Cryptography ECE5632 - Spring 2026

Lecture 3B

**Dr. Farah Raad**

Lecture Topic

Simplified DES (SDES) & DES

Simplified DES (SDES)

➢ Designed by Professor Edward Schaefer, for educational purposes.

➢ Similar properties and structure as DES (with much smaller parameters).

➢ The use of multiple stages of permutation and substitution results in a more complex algorithm, which increases the difficulty of cryptanalysis.

# Classification of S-DES & DES in the Field of Cryptology


You are here!
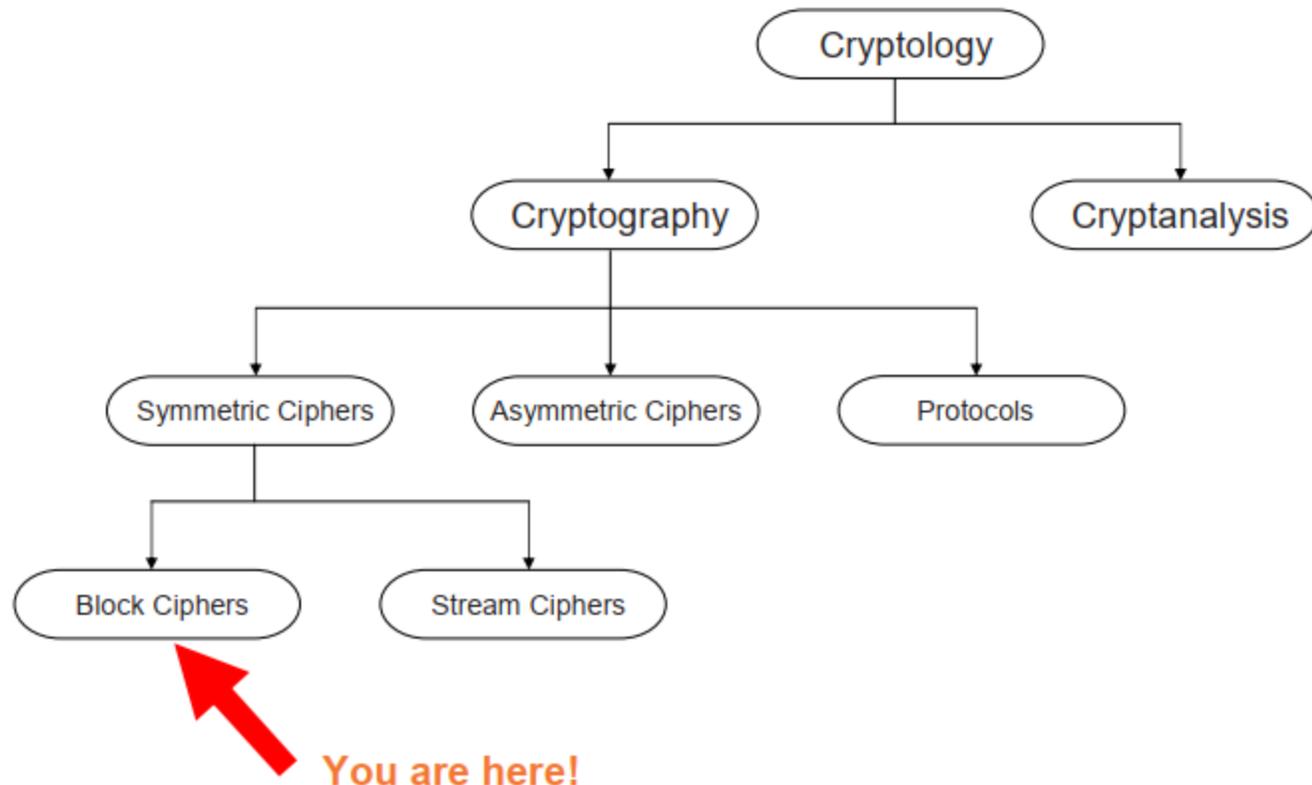
SDES: Overview
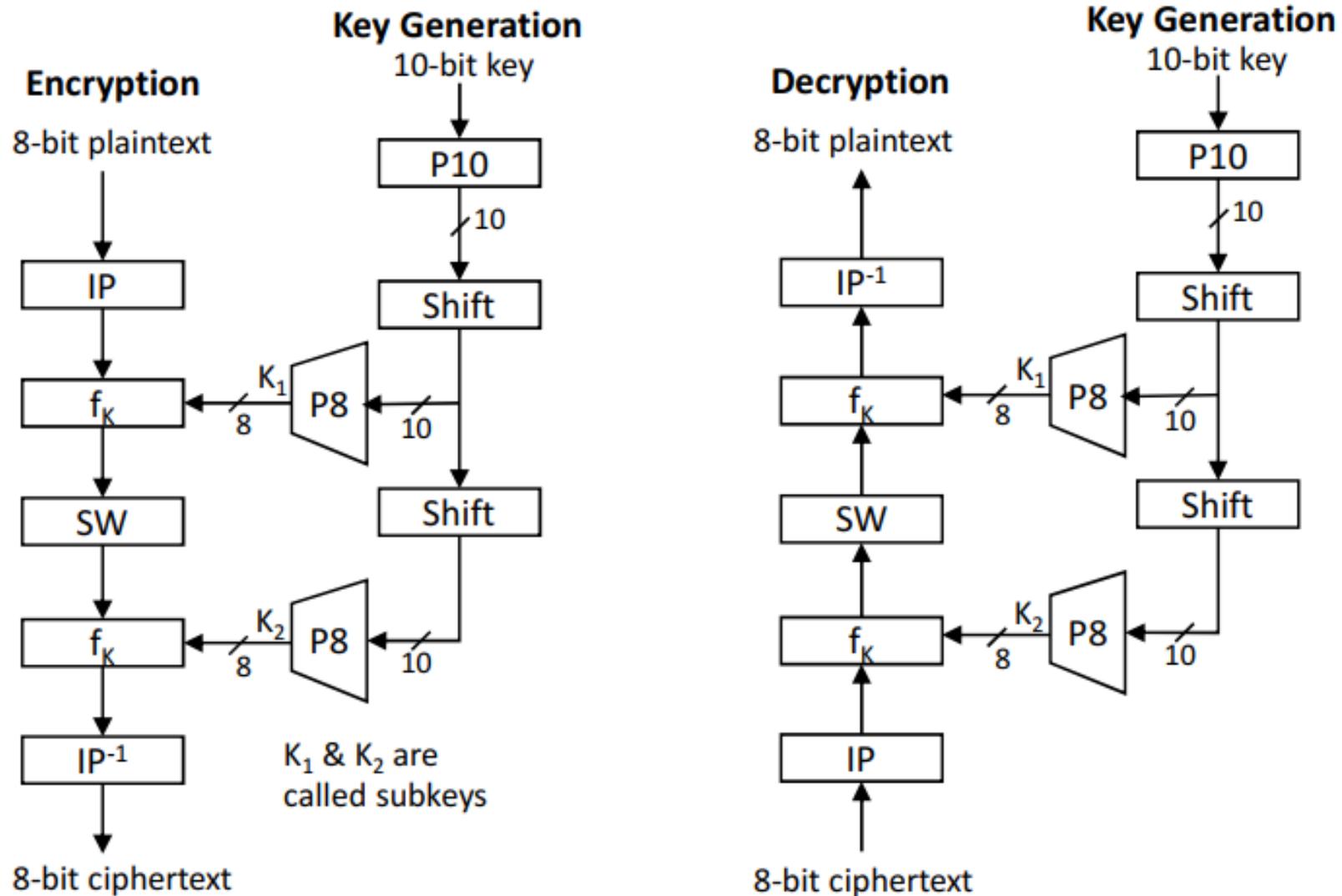
Encryption

The encryption algorithm involves five functions:

1. Initial permutation (IP)
2. Complex function labeled (f_k): which involves both permutation and substitution operations and depends on a key input.
3. Simple permutation function that switches (SW) the two halves of the data.
4. Function (f_k) again.
5. Permutation function (IP^{-1}): that is the inverse of the initial permutation.
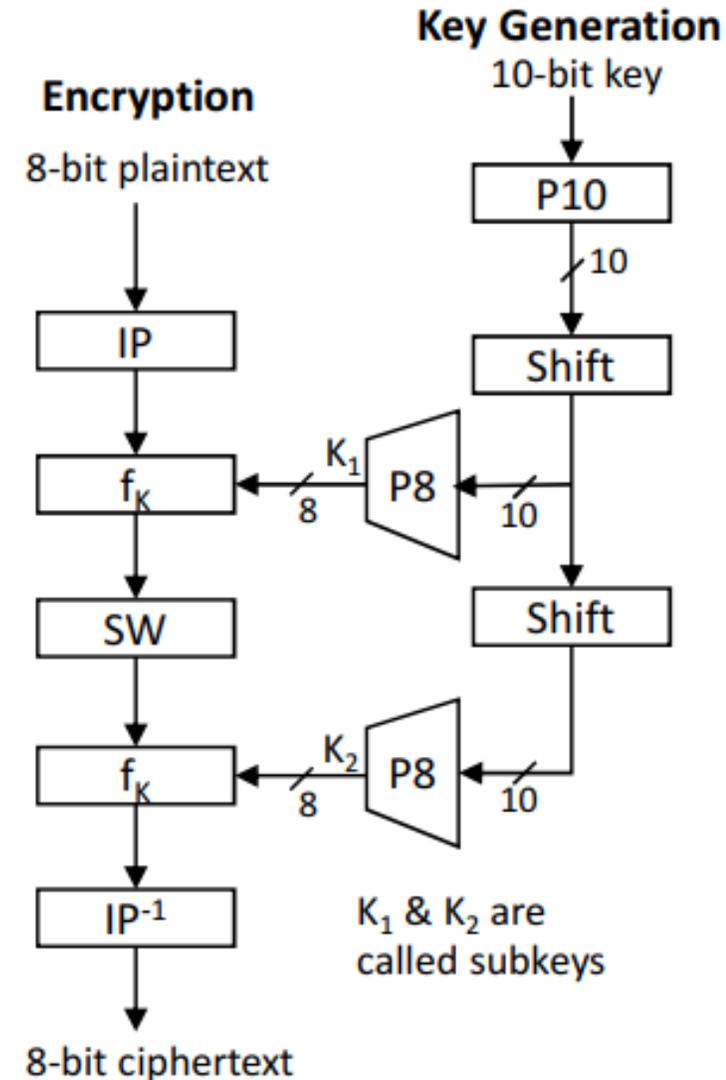
Encryption

➤ The function f_k has two inputs: data passing through the encryption algorithm and 8-bit key.

➤ The algorithm could have been designed to work with a 16-bit key, consisting of two 8-bit subkeys, one used for each occurrence of f_k .

➤ Alternatively, a single 8-bit key could have been used, with the same key used twice in the algorithm.

➤ A compromise is to use a 10-bit key from which two 8-bit subkeys are generated.

➤ **In this case:**

- The key is first subjected to a permutation (P10).
- Then a shift operation is performed.
- The output of the shift operation then passes through a permutation function that produces an 8-bit output (P8) for the first subkey (k_1).
- The output of the shift operation also feeds into another shift and another instance of P8 to produce the second subkey (k_2).
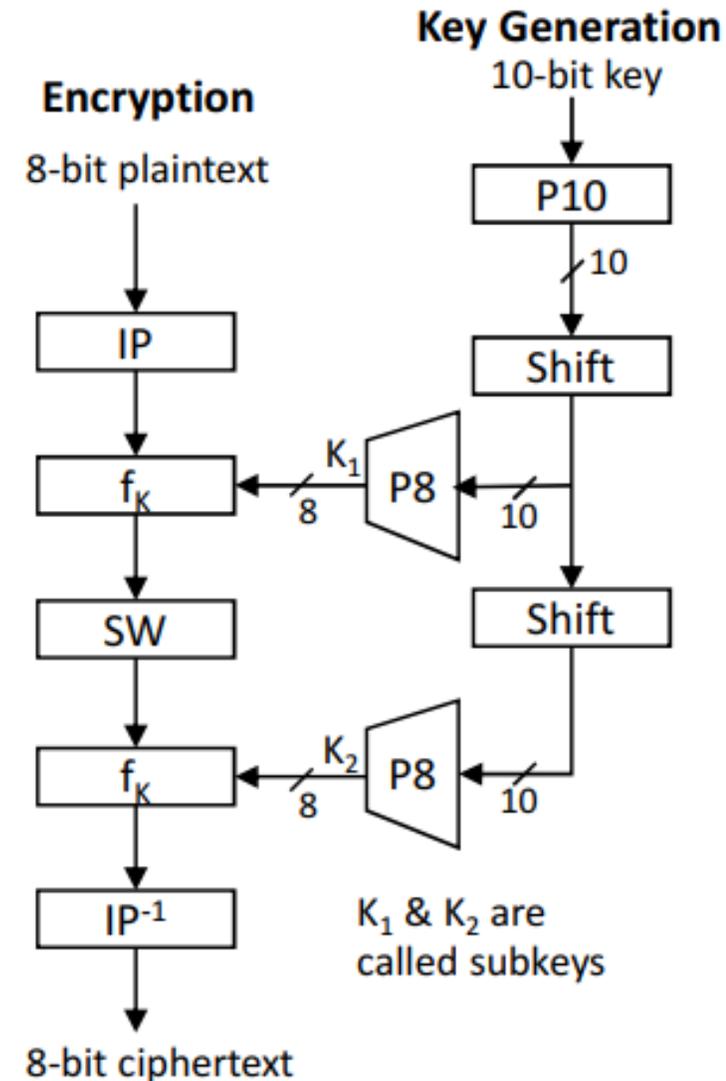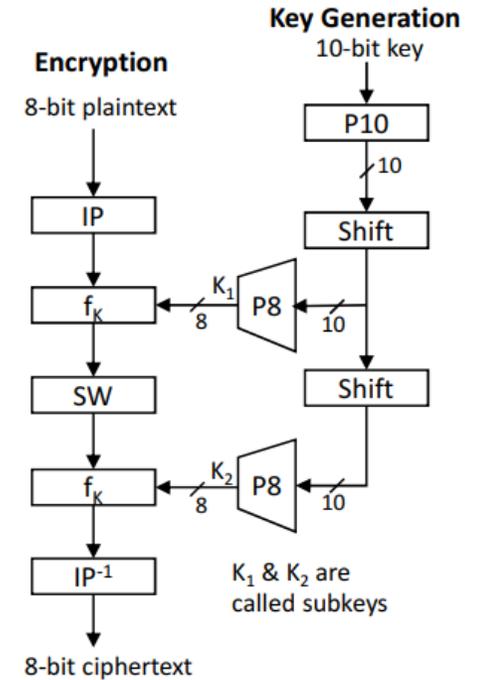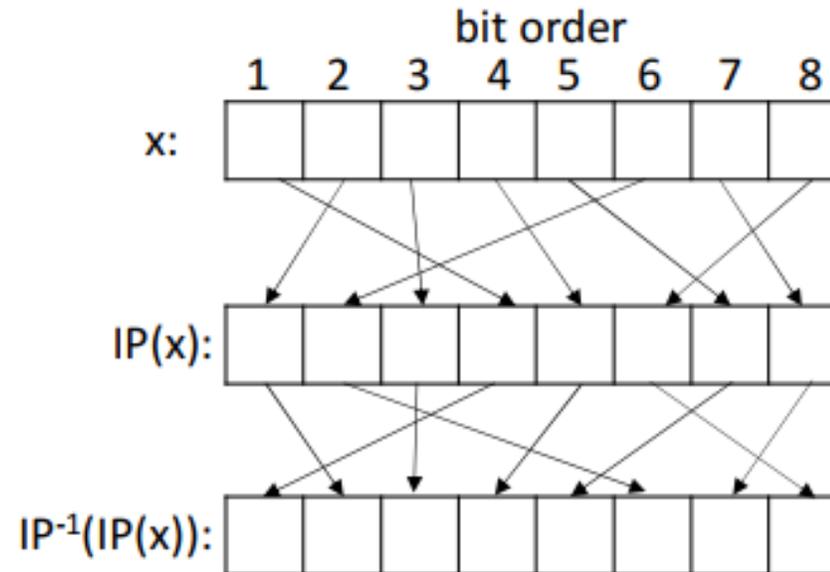
IP (Initial Permutation)

- The 8-bit input plaintext is permuted using the initial permutation function (IP).
- All bits are retained, but re-ordered (mixed).
- At the end of the algorithm, the inverse permutation (IP^{-1}) is used, such that: IP^{-1}(IP(x)) = x
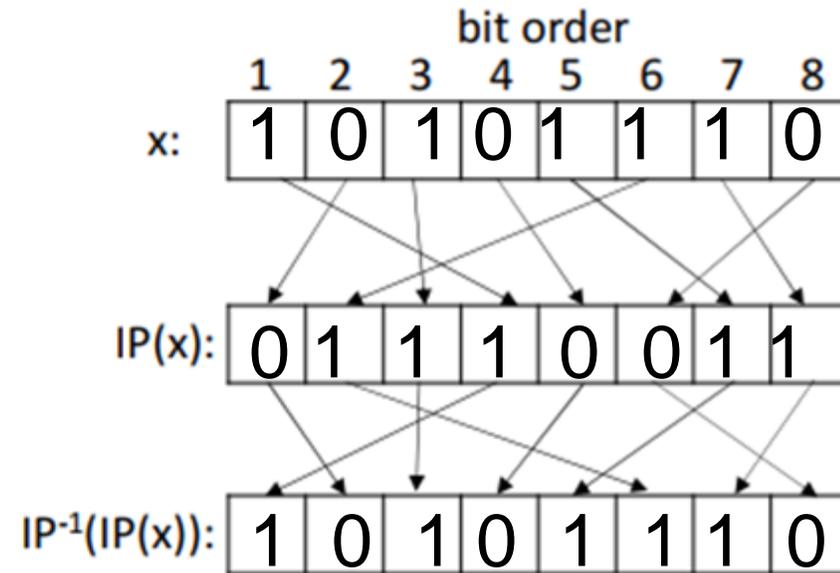
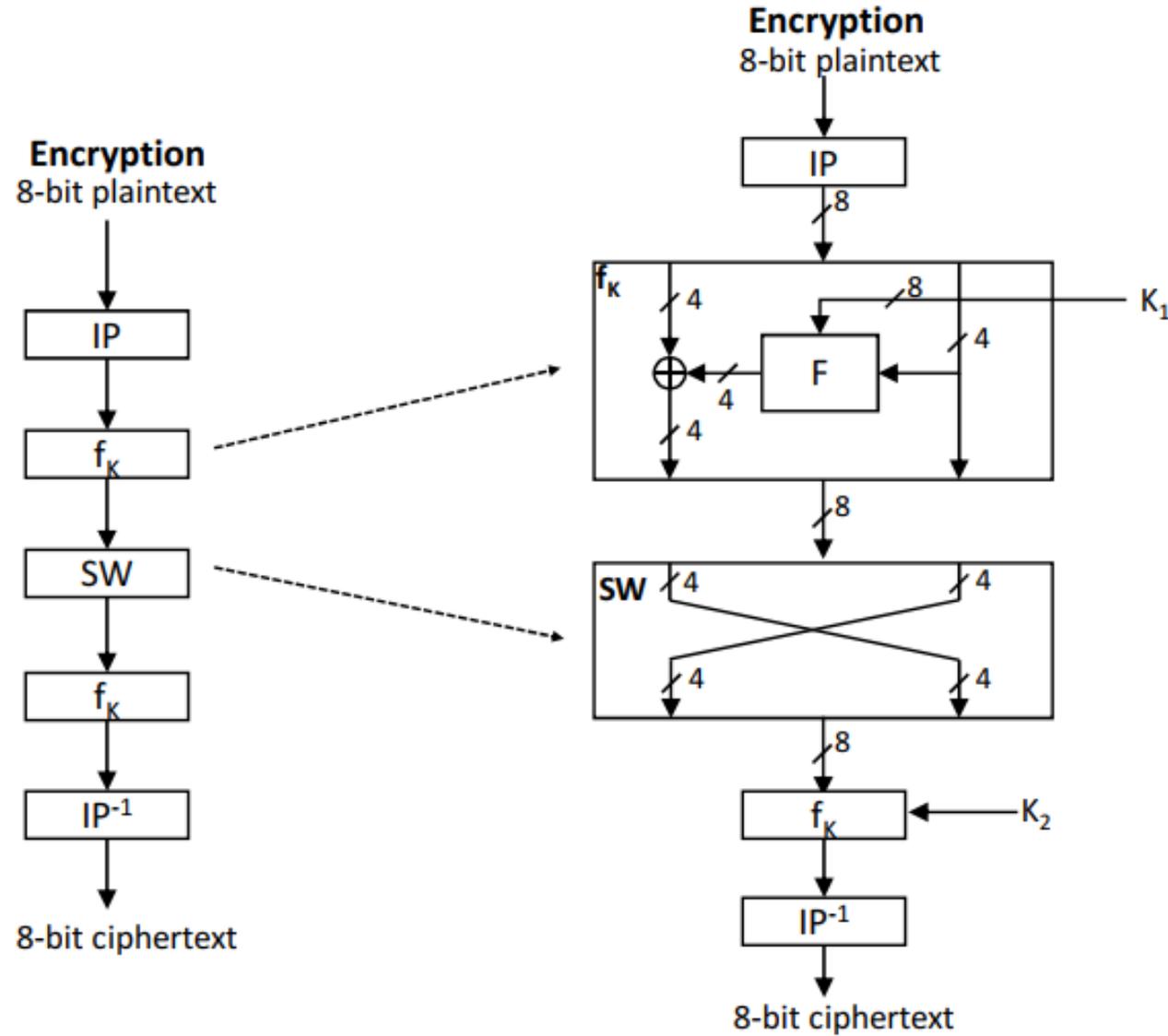e.g., IP = [2 6 3 1 4 8 5 7]

∴IP^{-1} = [4 1 3 5 7 2 8 6]

IP (Initial Permutation)

e.g., IP = [2 6 3 1 4 8 5 7]

$\therefore$IP^{-1} = [4 1 3 5 7 2 8 6]

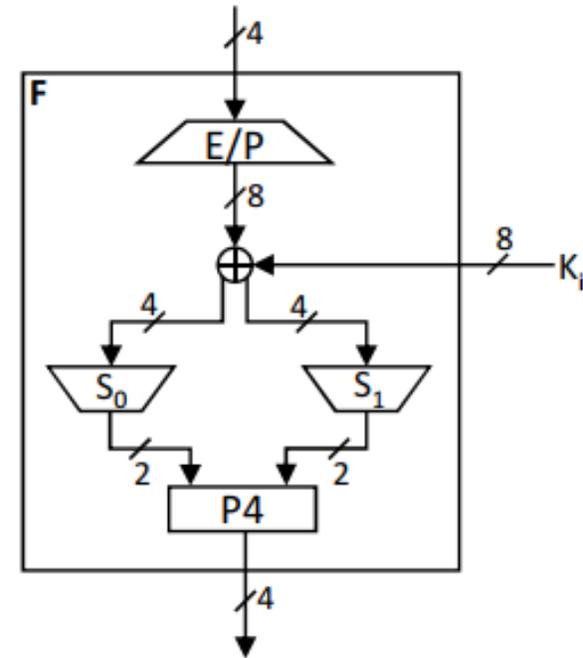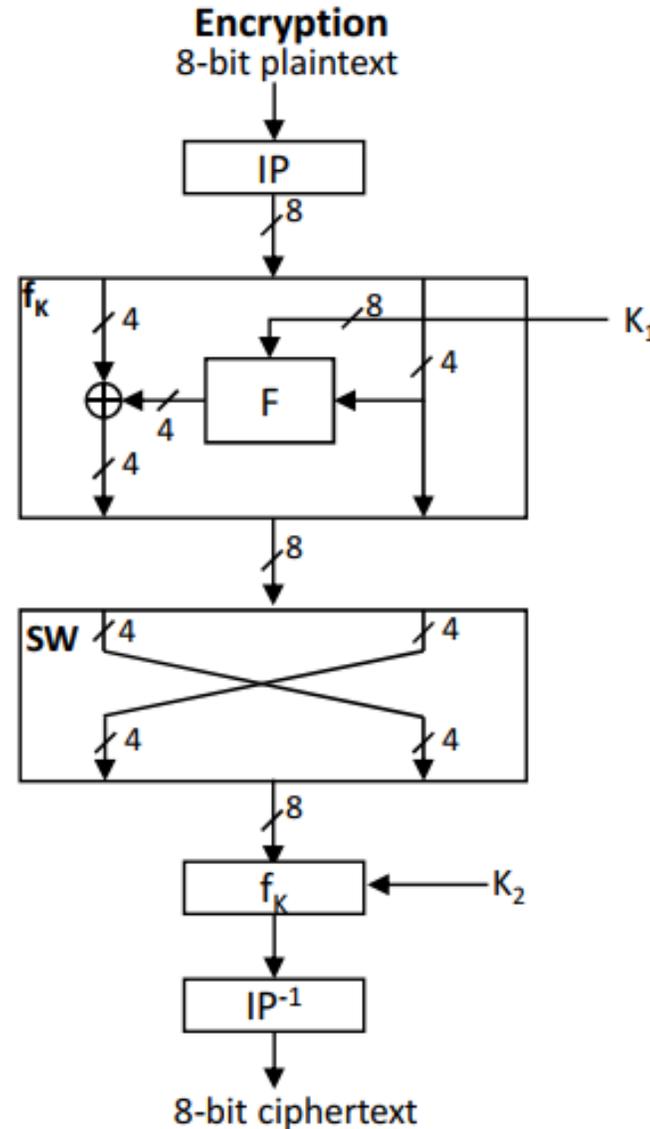# SW & Function f_k

Function F

In the block F
➢ **E/P Box**

➢ The expansion/permutation (E/P) operation expands the 4 bits into 8 and mixes them.

e.g., E/P = [4 1 2 3 2 3 4 1]

Ex, 1101
11101011

Function F

➢ Substitution Box (S-Box)

- In the block F, two S-boxes (S_0 and S_1) are defined.
- An S-box has a 4-bit input and 2-bit output.
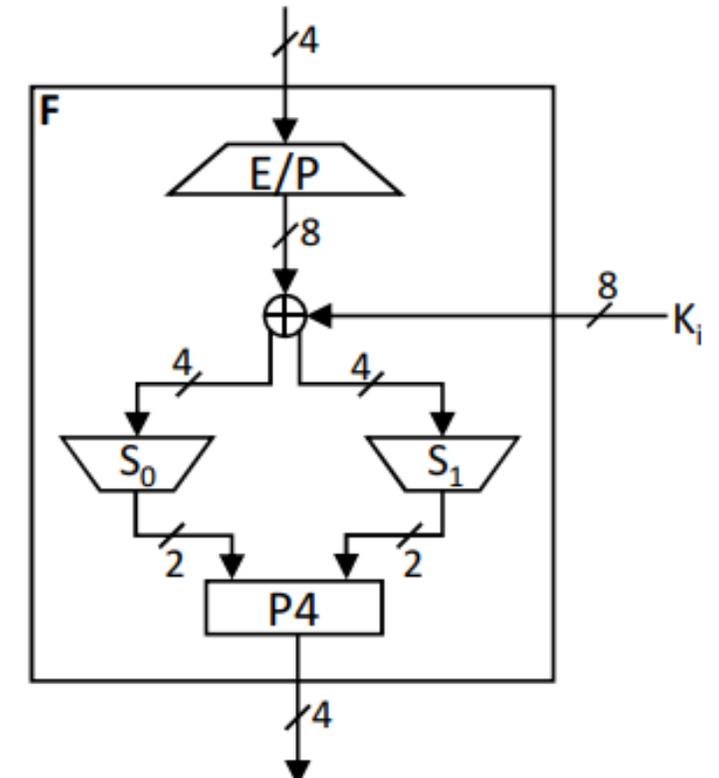- It operates as follows:

e.g., assume $S_0 = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{cccc} 0 & 1 & 2 & 3 \\ \left[\begin{array}{cccc} 1 & 0 & 3 & 2 \\ 3 & 2 & 1 & 0 \\ 0 & 2 & 1 & 3 \\ 3 & 1 & 3 & 2 \end{array}\right] \end{array}$, with input 0100

∵ the 1st and 4th bits of the input = 00 = 0

∵ the 2nd and 3rd bits of the input = 10 = 2

∴ the output is selected from row 0 and column 2
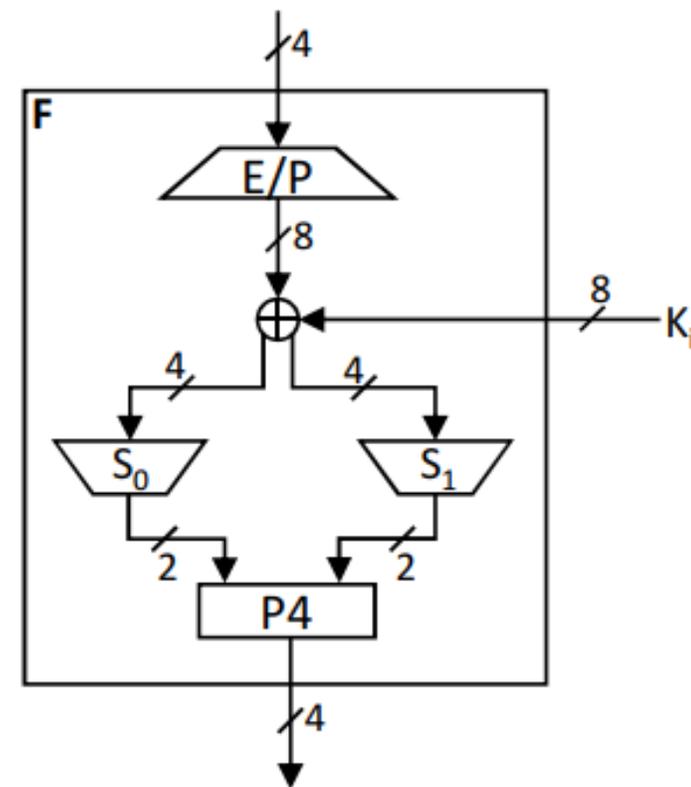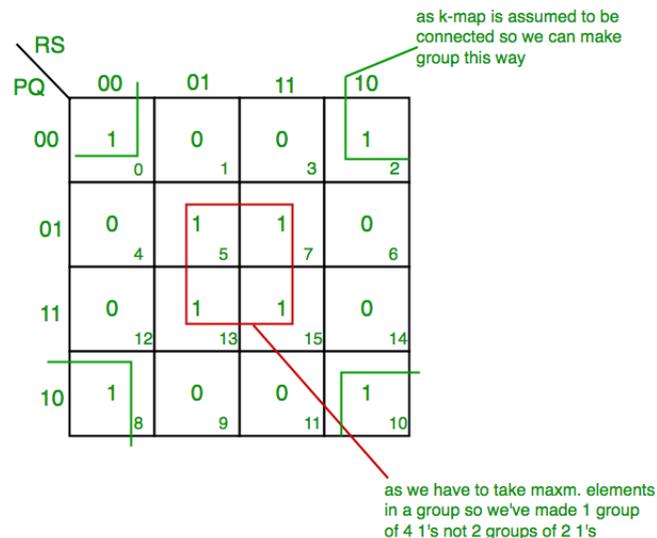
∴ the output = 3 = 11

	--00	--01	--10	--11
00--	0011	0000	1011	0101
01--	1000	0100	0111	0010
10--	1111	1100	0110	1110
11--	1001	0001	1010	1101

Design of S-Box

$$S_0 = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{cccc} 0 & 1 & 2 & 3 \\ \begin{bmatrix} 1 & 0 & 3 & 2 \\ 3 & 2 & 1 & 0 \\ 0 & 2 & 1 & 3 \\ 3 & 1 & 3 & 2 \end{bmatrix} \end{array}$$

1. Truth Table
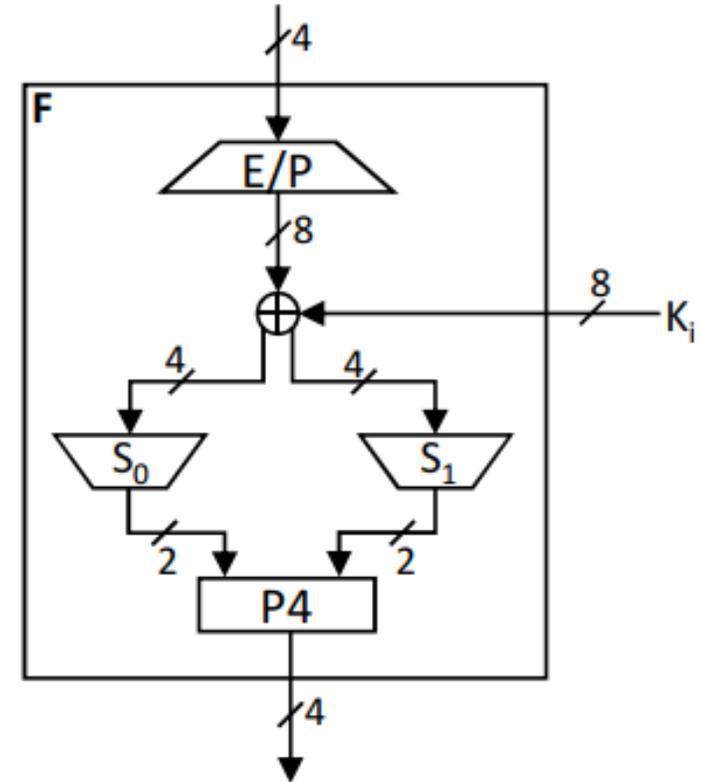2. Karnaugh map
3. Y0 and Y1 equation
4. Logic gate circuit
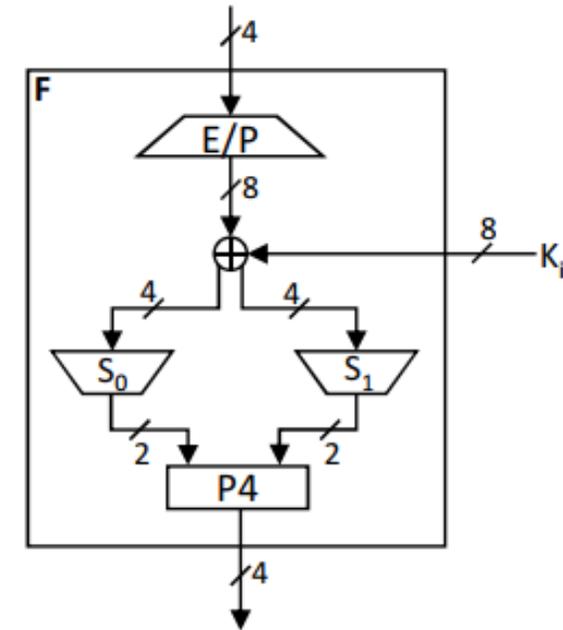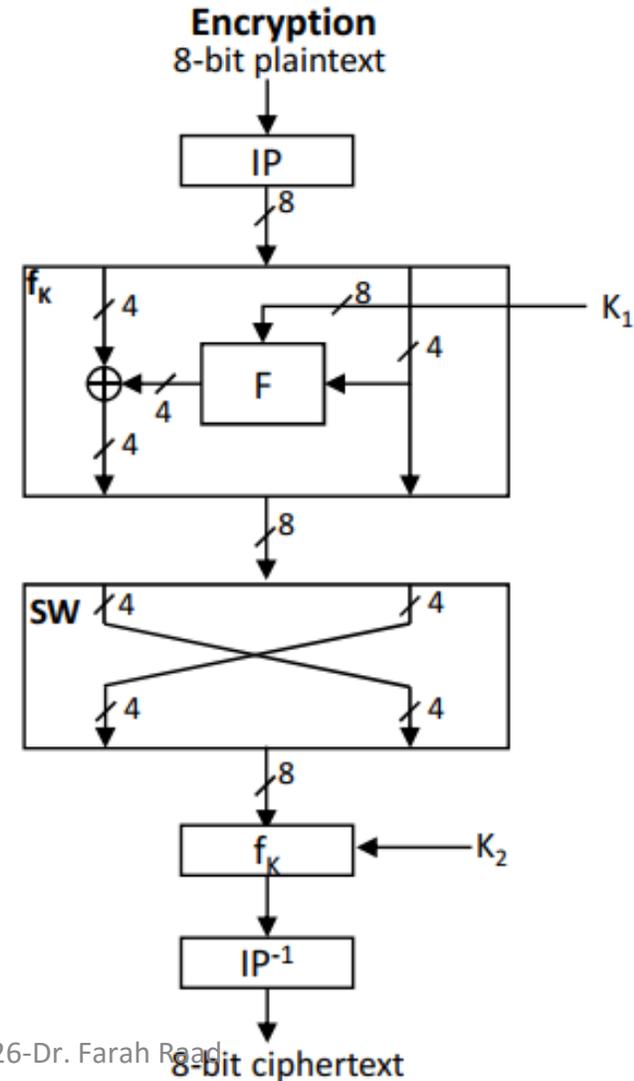
Function F

➢ **P4**

mixes and retains all 4 bits.
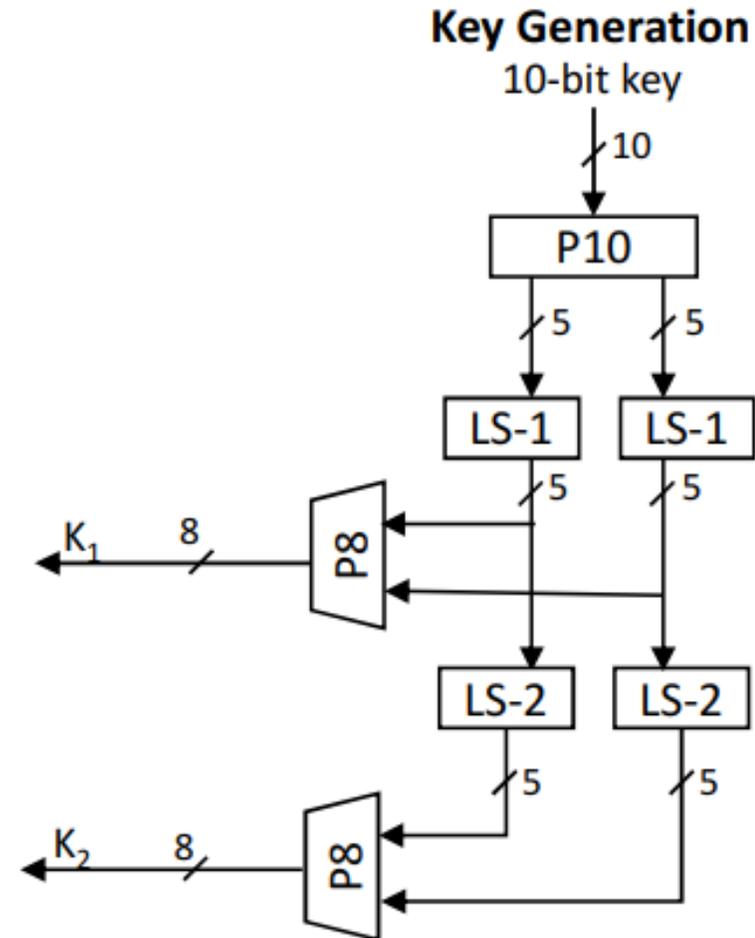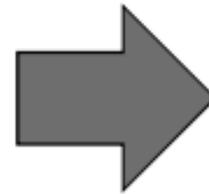
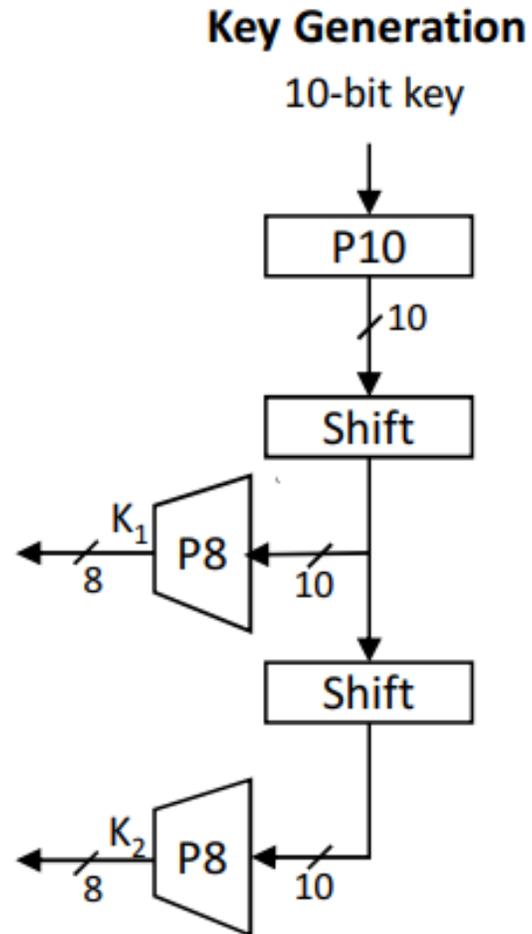P4 [2431]

Ex :   0100
         1000

SW & Function f_k

- Only the leftmost 4 bits of the input is altered by the function f_K.

- SW interchanges the left and right 4 bits so that the second round of f_K operates on a different 4 bits.

- In this second round, the E/P, S_0, S_1, and P4 functions are the same. The key input is K_2.
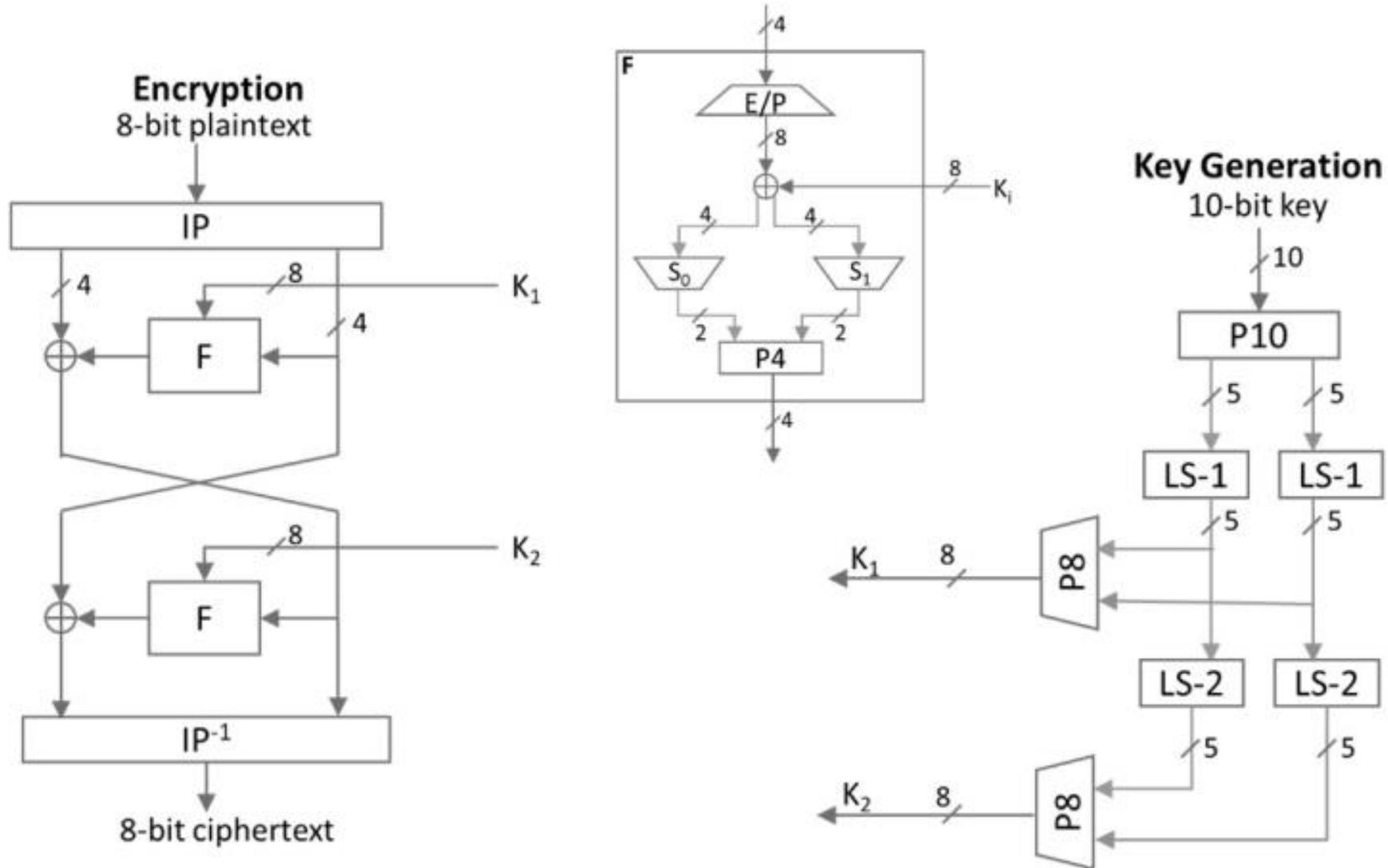
Key Generation

Key Generation

- Key generation includes its own permutation functions; P8 and P10.

- P10 mixes and retains all 10 bits.

- P8 mixes and selects 8 bits out of 10.

  e.g., P8 = [6 3 7 4 8 5 10 9] . . . bits 1 and 2 are gone..

- LS-1 rotates the input 5 bits one step to the left.

01101 >>> Left shift cycling 11010

- LS-2 rotates the input 5 bits two steps to the left.

Key Generation
10-bit key

Encryption
8-bit plaintext
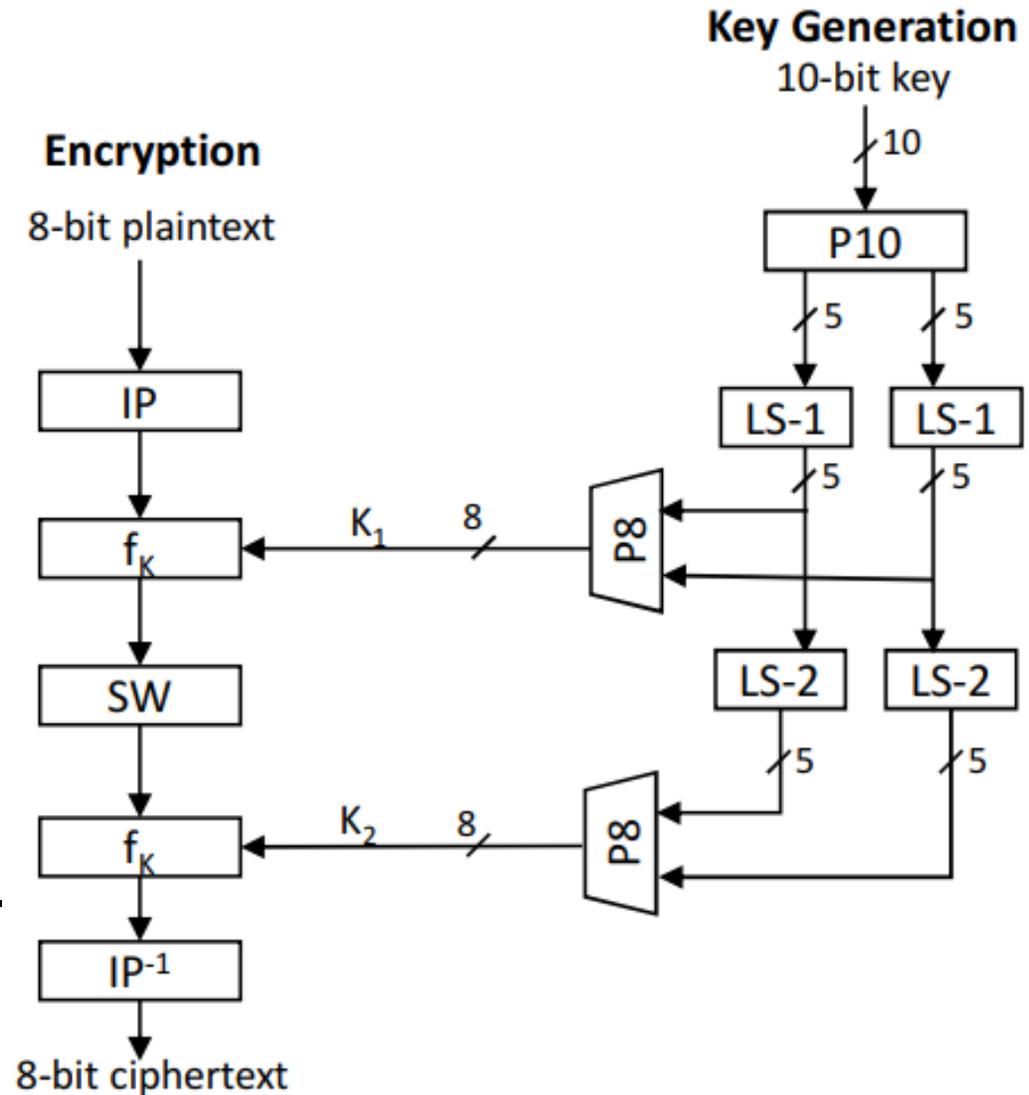
The Whole Picture (Encryption)

Decryption

Security of SDES

➤ A brute-force attack on SDES is doable.
➤ With a 10-bit key, there are only $2^{10} = 1024$ possibilities.

Relation between DES and SDES

	SDES	DES
Block size	8 bits	64 bits
Key size	10 bits	56 bits
Sub key size	8 bits	48 bit
Function F	Acts on 4 bits	Acts on 32 bits
S-boxes	2	8
S-box size	4 x 4	4 x 16
rounds	2	16

Example

Let the plaintext be the string 0010 1000. Let the 10 bit key be 1100011110

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Let the plaintext be the string 0010 1000. Let the 10 bit key be 1100011110

$k1$ = 1110 1001
$k2$ = 1010 0111

the final result of the encryption is 1000 1010

Thank You!

See You next Lectures!!
Any Question?

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