_7 \oplus$
$x_1x_3x_4 \oplus x_1x_3x_5x_6x_7 \oplus x_1x_3x_5x_7 \oplus x_1x_3x_5 \oplus x_1x_3x_6x_7 \oplus x_1x_3x_7 \oplus x_1x_4x_5x_6x_7 \oplus x_1x_4x_5x_7 \oplus$
$x_1x_4x_5 \oplus x_1x_4x_7 \oplus x_1x_4 \oplus x_1x_5x_6x_7 \oplus x_1x_5x_6 \oplus x_1x_5x_7 \oplus x_1 \oplus x_2x_3x_4x_5x_6x_7 \oplus x_2x_3x_4x_6x_7 \oplus$
$x_2x_3x_4x_6 \oplus x_2x_3x_4x_7 \oplus x_2x_3x_4 \oplus x_2x_3x_5x_6x_7 \oplus x_2x_3x_5x_6 \oplus x_2x_3x_6 \oplus x_2x_3x_7 \oplus x_2x_3 \oplus$
$x_2x_4x_5x_6 \oplus x_2x_4x_5x_7 \oplus x_2x_4x_5 \oplus x_2x_4x_6x_7 \oplus x_2x_5x_6x_7 \oplus x_2x_6x_7 \oplus x_3x_4x_5x_6x_7 \oplus x_3x_4x_5x_6 \oplus$
$x_3x_4x_5 \oplus x_3x_4x_6 \oplus x_3x_4 \oplus x_3x_5x_6x_7 \oplus x_3x_5x_6 \oplus x_4x_5x_6x_7 \oplus x_4x_6x_7 \oplus x_4x_7 \oplus x_5x_6 \oplus x_5 \oplus$
$x_6x_7 \oplus x_7$

$y_3 = x_0x_1x_2x_3x_4x_5x_6 \oplus x_0x_1x_2x_3x_4x_6 \oplus x_0x_1x_2x_3x_4x_7 \oplus x_0x_1x_2x_3x_4 \oplus x_0x_1x_2x_3x_5x_6x_7 \oplus$
$x_0x_1x_2x_3x_5x_6 \oplus x_0x_1x_2x_3x_5x_7 \oplus x_0x_1x_2x_3x_5 \oplus x_0x_1x_2x_3x_6x_7 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_3 \oplus$
$x_0x_1x_2x_4x_5x_7 \oplus x_0x_1x_2x_4x_6x_7 \oplus x_0x_1x_2x_4x_7 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5x_6 \oplus x_0x_1x_2x_5x_7 \oplus$
$x_0x_1x_2x_5 \oplus x_0x_1x_3x_4x_5x_6x_7 \oplus x_0x_1x_3x_4x_5x_7 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4x_6 \oplus x_0x_1x_3x_4x_7 \oplus$
$x_0x_1x_3x_5x_6 \oplus x_0x_1x_3x_6 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5x_7 \oplus x_0x_1x_4x_6 \oplus x_0x_1x_4 \oplus x_0x_1x_5x_6x_7 \oplus$
$x_0x_1x_5x_6 \oplus x_0x_1x_5 \oplus x_0x_1x_6x_7 \oplus x_0x_1x_6 \oplus x_0x_1x_7 \oplus x_0x_2x_3x_4x_5x_6x_7 \oplus x_0x_2x_3x_4x_5 \oplus$
$x_0x_2x_3x_4x_6x_7 \oplus x_0x_2x_3x_5x_6x_7 \oplus x_0x_2x_3x_5x_6 \oplus x_0x_2x_3x_5x_7 \oplus x_0x_2x_3x_6x_7 \oplus x_0x_2x_3x_7 \oplus$
$x_0x_2x_3 \oplus x_0x_2x_4x_5x_6 \oplus x_0x_2x_4x_5x_7 \oplus x_0x_2x_4x_6 \oplus x_0x_2x_4x_7 \oplus x_0x_2x_4 \oplus x_0x_2x_5x_6x_7 \oplus$
$x_0x_2x_5x_6 \oplus x_0x_2x_6x_7 \oplus x_0x_2x_6 \oplus x_0x_2x_7 \oplus x_0x_3x_4x_5x_6 \oplus x_0x_3x_4x_5x_7 \oplus x_0x_3x_4x_6x_7 \oplus$
$x_0x_3x_4x_6 \oplus x_0x_3x_4 \oplus x_0x_3x_5x_6x_7 \oplus x_0x_3x_6x_7 \oplus x_0x_3x_6 \oplus x_0x_3x_7 \oplus x_0x_3 \oplus x_0x_4x_5x_6x_7 \oplus$
$x_0x_4x_5x_6 \oplus x_0x_4x_5 \oplus x_0x_4x_6 \oplus x_0x_5x_6x_7 \oplus x_0x_7 \oplus x_0 \oplus x_1x_2x_3x_4x_5x_6 \oplus x_1x_2x_3x_4x_5x_7 \oplus$
$x_1x_2x_3x_4x_6x_7 \oplus x_1x_2x_3x_5x_6x_7 \oplus x_1x_2x_3x_5x_6 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3x_6 \oplus x_1x_2x_3x_7 \oplus x_1x_2x_3 \oplus$
$x_1x_2x_4x_5x_6x_7 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4x_7 \oplus x_1x_2x_5x_6x_7 \oplus x_1x_2x_5x_7 \oplus x_1x_2x_5 \oplus$
$x_1x_2x_6x_7 \oplus x_1x_2x_6 \oplus x_1x_2x_7 \oplus x_1x_2 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4x_6x_7 \oplus x_1x_3x_4x_6 \oplus x_1x_3x_4x_7 \oplus$
$x_1x_3x_4 \oplus x_1x_3x_5x_6x_7 \oplus x_1x_3x_5x_6 \oplus x_1x_4x_5x_6 \oplus x_1x_4x_5x_7 \oplus x_1x_4x_6x_7 \oplus x_1x_5x_6x_7 \oplus x_1x_5x_6 \oplus$
$x_1x_7 \oplus x_2x_3x_4x_5x_6x_7 \oplus x_2x_3x_4x_5x_6 \oplus x_2x_3x_4x_5x_7 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4 \oplus x_2x_3x_5 \oplus x_2x_3x_7 \oplus$
$x_2x_3 \oplus x_2x_4x_5x_6x_7 \oplus x_2x_4x_5x_6 \oplus x_2x_4x_5x_7 \oplus x_2x_4x_5 \oplus x_2x_4x_6x_7 \oplus x_2x_5x_7 \oplus x_3x_4x_5x_6x_7 \oplus$
$x_3x_4x_5x_6 \oplus x_3x_4x_6x_7 \oplus x_3x_4x_7 \oplus x_3x_5x_6x_7 \oplus x_3x_5x_6 \oplus x_3x_5x_7 \oplus x_3x_6 \oplus x_3x_7 \oplus x_4x_5x_6x_7 \oplus$
$x_4x_5 \oplus x_4 \oplus x_5x_6x_7 \oplus x_5x_6 \oplus x_5x_7 \oplus x_6x_7 \oplus x_6 \oplus x_7$

$y_4 = x_0x_1x_2x_3x_4x_5x_7 \oplus x_0x_1x_2x_3x_4x_5 \oplus x_0x_1x_2x_3x_4x_6x_7 \oplus x_0x_1x_2x_3x_4x_7 \oplus x_0x_1x_2x_3x_4 \oplus$
$x_0x_1x_2x_3x_5x_6 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_4x_5x_6 \oplus x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_5x_7 \oplus$
$x_0x_1x_2x_6x_7 \oplus x_0x_1x_2x_6 \oplus x_0x_1x_3x_4x_5x_6 \oplus x_0x_1x_3x_4x_6 \oplus x_0x_1x_3x_5x_7 \oplus x_0x_1x_3x_5 \oplus x_0x_1x_3x_6x_7 \oplus$
$x_0x_1x_3x_6 \oplus x_0x_1x_3x_7 \oplus x_0x_1x_4x_5x_6 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4x_6 \oplus x_0x_1x_5x_6x_7 \oplus x_0x_1x_5x_6 \oplus$
$x_0x_1x_5x_7 \oplus x_0x_1x_6x_7 \oplus x_0x_1 \oplus x_0x_2x_3x_4x_5x_6x_7 \oplus x_0x_2x_3x_4x_5x_7 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4x_6 \oplus$
$x_0x_2x_3x_4 \oplus x_0x_2x_3x_5x_6 \oplus x_0x_2x_3x_5x_7 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_6x_7 \oplus x_0x_2x_5x_7 \oplus x_0x_2x_6 \oplus$
$x_0x_3x_4x_5x_6x_7 \oplus x_0x_3x_4x_5 \oplus x_0x_3x_4x_6x_7 \oplus x_0x_3x_4x_6 \oplus x_0x_3x_4x_7 \oplus x_0x_3x_4 \oplus x_0x_3x_5x_6x_7 \oplus$
$x_0x_3x_5x_6 \oplus x_0x_3x_5x_7 \oplus x_0x_3x_5 \oplus x_0x_3x_6x_7 \oplus x_0x_4x_5x_6x_7 \oplus x_0x_4x_5x_6 \oplus x_0x_4x_5 \oplus x_0x_4x_6x_7 \oplus$
$x_0x_4x_6 \oplus x_0x_4x_7 \oplus x_0x_4 \oplus x_0x_5 \oplus x_0x_6x_7 \oplus x_0x_6 \oplus x_0x_7 \oplus x_0 \oplus x_1x_2x_3x_4x_5x_6 \oplus x_1x_2x_3x_4x_5x_7 \oplus$
$x_1x_2x_3x_4x_6x_7 \oplus x_1x_2x_3x_4x_6 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5x_6x_7 \oplus x_1x_2x_3x_5x_6 \oplus x_1x_2x_3x_5x_7 \oplus$
$x_1x_2x_3x_5 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_5x_7 \oplus x_1x_2x_4x_6 \oplus x_1x_2x_4 \oplus x_1x_2x_5x_6x_7 \oplus x_1x_2x_5x_7 \oplus$
$x_1x_2x_6x_7 \oplus x_1x_3x_4x_5x_6 \oplus x_1x_3x_4x_5x_7 \oplus x_1x_3x_4x_5 \oplus x_1x_3x_4x_7 \oplus x_1x_3x_5x_6x_7 \oplus x_1x_3x_5 \oplus$
$x_1x_4x_5x_6x_7 \oplus x_1x_4x_5 \oplus x_1x_4 \oplus x_1x_5x_7 \oplus x_1x_5 \oplus x_1x_6x_7 \oplus x_1x_6 \oplus x_1 \oplus x_2x_3x_4x_5x_6 \oplus$
$x_2x_3x_4x_5x_7 \oplus x_2x_3x_4x_6x_7 \oplus x_2x_3x_4x_7 \oplus x_2x_3x_4 \oplus x_2x_3x_5x_6 \oplus x_2x_3x_5x_7 \oplus x_2x_3x_5 \oplus x_2x_3x_6 \oplus$
$x_2x_3 \oplus x_2x_4x_5x_6x_7 \oplus x_2x_4x_5 \oplus x_2x_4x_7 \oplus x_2x_5x_6 \oplus x_2x_5 \oplus x_2x_6x_7 \oplus x_2 \oplus x_3x_4x_5x_6x_7 \oplus$
$x_3x_4x_5x_7 \oplus x_3x_4x_5 \oplus x_3x_4x_6x_7 \oplus x_3x_4x_6 \oplus x_3x_4x_7 \oplus x_3x_4 \oplus x_3x_5x_6x_7 \oplus x_3x_5x_6 \oplus x_3x_5x_7 \oplus$
$x_3x_5 \oplus x_3x_6x_7 \oplus x_3x_7 \oplus x_3 \oplus x_4x_5x_7 \oplus x_4x_5 \oplus x_4x_6x_7 \oplus x_4x_6 \oplus x_5x_6x_7 \oplus x_5x_7 \oplus x_5 \oplus x_6x_7$

$y_5 = x_0x_1x_2x_3x_4x_5 \oplus x_0x_1x_2x_3x_4 \oplus x_0x_1x_2x_3x_5x_6x_7 \oplus x_0x_1x_2x_3x_5x_6 \oplus x_0x_1x_2x_3x_5x_7 \oplus$
$x_0x_1x_2x_3x_5 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_3 \oplus x_0x_1x_2x_4x_5x_6x_7 \oplus x_0x_1x_2x_4x_5x_6 \oplus$
$x_0x_1x_2x_4x_5x_7 \oplus x_0x_1x_2x_4x_5 \oplus x_0x_1x_2x_4x_6 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2x_6x_7 \oplus x_0x_1x_2 \oplus x_0x_1x_3x_4 \oplus$
$x_0x_1x_3x_5x_7 \oplus x_0x_1x_3x_7 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5x_6 \oplus x_0x_1x_4x_5x_7 \oplus x_0x_1x_4x_5 \oplus x_0x_1x_4x_6x_7 \oplus$
$x_0x_1x_4x_6 \oplus x_0x_1x_4x_7 \oplus x_0x_1x_4 \oplus x_0x_1x_5x_6x_7 \oplus x_0x_1x_5x_6 \oplus x_0x_1x_5x_7 \oplus x_0x_1x_5 \oplus x_0x_1x_6 \oplus$
$x_0x_1x_7 \oplus x_0x_2x_3x_4x_6x_7 \oplus x_0x_2x_3x_4x_7 \oplus x_0x_2x_3x_4 \oplus x_0x_2x_3x_5x_7 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3x_6x_7 \oplus$

$x_0x_2x_4x_5x_6x_7 \oplus x_0x_2x_4x_5x_7 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4 \oplus x_0x_2x_6 \oplus x_0x_3x_4x_5x_6 \oplus x_0x_3x_4x_5x_7 \oplus$
$x_0x_3x_4x_7 \oplus x_0x_3x_5 \oplus x_0x_3 \oplus x_0x_4x_5x_6x_7 \oplus x_0x_4x_6x_7 \oplus x_0x_4x_7 \oplus x_0x_5x_6x_7 \oplus x_0x_5x_6 \oplus$
$x_1x_2x_3x_4x_6x_7 \oplus x_1x_2x_3x_4x_6 \oplus x_1x_2x_3x_4x_7 \oplus x_1x_2x_3x_5x_6x_7 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3x_6 \oplus$
$x_1x_2x_4x_5x_6x_7 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4x_7 \oplus x_1x_2x_4 \oplus x_1x_2x_5 \oplus x_1x_2x_6 \oplus x_1x_3x_4x_5x_6 \oplus$
$x_1x_3x_4x_6x_7 \oplus x_1x_3x_4x_6 \oplus x_1x_3x_4x_7 \oplus x_1x_3x_5x_6 \oplus x_1x_3x_5x_7 \oplus x_1x_3x_5 \oplus x_1x_3x_6 \oplus x_1x_3x_7 \oplus$
$x_1x_4x_5x_7 \oplus x_1x_4x_6 \oplus x_1x_4x_7 \oplus x_1x_5x_6 \oplus x_1x_5x_7 \oplus x_1x_5 \oplus x_1x_6x_7 \oplus x_1x_6 \oplus x_2x_3x_4x_5x_6 \oplus$
$x_2x_3x_4x_5 \oplus x_2x_3x_4x_6 \oplus x_2x_3x_4x_7 \oplus x_2x_3x_5x_6x_7 \oplus x_2x_3x_5x_6 \oplus x_2x_3x_6 \oplus x_2x_3x_7 \oplus x_2x_4x_5x_6x_7 \oplus$
$x_2x_4x_5x_7 \oplus x_2x_4x_5 \oplus x_2x_4x_7 \oplus x_2x_4 \oplus x_2x_5x_7 \oplus x_2x_6x_7 \oplus x_3x_4x_5x_6 \oplus x_3x_4x_5x_7 \oplus x_3x_4x_5 \oplus$
$x_3x_4x_6x_7 \oplus x_3x_4 \oplus x_3x_5x_7 \oplus x_4x_5x_7 \oplus x_4x_6 \oplus x_4 \oplus x_5x_6x_7 \oplus x_5x_7 \oplus x_6 \oplus x_7 \oplus 1$

$y_6 = x_0x_1x_2x_3x_4x_7 \oplus x_0x_1x_2x_3x_5x_6 \oplus x_0x_1x_2x_3x_5 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3x_7 \oplus x_0x_1x_2x_4x_5x_6x_7 \oplus$
$x_0x_1x_2x_4x_5x_6 \oplus x_0x_1x_2x_4x_5x_7 \oplus x_0x_1x_2x_4x_6x_7 \oplus x_0x_1x_2x_4 \oplus x_0x_1x_2x_5x_6x_7 \oplus x_0x_1x_2x_5 \oplus$
$x_0x_1x_3x_4x_5x_6x_7 \oplus x_0x_1x_3x_4x_5x_6 \oplus x_0x_1x_3x_4x_5x_7 \oplus x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4x_6x_7 \oplus x_0x_1x_3x_4 \oplus$
$x_0x_1x_3x_5x_6x_7 \oplus x_0x_1x_3x_6x_7 \oplus x_0x_1x_3x_6 \oplus x_0x_1x_3x_7 \oplus x_0x_1x_3 \oplus x_0x_1x_4x_5x_7 \oplus x_0x_1x_4 \oplus$
$x_0x_1x_5 \oplus x_0x_1x_6x_7 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_5x_6 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3x_6 \oplus x_0x_2x_3x_7 \oplus$
$x_0x_2x_4x_5x_7 \oplus x_0x_2x_4x_5 \oplus x_0x_2x_4x_6x_7 \oplus x_0x_2x_4x_6 \oplus x_0x_2x_4 \oplus x_0x_2x_5x_6x_7 \oplus x_0x_2x_5x_7 \oplus$
$x_0x_2x_5 \oplus x_0x_2x_6 \oplus x_0x_3x_4x_6x_7 \oplus x_0x_3x_4x_6 \oplus x_0x_3x_4x_7 \oplus x_0x_3x_5 \oplus x_0x_3x_6 \oplus x_0x_4x_5x_6x_7 \oplus$
$x_0x_4x_5 \oplus x_0x_4x_6x_7 \oplus x_0x_4x_6 \oplus x_0x_4x_7 \oplus x_0x_4 \oplus x_0x_5x_6 \oplus x_0x_5x_7 \oplus x_0x_5 \oplus x_0x_7 \oplus x_1x_2x_3x_4x_5 \oplus$
$x_1x_2x_3x_4x_7 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5x_7 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3x_6 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_5 \oplus$
$x_1x_2x_4x_7 \oplus x_1x_2x_5x_6x_7 \oplus x_1x_2x_5 \oplus x_1x_2x_6 \oplus x_1x_2x_7 \oplus x_1x_3x_4x_5x_6x_7 \oplus x_1x_3x_4x_5x_6 \oplus$
$x_1x_3x_4x_5x_7 \oplus x_1x_3x_4x_6 \oplus x_1x_3x_4x_7 \oplus x_1x_3x_4 \oplus x_1x_3x_5x_7 \oplus x_1x_3x_6 \oplus x_1x_3 \oplus x_1x_4x_5x_6x_7 \oplus$
$x_1x_4x_5x_7 \oplus x_1x_4x_6x_7 \oplus x_1x_4x_6 \oplus x_1x_4x_7 \oplus x_1x_5x_6 \oplus x_1x_6x_7 \oplus x_1x_7 \oplus x_2x_3x_4x_5 \oplus x_2x_3x_4x_6x_7 \oplus$
$x_2x_3x_4x_6 \oplus x_2x_3x_4 \oplus x_2x_3x_5x_6x_7 \oplus x_2x_3x_5x_6 \oplus x_2x_3x_5x_7 \oplus x_2x_3x_7 \oplus x_2x_3 \oplus x_2x_4x_6 \oplus$
$x_2x_4x_7 \oplus x_3x_4x_5x_6x_7 \oplus x_3x_4x_6 \oplus x_3x_5x_7 \oplus x_3x_5 \oplus x_3x_6x_7 \oplus x_3x_7 \oplus x_3 \oplus x_4x_5x_6x_7 \oplus x_4x_5x_6 \oplus$
$x_4x_6 \oplus x_5x_6x_7 \oplus x_5x_7 \oplus x_5 \oplus x_6 \oplus 1$

$y_7 = x_0x_1x_2x_3x_4 \oplus x_0x_1x_2x_3x_6x_7 \oplus x_0x_1x_2x_3x_6 \oplus x_0x_1x_2x_3 \oplus x_0x_1x_2x_4x_5x_7 \oplus x_0x_1x_2x_4x_6 \oplus$
$x_0x_1x_2x_4 \oplus x_0x_1x_2x_5x_7 \oplus x_0x_1x_2x_5 \oplus x_0x_1x_2x_6x_7 \oplus x_0x_1x_2x_7 \oplus x_0x_1x_3x_4x_5x_6x_7 \oplus x_0x_1x_3x_4x_5x_7 \oplus$
$x_0x_1x_3x_4x_5 \oplus x_0x_1x_3x_4x_6x_7 \oplus x_0x_1x_3x_4x_7 \oplus x_0x_1x_3x_4 \oplus x_0x_1x_3x_5x_6x_7 \oplus x_0x_1x_3x_6 \oplus$
$x_0x_1x_4x_5x_6 \oplus x_0x_1x_4x_5x_7 \oplus x_0x_1x_4x_7 \oplus x_0x_1x_4 \oplus x_0x_1x_5x_6x_7 \oplus x_0x_1x_5 \oplus x_0x_1x_6 \oplus x_0x_2x_3x_4x_5x_6x_7 \oplus$
$x_0x_2x_3x_4x_5x_6 \oplus x_0x_2x_3x_4x_5x_7 \oplus x_0x_2x_3x_4x_5 \oplus x_0x_2x_3x_4x_6x_7 \oplus x_0x_2x_3x_4x_6 \oplus x_0x_2x_3x_4x_7 \oplus$
$x_0x_2x_3x_5x_6x_7 \oplus x_0x_2x_3x_5 \oplus x_0x_2x_3x_6 \oplus x_0x_2x_3x_7 \oplus x_0x_2x_3 \oplus x_0x_2x_4x_5x_6x_7 \oplus x_0x_2x_4x_6 \oplus$
$x_0x_2x_4x_7 \oplus x_0x_2x_5 \oplus x_0x_2x_7 \oplus x_0x_2 \oplus x_0x_3x_4x_5x_6 \oplus x_0x_3x_4x_6x_7 \oplus x_0x_3x_4x_6 \oplus x_0x_3x_4x_7 \oplus$
$x_0x_3x_5x_6x_7 \oplus x_0x_3x_5x_6 \oplus x_0x_3x_5x_7 \oplus x_0x_3x_5 \oplus x_0x_3x_6x_7 \oplus x_0x_3x_6 \oplus x_0x_3x_7 \oplus x_0x_4x_5 \oplus$
$x_0x_4x_6x_7 \oplus x_0x_5x_6 \oplus x_0x_6x_7 \oplus x_0x_6 \oplus x_0x_7 \oplus x_1x_2x_3x_4 \oplus x_1x_2x_3x_5x_6 \oplus x_1x_2x_3x_5 \oplus x_1x_2x_3x_7 \oplus$
$x_1x_2x_3 \oplus x_1x_2x_4x_5x_6 \oplus x_1x_2x_4x_5 \oplus x_1x_2x_4x_6x_7 \oplus x_1x_2x_4x_6 \oplus x_1x_2x_5x_6x_7 \oplus x_1x_2x_6 \oplus x_1x_2 \oplus$
$x_1x_3x_4x_5x_6x_7 \oplus x_1x_3x_4x_7 \oplus x_1x_3x_5x_6x_7 \oplus x_1x_3x_5 \oplus x_1x_3x_6x_7 \oplus x_1x_3x_6 \oplus x_1x_4x_5x_6x_7 \oplus$
$x_1x_4x_5x_7 \oplus x_1x_4x_6x_7 \oplus x_1x_4x_7 \oplus x_1x_5x_6x_7 \oplus x_1x_7 \oplus x_2x_3x_4x_5x_6 \oplus x_2x_3x_4x_7 \oplus x_2x_3x_5 \oplus$
$x_2x_4x_6x_7 \oplus x_2x_4x_6 \oplus x_2x_4 \oplus x_2x_5x_6x_7 \oplus x_2x_5x_6 \oplus x_2x_6x_7 \oplus x_2x_6 \oplus x_2 \oplus x_3x_4x_5x_6x_7 \oplus$
$x_3x_4x_5x_6 \oplus x_3x_4x_5 \oplus x_3x_5x_7 \oplus x_3x_5 \oplus x_4x_5x_6x_7 \oplus x_4x_5x_6 \oplus x_4x_5x_7 \oplus x_4x_6x_7 \oplus x_4x_6 \oplus$
$x_4 \oplus x_5x_7 \oplus x_5 \oplus x_7$

References

[1] Lawrence Bassham, Andrew Rukhin, Juan Soto, James Nechvatal, Miles Smid, Stefan Leigh, M Levenson, M Vangel, Nathanael Heckert, and D Banks. A statistical test suite for random and pseudorandom number generators for cryptographic applications, 2010-09-16 2010.

[2] William J. Buchanan, Shancang Li, and Rameez Asif. Lightweight cryptography methods. *Journal of Cyber Security Technology*, 1(3-4):187–201, 2017.

[3] Chris Christensen. Monoalphabetic substitution ciphers (mascs). https://www.nku.edu/~christensen/1901%20cscmat%20483%20section%201%20introduction%20and%20MASCs.pdf, 2019.

[4] Thomas Häner and Mathias Soeken. The multiplicative complexity of interval checking. *IACR Cryptol. ePrint Arch.*, page 91, 2022.

[5] Kyung-Bae Jang, Gyeong-Ju Song, Hyun-Ji Kim, and Hwa-Jeong Seo. Grover on simplified aes. In *2021 IEEE International Conference on Consumer Electronics-Asia (ICCE-Asia)*, pages 1–4, 2021.

[6] Kyungbae Jang, Gyeongju Song, Hyunjun Kim, Hyeokdong Kwon, Hyunji Kim, and Hwajeong Seo. Efficient implementation of present and gift on quantum computers. *Applied Sciences*, 11(11), 2021.

[7] Jérémy Jean, Thomas Peyrin, Siang Meng Sim, and Jade Tourteaux. Optimizing implementations of lightweight building blocks. *IACR Transactions on Symmetric Cryptology*, 2017(4):130–168, Dec. 2017.

[8] Mohammad Ayoub Khan, Mohammad Tabrez Quasim, Norah Saleh Alghamdi, and Mohammad Yahiya Khan. A secure framework for authentication and encryption using improved ecc for iot-based medical sensor data. *IEEE Access*, 8:52018–52027, 2020.

[9] Ilan Komargodski, Moni Naor, and Eylon Yogev. Collision resistant hashing for paranoids: Dealing with multiple collisions. In Jesper Buus Nielsen and Vincent Rijmen, editors, *Advances in Cryptology – EUROCRYPT 2018*, pages 162–194, Cham, 2018. Springer International Publishing.

[10] Carlos Andres Lara-Nino, Arturo Diaz-Perez, and Miguel Morales-Sandoval. Energy and area costs of lightweight cryptographic algorithms for authenticated encryption in WSN. *Security and Communication Networks*, 2018:14, 2018.

[11] Ryan Morrison. Post-quantum cryptography algorithm used by aws cracked "in about an hour", Aug 2022.

[12] Yusuf Moosa Motara and Barry Irwin. SHA-1 and the strict avalanche criterion. In Hein S. Venter, Marianne Loock, Marijke Coetzee, Mariki M. Eloff, and Jan H. P. Eloff, editors, *2016 Information Security for South Africa, ISSA 2016, Johannesburg, South Africa, August 17-18, 2016*, pages 35–40. IEEE, 2016.

[13] Mohammad A. Musa, Edward F. Schaefer, and Stephen Wedig. A simplified aes algorithm and its linear and differential cryptanalyses. *Cryptologia*, 27(2):148–177, 2003.

[14] Kaisa Nyberg. Statistical and linear independence of binary random variables. *IACR Cryptol. ePrint Arch.*, page 432, 2017.

[15] Sudheesh K. Rajput and Naveen K. Nishchal. Known-plaintext attack on encryption domain independent optical asymmetric cryptosystem. *Optics Communications*, 309:231–235, 2013.

[16] Stefan Scheel, Jiannis Pachos, E. A. Hinds, and Peter L. Knight. Quantum gates and decoherence, 2004.

[17] Mister Serge and Adams Carlisle. Practical s-box design. 03 1997.

[18] Juan Soto and Lawrence Bassham. Randomness testing of the advanced encryption standard finalist candidates, 2000-04-01 00:04:00 2000.

[19] IonQ Staff. Unveiling IonQ Forte: The First Software-Configurable Quantum Computer — ionq.com. https://ionq.com/posts/may-17-2022-ionq-forte, 2022. [Accessed 23-Feb-2023].

[20] The Qiskit Team. Grover's algorithm, Nov 2022.

[21] Okamura Toshihiko. Lightweight cryptography applicable to various iot devices. *NEC*, 12(1), 2017.

[22] Lionel Sujay Vailshery. IoT connected devices worldwide 2019-2030 | Statista — statista.com. https://www.statista.com/statistics/1183457/iot-connected-devices-worldwide/, 2022. [Accessed 23-Feb-2023].

[23] David Wagner, Nicholas Weaver, Peyrin Kao, Fuzail Shakir, Andrew Law, and Nicholas Ngai. Symmetric-key cryptography. In *Computer Security*, chapter 6. Berkely, 2023.