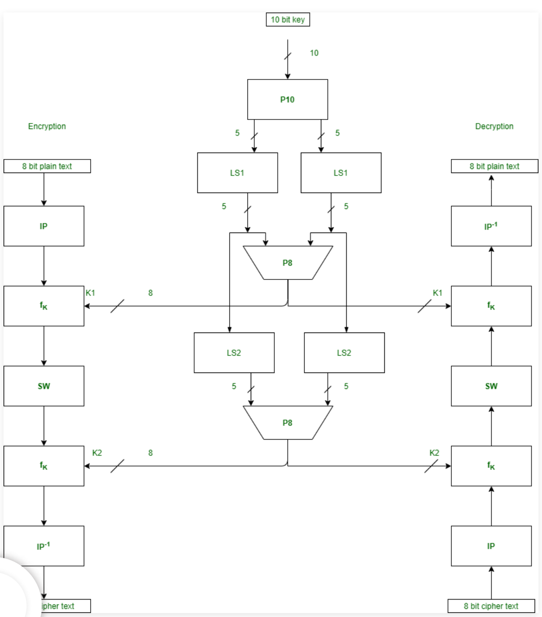
# Simplified Data Encryption Standard | Set 2

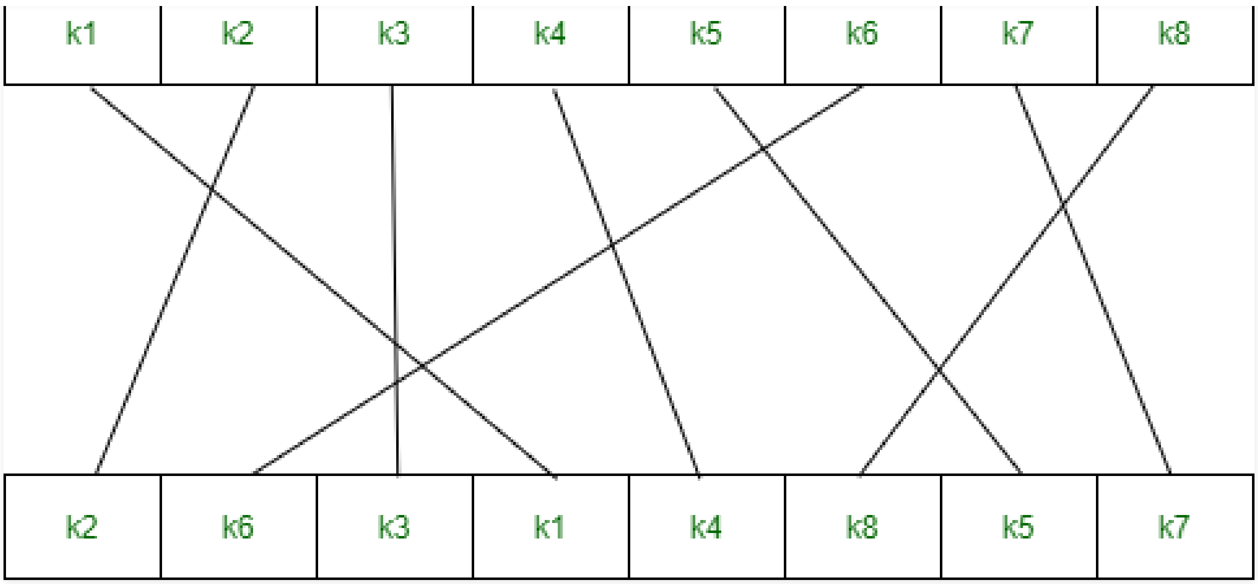
Difficulty Level : Expert • Last Updated : 22 Oct, 2021

**Prerequisite –** Simplified Data Encryption Standard | Set 1

**Simplified Data Encryption Standard** is a simple version of Data Encryption Standard having a 10-bit key and 8-bit plain text. It is much smaller than the DES algorithm as it takes only 8-bit plain text whereas DES takes 64-bit plain text. It was developed for educational purpose so that understanding DES can become easy. It is a block cipher algorithm and uses a symmetric key for its algorithm i.e. they use the same key for both encryption and decryption. It has 2 rounds for encryption which use two different keys.

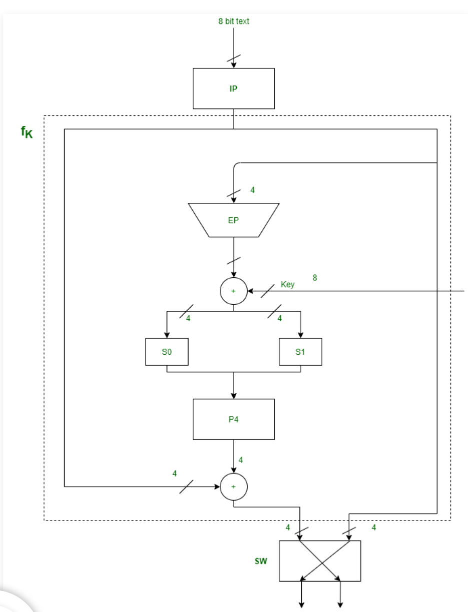
First, we need to generate 2 keys before encryption. After generating keys we pass them to each individual round for s-des encryption. The below diagram shows the steps involved in the s-des algorithm.

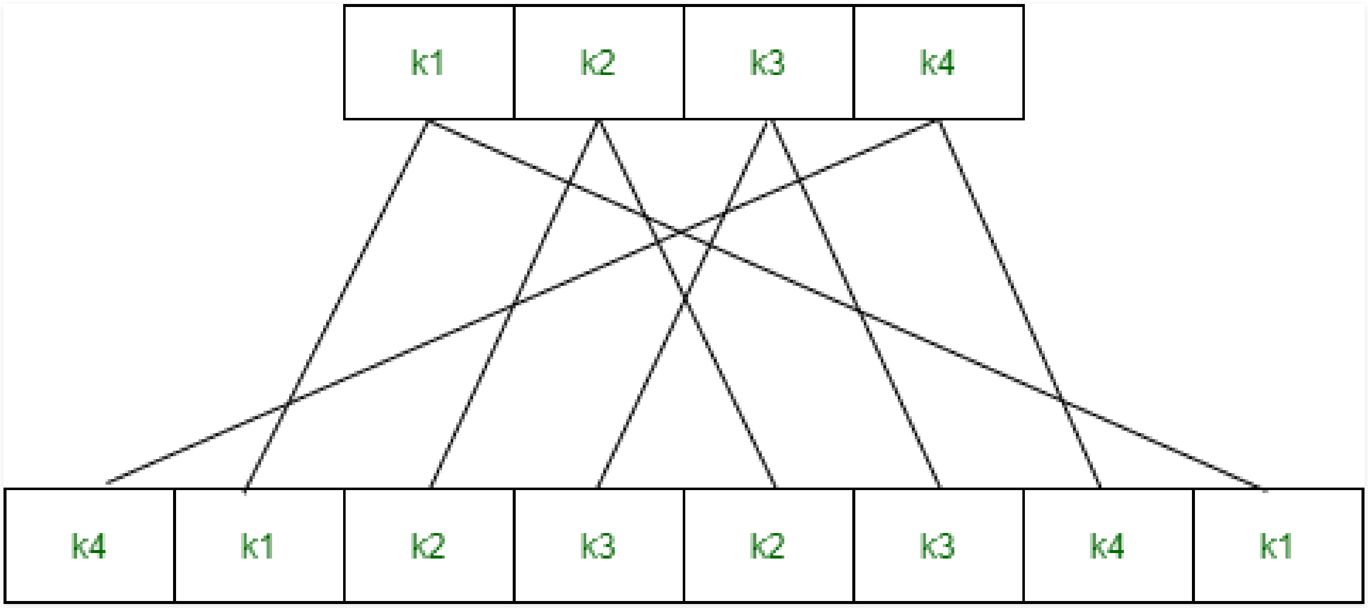





### 2. Complex function ($f_k$) –

It is the combination of permutation and substitution functions. The below image represents a round of encryption and decryption. This round is repeated twice in each encryption and decryption.






**b. S-boxes (S0 and S1) –**

It is a basic component of a symmetric key algorithm that performs substitution.

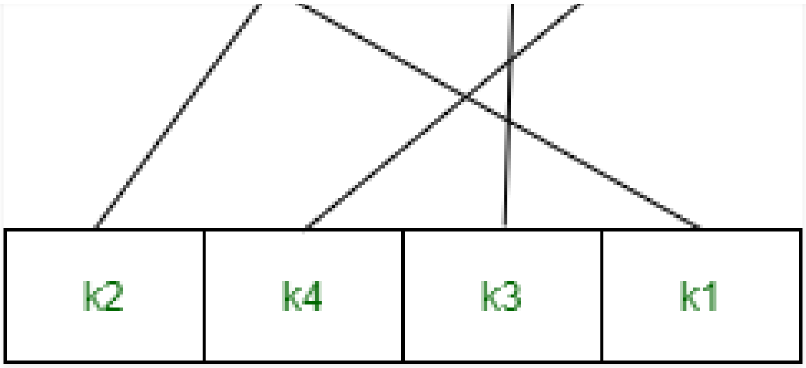
**S0**

| | | | |
|---|---|---|---|
| 1 | 0 | 3 | 2 |
| 3 | 2 | 1 | 0 |
| 0 | 2 | 1 | 3 |
| 3 | 1 | 3 | 2 |

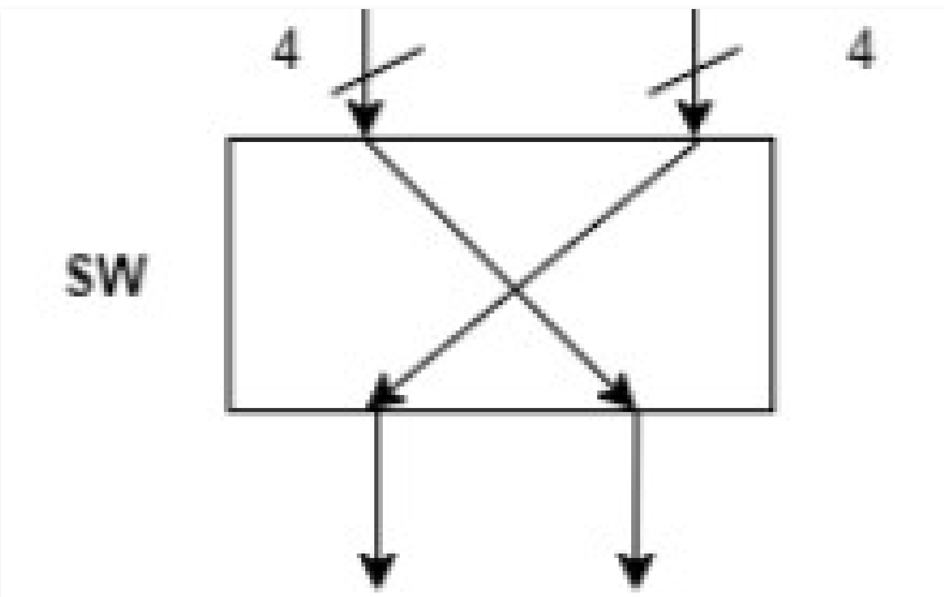
**S1**

| | | | |
|---|---|---|---|
| 0 | 1 | 2 | 3 |
| 2 | 0 | 1 | 3 |
| 3 | 0 | 1 | 0 |
| 2 | 1 | 0 | 3 |

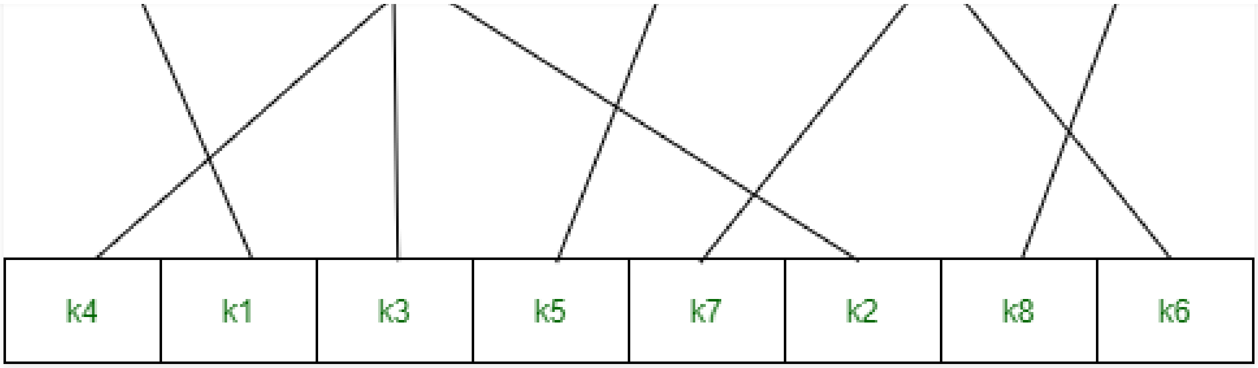
**c. Permutation P4 –**




### 3. Switch (SW) –




### 4. Inverse of Initial Permutation ($IP^{-1}$) –




**First, we need to generate 2 keys before encryption.**

```
Consider, the entered 10-bit key is - 1 0 1 0 0 0 0 0 1 0
```

Therefore,

```
Key-1 is - 1 0 1 0 0 1 0 0
Key-2 is - 0 1 0 0 0 0 1 1
```

**Encryption –**

```
Entered 8-bit plaintext is - 1 0 0 1 0 1 1 1
```

**Step-1:**
We perform initial permutation on our 8-bit plain text using the IP table. The initial permutation is defined as –

```
IP(k1, k2, k3, k4, k5, k6, k7, k8) = (k2, k6, k3, k1, k4, k8, k5, k7)
After ip = 0 1 0 1 1 1 0 1
```

**Step-2:**
After the initial permutation, we get an 8-bit block of text which we divide into 2 halves 4 bit each.

```
l = 0 1 0 1  and r = 1 1 0 1
```

```
After ep = 1 1 1 0 1 0 1 1
```

We perform XOR operation using the first key K1 with the output of expanded permutation.

```
Key-1 is - 1 0 1 0 0 1 0 0
(1 0 1 0 0 1 0 0) XOR (1 1 1 0 1 0 1 1) =  0 1 0 0 1 1 1 1
After XOR operation with 1st Key = 0 1 0 0 1 1 1 1
```

Again we divide the output of XOR into 2 halves of 4 bit each.

```
l = 0 1 0 0  and r = 1 1 1 1
```

We take the first and fourth bit as row and the second and third bit as a column for our S boxes.

```
S0 = [1,0,3,2
      3,2,1,0
      0,2,1,3
      3,1,3,2]

S1=  [0,1,2,3
      2,0,1,3
      3,0,1,0
      2,1,0,3]

For l = 0 1 0 0
row = 00 = 0, column = 10 = 2
S0 = 3 = 11

For r = 1 1 1 1
row = 11 = 3, column = 11 = 3
```

permutation using the P4 table. P4 is defined as –

```
P4(k1, k2, k3, k4) = (k2, k4, k3, k1)
After P4 = 1 1 1 1
```

We XOR the output of the P4 table with the left half of the initial permutation table i.e. IP table.

```
(0 1 0 1) XOR (1 1 1 1) = 1 0 1 0
After XOR operation with left nibble of after ip = 1 0 1 0
```

We combine both halves i.e. right half of initial permutation and output of ip.

```
Combine 1 1 0 1 and 1 0 1 0
After combine = 1 0 1 0 1 1 0 1
```

**Step-3:**
Now, divide the output into two halves of 4 bit each. Combine them again, but now the left part should become right and the right part should become left.

```
After step 3 = 1 1 0 1 1 0 1 0
```

**Step-4:**
Again perform step 2, but this time while doing XOR operation after expanded permutation use key 2 instead of key 1.

```
Expand permutation is defined as - 4 1 2 3 2 3 4 1
After second ep = 0 1 0 1 0 1 0 1
After XOR operation with 2nd Key = 0 0 0 1 0 1 1 0
After second S-Boxes = 1 1 1 1

P4 is defined as - 2 4 3 1
```

```
l = 1 1 0 1  and r = 1 0 1 0
```

On the right half, we perform expanded permutation using EP table which converts 4 bits into 8 bits. Expand permutation is defined as –

```
EP(k1, k2, k3, k4) = (k4, k1, k2, k3, k2, k3, k4, k1)
After second ep = 0 1 0 1 0 1 0 1
```

We perform XOR operation using second key K2 with the output of expanded permutation.

```
Key-2 is - 0 1 0 0 0 0 1 1
(0 1 0 0 0 0 1 1) XOR (0 1 0 1 0 1 0 1) =  0 0 0 1 0 1 1 0
After XOR operation with 2nd Key = 0 0 0 1 0 1 1 0
```

Again we divide the output of XOR into 2 halves of 4 bit each.

```
l = 0 0 0 1  and r = 0 1 1 0
```

We take the first and fourth bit as row and the second and third bit as a column for our S boxes.

```
S0 = [1,0,3,2
      3,2,1,0
      0,2,1,3
      3,1,3,2]

S1 = [0,1,2,3
      2,0,1,3
      3,0,1,0
      2,1,0,3]
```

```
For P = 0 1 1 0
row = 00 = 0 , column = 11 = 3
S1 = 3 = 11

After first S-Boxes combining S0 and S1 = 1 1 1 1
```

S boxes gives a 2-bit output which we combine to get 4 bits and then perform permutation using the P4 table. P4 is defined as –

```
P4(k1, k2, k3, k4) = (k2, k4, k3, k1)
After P4 = 1 1 1 1
```

We XOR the output of the P4 table with the left half of the initial permutation table i.e. IP table.

```
(1 1 0 1) XOR (1 1 1 1) = 0 0 1 0
After XOR operation with left nibble of after first part = 0 0 1 0
```

We combine both halves i.e. right half of initial permutation and output of ip.

```
Combine 1 0 1 0 and 0 0 1 0
After combine = 0 0 1 0 1 0 1 0
After second part = 0 0 1 0 1 0 1 0
```

**Step-5:**

Perform inverse initial permutation. The output of this table is the cipher text of 8 bit.

```
Output of step 4 : 0 0 1 0 1 0 1 0
```

Inverse Initial permutation is defined as –

```
IP-1(k1, k2, k3, k4, k5, k6, k7, k8) = (k4, k1, k3, k5, k7, k2, k8, k6)
```

```
/ package whatever //do not write package name here */

import java.io.*;

public class GFG {
    // int key[]= {0,0,1,0,0,1,0,1,1,1};
    int key[] = {
        1, 0, 1, 0, 0, 0, 0, 0, 1, 0
    }; // extra example for checking purpose
    int P10[] = { 3, 5, 2, 7, 4, 10, 1, 9, 8, 6 };
    int P8[] = { 6, 3, 7, 4, 8, 5, 10, 9 };

    int key1[] = new int[8];
    int key2[] = new int[8];

    int[] IP = { 2, 6, 3, 1, 4, 8, 5, 7 };
    int[] EP = { 4, 1, 2, 3, 2, 3, 4, 1 };
    int[] P4 = { 2, 4, 3, 1 };
    int[] IP_inv = { 4, 1, 3, 5, 7, 2, 8, 6 };

    int[][] S0 = { { 1, 0, 3, 2 },
                   { 3, 2, 1, 0 },
                   { 0, 2, 1, 3 },
                   { 3, 1, 3, 2 } };
    int[][] S1 = { { 0, 1, 2, 3 },
                   { 2, 0, 1, 3 },
                   { 3, 0, 1, 0 },
                   { 2, 1, 0, 3 } };

    //    this function basically generates the key(key1 and
    //key2)     using P10 and P8 with (1 and 2)left shifts

    void key_generation()
    {
        int key_[] = new int[10];

        for (int i = 0; i < 10; i++) {
            key_[i] = key[P10[i] - 1];
        }

        int Ls[] = new int[5];
        int Rs[] = new int[5];

        for (int i = 0; i < 5; i++) {
```

```
        for (int i = 0; i < 5; i++) {
            key_[i] = Ls_1[i];
            key_[i + 5] = Rs_1[i];
        }

        for (int i = 0; i < 8; i++) {
            key1[i] = key_[P8[i] - 1];
        }

        int[] Ls_2 = shift(Ls, 2);
        int[] Rs_2 = shift(Rs, 2);

        for (int i = 0; i < 5; i++) {
            key_[i] = Ls_2[i];
            key_[i + 5] = Rs_2[i];
        }

        for (int i = 0; i < 8; i++) {
            key2[i] = key_[P8[i] - 1];
        }

        System.out.println("Your Key-1 :");

        for (int i = 0; i < 8; i++)
            System.out.print(key1[i] + " ");

        System.out.println();
        System.out.println("Your Key-2 :");

        for (int i = 0; i < 8; i++)
            System.out.print(key2[i] + " ");
    }

    //    this function is use full for shifting(circular) the
    //array n position towards left

    int[] shift(int[] ar, int n)
    {
        while (n > 0) {
            int temp = ar[0];
            for (int i = 0; i < ar.length - 1; i++) {
                ar[i] = ar[i + 1];
            }
```

```
//    this is main encryption function takes plain text as
//input     uses another functions and returns the array of
//cipher text

int[] encryption(int[] plaintext)
{
    int[] arr = new int[8];

    for (int i = 0; i < 8; i++) {
        arr[i] = plaintext[IP[i] - 1];
    }
    int[] arr1 = function_(arr, key1);

    int[] after_swap = swap(arr1, arr1.length / 2);

    int[] arr2 = function_(after_swap, key2);

    int[] ciphertext = new int[8];

    for (int i = 0; i < 8; i++) {
        ciphertext[i] = arr2[IP_inv[i] - 1];
    }

    return ciphertext;
}

// decimal to binary string 0-3

String binary_(int val)
{
    if (val == 0)
        return "00";
    else if (val == 1)
        return "01";
    else if (val == 2)
        return "10";
    else
        return "11";
}

//    this function is doing core things like expansion
//    then xor with desired key then S0 and S1
//substitution     P4 permutation and again xor     we have used
//this function 2 times(key-1 and key-2) during
```

```
        int[] l = new int[4];
        int[] r = new int[4];

        for (int i = 0; i < 4; i++) {
            l[i] = ar[i];
            r[i] = ar[i + 4];
        }

        int[] ep = new int[8];

        for (int i = 0; i < 8; i++) {
            ep[i] = r[EP[i] - 1];
        }

        for (int i = 0; i < 8; i++) {
            ar[i] = key_[i] ^ ep[i];
        }

        int[] l_1 = new int[4];
        int[] r_1 = new int[4];

        for (int i = 0; i < 4; i++) {
            l_1[i] = ar[i];
            r_1[i] = ar[i + 4];
        }

        int row, col, val;

        row = Integer.parseInt("" + l_1[0] + l_1[3], 2);
        col = Integer.parseInt("" + l_1[1] + l_1[2], 2);
        val = S0[row][col];
        String str_l = binary_(val);

        row = Integer.parseInt("" + r_1[0] + r_1[3], 2);
        col = Integer.parseInt("" + r_1[1] + r_1[2], 2);
        val = S1[row][col];
        String str_r = binary_(val);

        int[] r_ = new int[4];
        for (int i = 0; i < 2; i++) {
            char c1 = str_l.charAt(i);
            char c2 = str_r.charAt(i);
            r_[i] = Character.getNumericValue(c1);
            r_[i + 2] = Character.getNumericValue(c2);
```

```
        for (int i = 0; i < 4; i++) {
            l[i] = l[i] ^ r_p4[i];
        }

        int[] output = new int[8];
        for (int i = 0; i < 4; i++) {
            output[i] = l[i];
            output[i + 4] = r[i];
        }
        return output;
    }

    //    this function swaps the nibble of size n(4)

    int[] swap(int[] array, int n)
    {
        int[] l = new int[n];
        int[] r = new int[n];

        for (int i = 0; i < n; i++) {
            l[i] = array[i];
            r[i] = array[i + n];
        }

        int[] output = new int[2 * n];
        for (int i = 0; i < n; i++) {
            output[i] = r[i];
            output[i + n] = l[i];
        }

        return output;
    }

    //    this is main decryption function
    //    here we have used all previously defined function
    //    it takes cipher text as input and returns the array
    //of     decrypted text

    int[] decryption(int[] ar)
    {
        int[] arr = new int[8];

        for (int i = 0; i < 8; i++) {
            arr[i] = ar[IP[i] - 1];
```

```
        int[] arr2 = function_(after_swap, key1);

        int[] decrypted = new int[8];

        for (int i = 0; i < 8; i++) {
            decrypted[i] = arr2[IP_inv[i] - 1];
        }

        return decrypted;
    }

    public static void main(String[] args)
    {

        GFG obj = new GFG();

        obj.key_generation(); // call to key generation
                              // function

        // int []plaintext= {1,0,1,0,0,1,0,1};
        int[] plaintext = {
            1, 0, 0, 1, 0, 1, 1, 1
        }; // extra example for checking purpose

        System.out.println();
        System.out.println("Your plain Text is :");
        for (int i = 0; i < 8; i++) // printing the
                                    // plaintext
            System.out.print(plaintext[i] + " ");

        int[] ciphertext = obj.encryption(plaintext);

        System.out.println();
        System.out.println(
            "Your cipher Text is :"); // printing the cipher
                                      // text
        for (int i = 0; i < 8; i++)
            System.out.print(ciphertext[i] + " ");

        int[] decrypted = obj.decryption(ciphertext);

        System.out.println();
        System.out.println(
            "Your decrypted Text is :"); // printing the
```

```
//Omkar Varhadi
```

**Output**

```
Your Key-1 :
1 0 1 0 0 1 0 0
Your Key-2 :
0 1 0 0 0 0 1 1
Your plain Text is :
1 0 0 1 0 1 1 1
Your cipher Text is :
0 0 1 1 1 0 0 0
Your decrypted Text is :
1 0 0 1 0 1 1 1
```

01 Simplified Data Encryption Standard Key Generation
31, Jan 21

02 Simplified International Data Encryption Algorithm (IDEA)
17, Jan 20

03 Data encryption standard (DES) | Set 1
17, Aug 18

04 Difference between Software Encryption and Hardware Encryption
05, Feb 21

05 Strength of Data encryption standard (DES)
31, Jan 20

06 Advanced Encryption Standard (AES)
15, Oct 21

07 What is Data Encryption?
16, Jan 22

08 Rail Fence Cipher - Encryption and Decryption
20, Jan 17

## Article Contributed By :

devangj9689
@devangj9689

## Vote for difficulty

Current difficulty : Expert

Easy Normal Medium Hard Expert

Practice Tags : cryptography, Computer Networks

Improve Article Report Issue

Writing code in comment? Please use ide.geeksforgeeks.org, generate link and share the link here.

Load Comments

GeeksforGeeks
5th Floor, A-118,
Sector-136, Noida, Uttar Pradesh - 201305

feedback@geeksforgeeks.org

Contact Us

Copyright Policy

CS Subjects

Video Tutorials

Web Development

Web Tutorials

HTML

CSS

JavaScript

Bootstrap

Contribute

Write an Article

Write Interview Experience

Internships

Videos