Name : Karuna Bajirao Randive.

PRN : 2020BTECS00024

SUB : CNS

BATCH: B2

Assignment no 5.

Aim: To implement the DES cipher for encryption and decryption.

Algorithm:

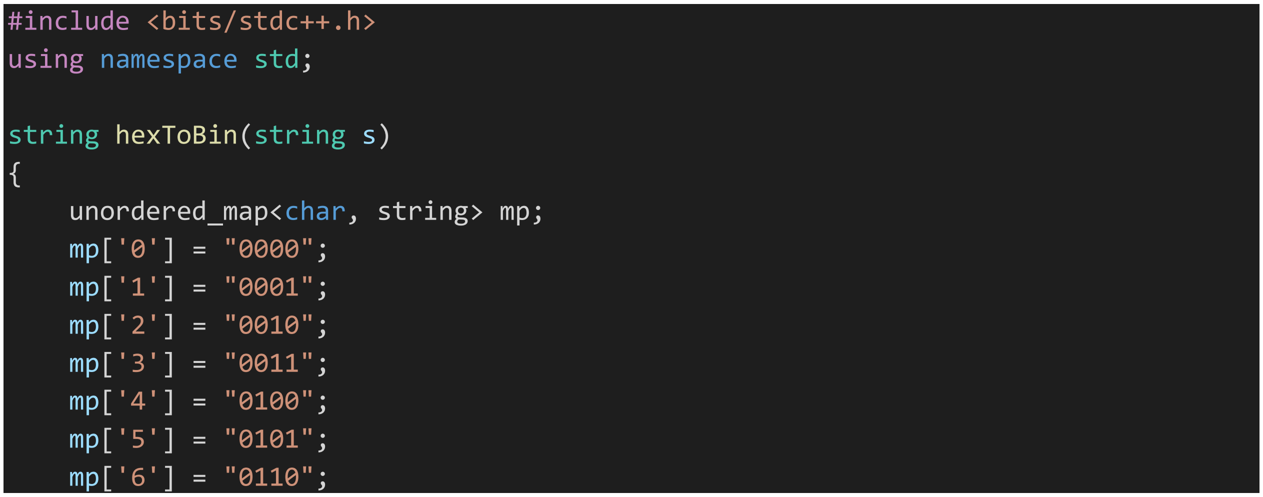
It operates on fixed-size blocks of data, dividing them into 64-bit blocks and using a fixed-length 56-bit secret key.

DES employs a Feistel network structure with 16 rounds of encryption, incorporating substitution-permutation operations, S-boxes, and P-boxes.

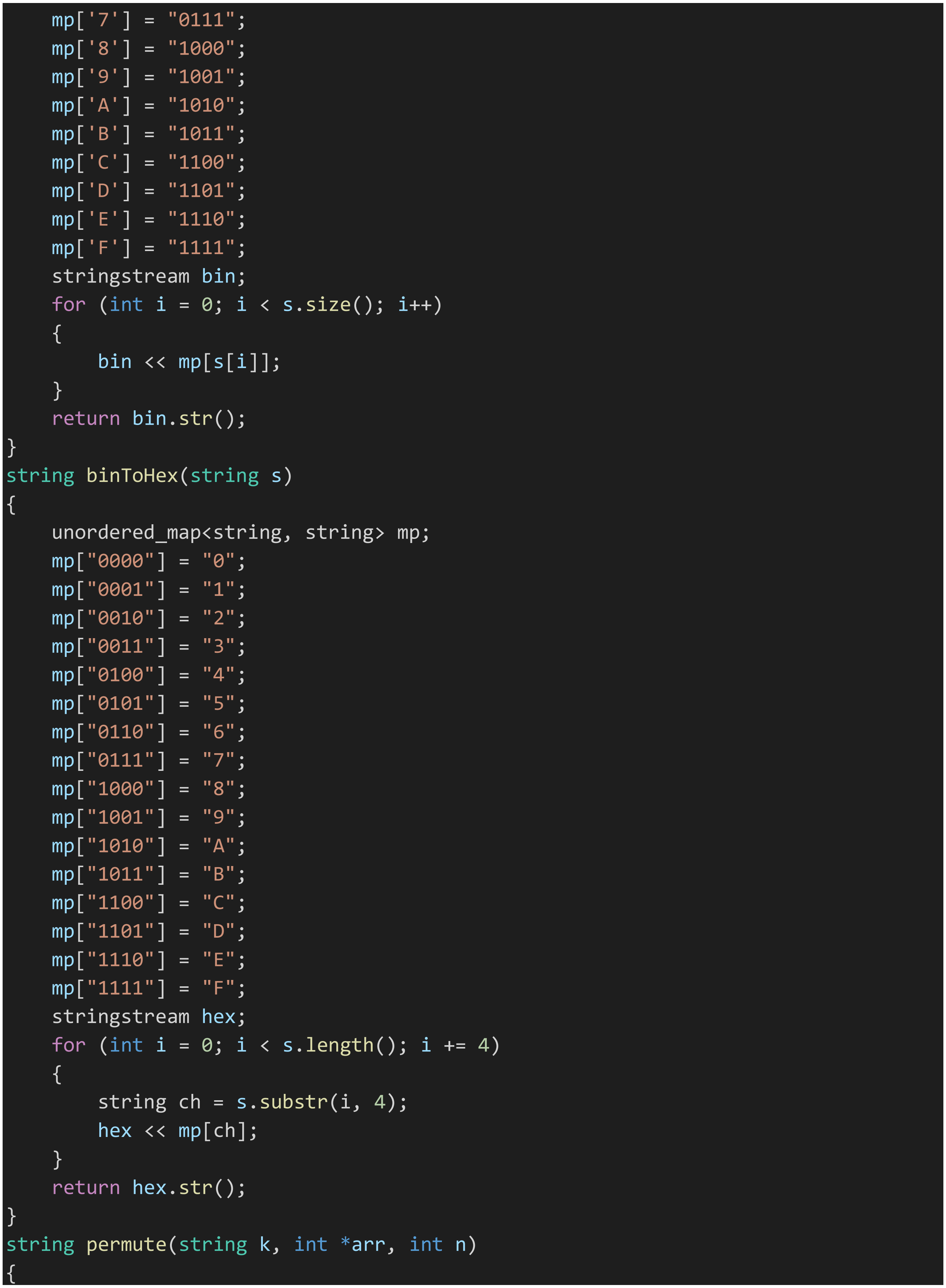
While it was a foundational encryption standard, DES is no longer considered secure due to its short key length, making it susceptible to modern brute-force attacks.

It has been replaced by more robust encryption algorithms, such as the Advanced Encryption Standard (AES).

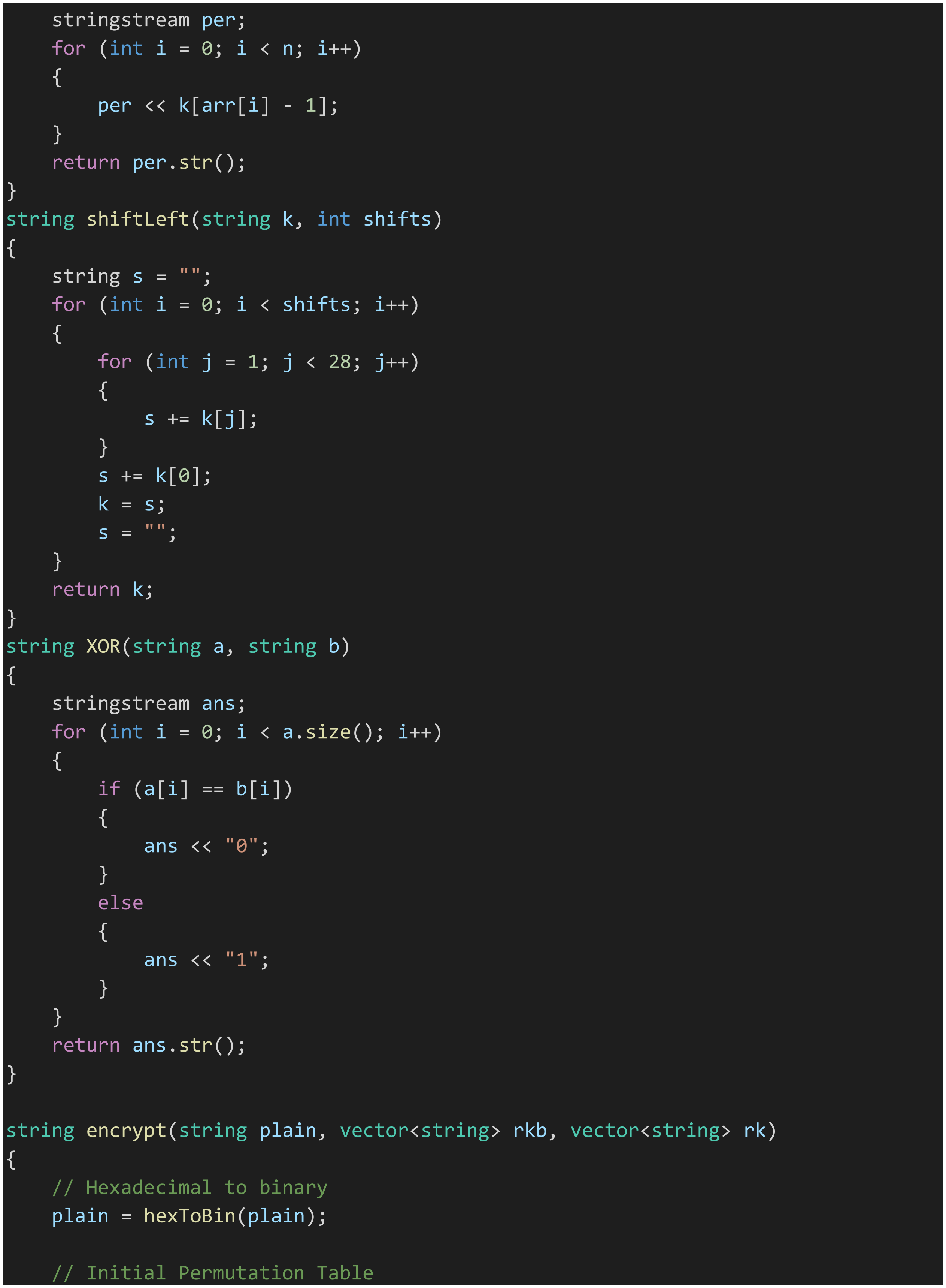
CODE :-



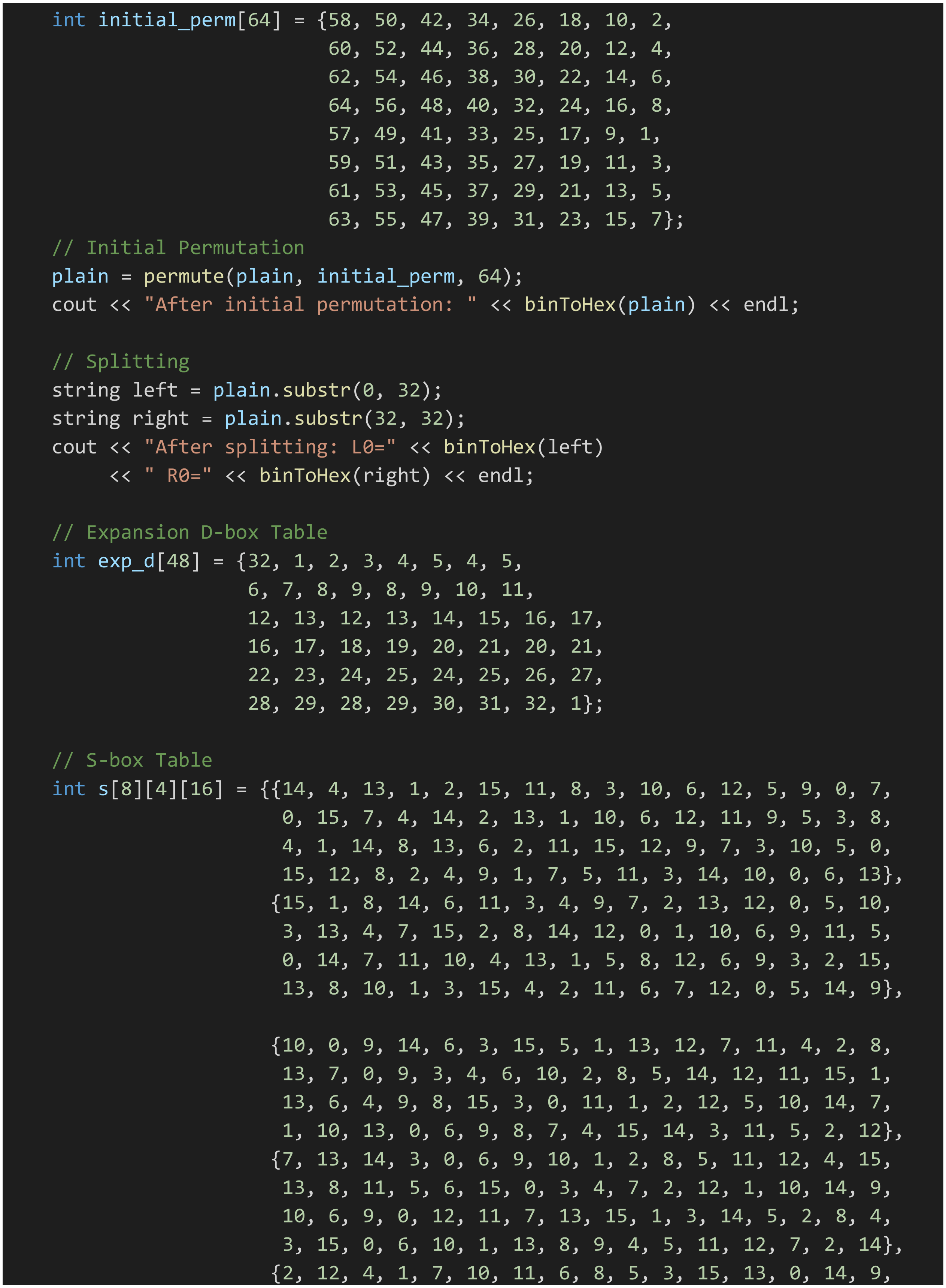
```
#include <bits/stdc++.h>
using namespace std;

string hexToBin(string s)
{
    unordered_map<char, string> mp;
    mp['0'] = "0000";
    mp['1'] = "0001";
    mp['2'] = "0010";
    mp['3'] = "0011";
    mp['4'] = "0100";
    mp['5'] = "0101";
    mp['6'] = "0110";
```



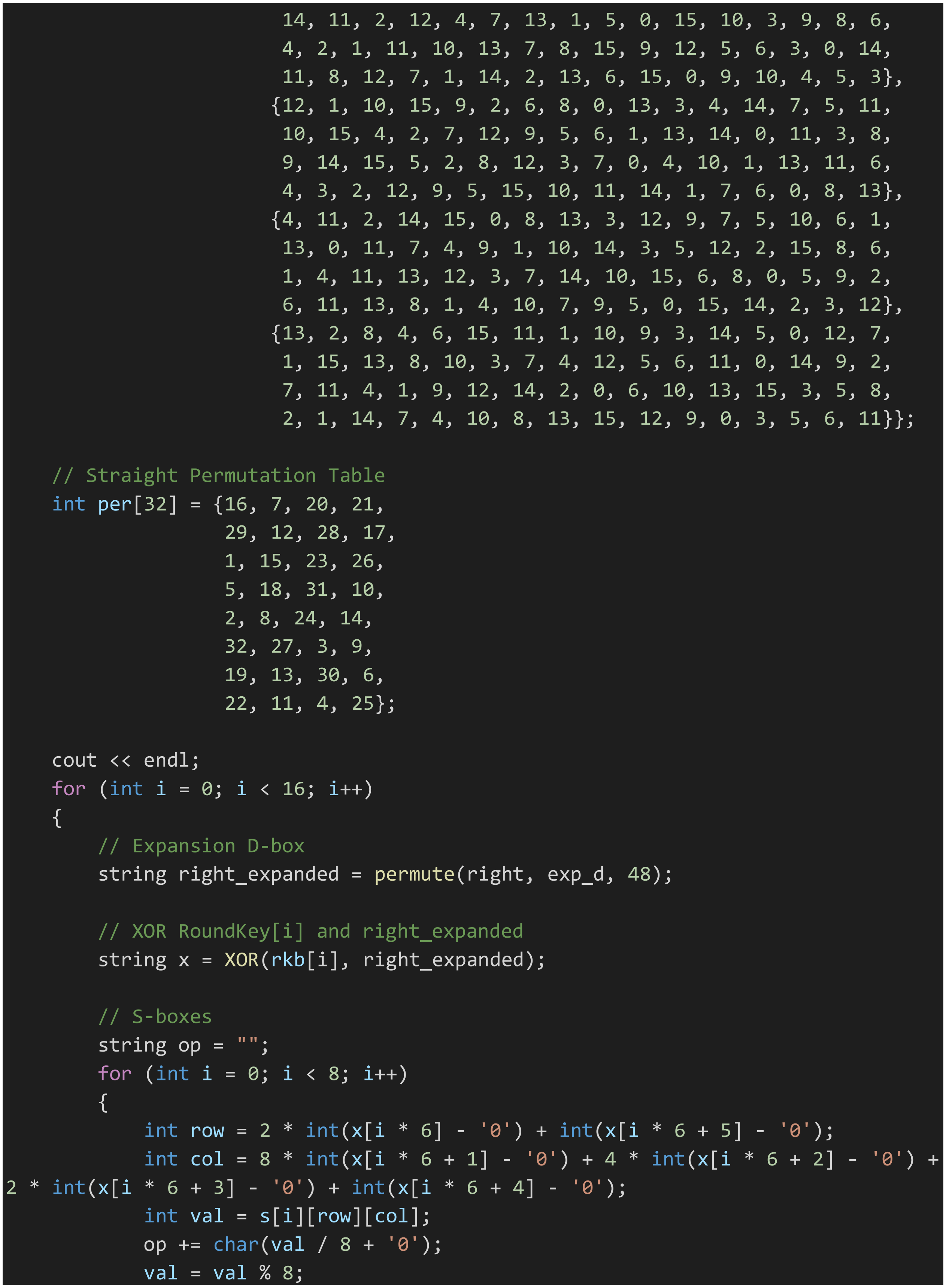
```
    mp['7'] = "0111";
    mp['8'] = "1000";
    mp['9'] = "1001";
    mp['A'] = "1010";
    mp['B'] = "1011";
    mp['C'] = "1100";
    mp['D'] = "1101";
    mp['E'] = "1110";
    mp['F'] = "1111";
    stringstream bin;
    for (int i = 0; i < s.size(); i++)
    {
        bin << mp[s[i]];
    }
    return bin.str();
}
string binToHex(string s)
{
    unordered_map<string, string> mp;
    mp["0000"] = "0";
    mp["0001"] = "1";
    mp["0010"] = "2";
    mp["0011"] = "3";
    mp["0100"] = "4";
    mp["0101"] = "5";
    mp["0110"] = "6";
    mp["0111"] = "7";
    mp["1000"] = "8";
    mp["1001"] = "9";
    mp["1010"] = "A";
    mp["1011"] = "B";
    mp["1100"] = "C";
    mp["1101"] = "D";
    mp["1110"] = "E";
    mp["1111"] = "F";
    stringstream hex;
    for (int i = 0; i < s.length(); i += 4)
    {
        string ch = s.substr(i, 4);
        hex << mp[ch];
    }
    return hex.str();
}
string permute(string k, int *arr, int n)
{
```



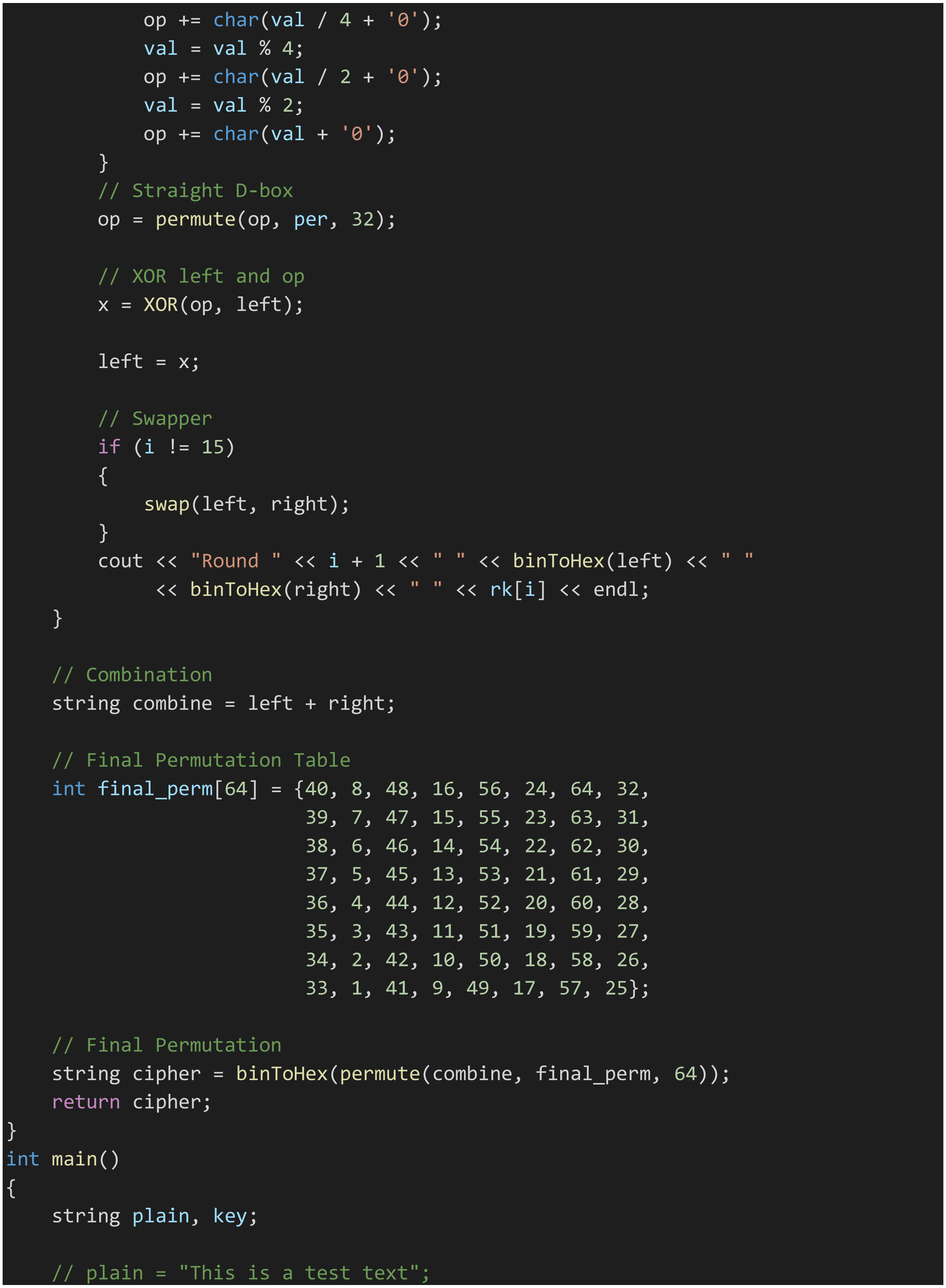
```
    stringstream per;
    for (int i = 0; i < n; i++)
    {
        per << k[arr[i] - 1];
    }
    return per.str();
}
string shiftLeft(string k, int shifts)
{
    string s = "";
    for (int i = 0; i < shifts; i++)
    {
        for (int j = 1; j < 28; j++)
        {
            s += k[j];
        }
        s += k[0];
        k = s;
        s = "";
    }
    return k;
}
string XOR(string a, string b)
{
    stringstream ans;
    for (int i = 0; i < a.size(); i++)
    {
        if (a[i] == b[i])
        {
            ans << "0";
        }
        else
        {
            ans << "1";
        }
    }
    return ans.str();
}

string encrypt(string plain, vector<string> rkb, vector<string> rk)
{
    // Hexadecimal to binary
    plain = hexToBin(plain);

    // Initial Permutation Table
```



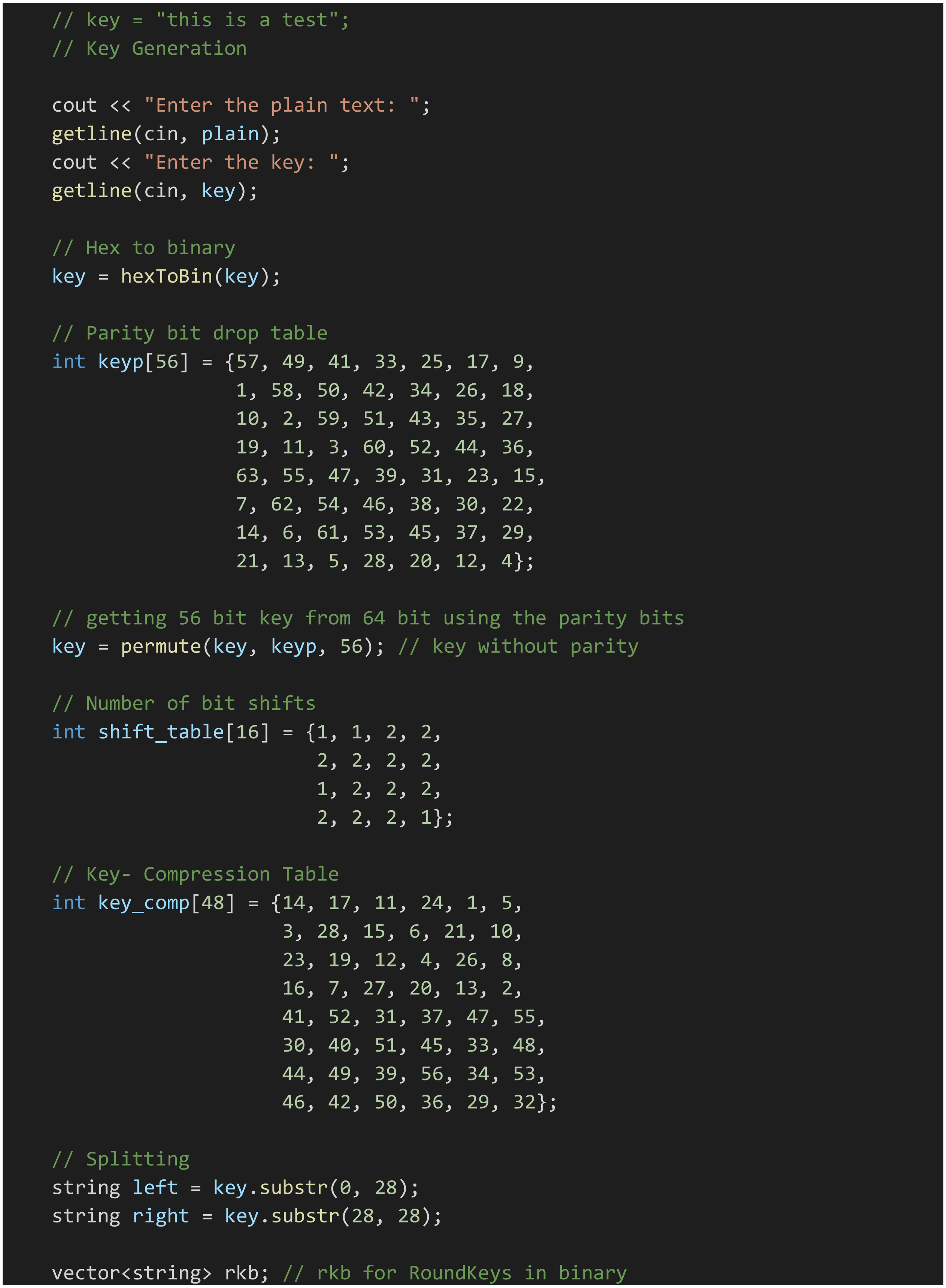
```
    int initial_perm[64] = {58, 50, 42, 34, 26, 18, 10, 2,
                            60, 52, 44, 36, 28, 20, 12, 4,
                            62, 54, 46, 38, 30, 22, 14, 6,
                            64, 56, 48, 40, 32, 24, 16, 8,
                            57, 49, 41, 33, 25, 17, 9, 1,
                            59, 51, 43, 35, 27, 19, 11, 3,
                            61, 53, 45, 37, 29, 21, 13, 5,
                            63, 55, 47, 39, 31, 23, 15, 7};
    // Initial Permutation
    plain = permute(plain, initial_perm, 64);
    cout << "After initial permutation: " << binToHex(plain) << endl;

    // Splitting
    string left = plain.substr(0, 32);
    string right = plain.substr(32, 32);
    cout << "After splitting: L0=" << binToHex(left)
         << " R0=" << binToHex(right) << endl;

    // Expansion D-box Table
    int exp_d[48] = {32, 1, 2, 3, 4, 5, 4, 5,
                     6, 7, 8, 9, 8, 9, 10, 11,
                     12, 13, 12, 13, 14, 15, 16, 17,
                     16, 17, 18, 19, 20, 21, 20, 21,
                     22, 23, 24, 25, 24, 25, 26, 27,
                     28, 29, 28, 29, 30, 31, 32, 1};

    // S-box Table
    int s[8][4][16] = {{14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5, 9, 0, 7,
                        0, 15, 7, 4, 14, 2, 13, 1, 10, 6, 12, 11, 9, 5, 3, 8,
                        4, 1, 14, 8, 13, 6, 2, 11, 15, 12, 9, 7, 3, 10, 5, 0,
                        15, 12, 8, 2, 4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13},
                       {15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12, 0, 5, 10,
                        3, 13, 4, 7, 15, 2, 8, 14, 12, 0, 1, 10, 6, 9, 11, 5,
                        0, 14, 7, 11, 10, 4, 13, 1, 5, 8, 12, 6, 9, 3, 2, 15,
                        13, 8, 10, 1, 3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9},

                       {10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12, 7, 11, 4, 2, 8,
                        13, 7, 0, 9, 3, 4, 6, 10, 2, 8, 5, 14, 12, 11, 15, 1,
                        13, 6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12, 5, 10, 14, 7,
                        1, 10, 13, 0, 6, 9, 8, 7, 4, 15, 14, 3, 11, 5, 2, 12},
                       {7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11, 12, 4, 15,
                        13, 8, 11, 5, 6, 15, 0, 3, 4, 7, 2, 12, 1, 10, 14, 9,
                        10, 6, 9, 0, 12, 11, 7, 13, 15, 1, 3, 14, 5, 2, 8, 4,
                        3, 15, 0, 6, 10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14},
                       {2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13, 0, 14, 9,
```



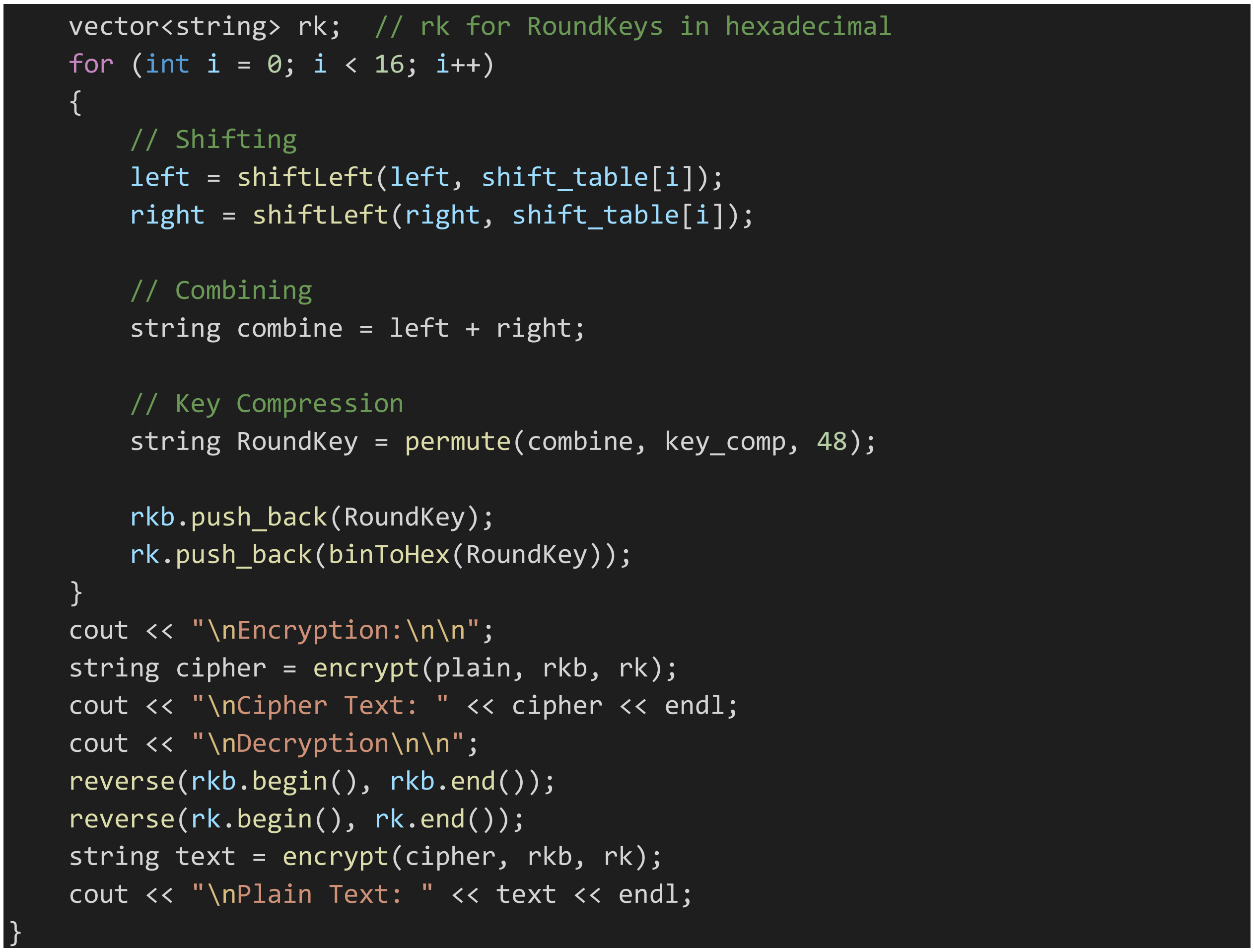
```
                        14, 11, 2, 12, 4, 7, 13, 1, 5, 0, 15, 10, 3, 9, 8, 6,
                        4, 2, 1, 11, 10, 13, 7, 8, 15, 9, 12, 5, 6, 3, 0, 14,
                        11, 8, 12, 7, 1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3},
                       {12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14, 7, 5, 11,
                        10, 15, 4, 2, 7, 12, 9, 5, 6, 1, 13, 14, 0, 11, 3, 8,
                        9, 14, 15, 5, 2, 8, 12, 3, 7, 0, 4, 10, 1, 13, 11, 6,
                        4, 3, 2, 12, 9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13},
                       {4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5, 10, 6, 1,
                        13, 0, 11, 7, 4, 9, 1, 10, 14, 3, 5, 12, 2, 15, 8, 6,
                        1, 4, 11, 13, 12, 3, 7, 14, 10, 15, 6, 8, 0, 5, 9, 2,
                        6, 11, 13, 8, 1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12},
                       {13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5, 0, 12, 7,
                        1, 15, 13, 8, 10, 3, 7, 4, 12, 5, 6, 11, 0, 14, 9, 2,
                        7, 11, 4, 1, 9, 12, 14, 2, 0, 6, 10, 13, 15, 3, 5, 8,
                        2, 1, 14, 7, 4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11}};

    // Straight Permutation Table
    int per[32] = {16, 7, 20, 21,
                   29, 12, 28, 17,
                   1, 15, 23, 26,
                   5, 18, 31, 10,
                   2, 8, 24, 14,
                   32, 27, 3, 9,
                   19, 13, 30, 6,
                   22, 11, 4, 25};

    cout << endl;
    for (int i = 0; i < 16; i++)
    {
        // Expansion D-box
        string right_expanded = permute(right, exp_d, 48);

        // XOR RoundKey[i] and right_expanded
        string x = XOR(rkb[i], right_expanded);

        // S-boxes
        string op = "";
        for (int i = 0; i < 8; i++)
        {
            int row = 2 * int(x[i * 6] - '0') + int(x[i * 6 + 5] - '0');
            int col = 8 * int(x[i * 6 + 1] - '0') + 4 * int(x[i * 6 + 2] - '0') +
2 * int(x[i * 6 + 3] - '0') + int(x[i * 6 + 4] - '0');
            int val = s[i][row][col];
            op += char(val / 8 + '0');
            val = val % 8;
```



```
            op += char(val / 4 + '0');
            val = val % 4;
            op += char(val / 2 + '0');
            val = val % 2;
            op += char(val + '0');
        }
        // Straight D-box
        op = permute(op, per, 32);

        // XOR left and op
        x = XOR(op, left);

        left = x;

        // Swapper
        if (i != 15)
        {
            swap(left, right);
        }
        cout << "Round " << i + 1 << " " << binToHex(left) << " "
             << binToHex(right) << " " << rk[i] << endl;
    }

    // Combination
    string combine = left + right;

    // Final Permutation Table
    int final_perm[64] = {40, 8, 48, 16, 56, 24, 64, 32,
                          39, 7, 47, 15, 55, 23, 63, 31,
                          38, 6, 46, 14, 54, 22, 62, 30,
                          37, 5, 45, 13, 53, 21, 61, 29,
                          36, 4, 44, 12, 52, 20, 60, 28,
                          35, 3, 43, 11, 51, 19, 59, 27,
                          34, 2, 42, 10, 50, 18, 58, 26,
                          33, 1, 41, 9, 49, 17, 57, 25};

    // Final Permutation
    string cipher = binToHex(permute(combine, final_perm, 64));
    return cipher;
}
int main()
{
    string plain, key;

    // plain = "This is a test text";
```

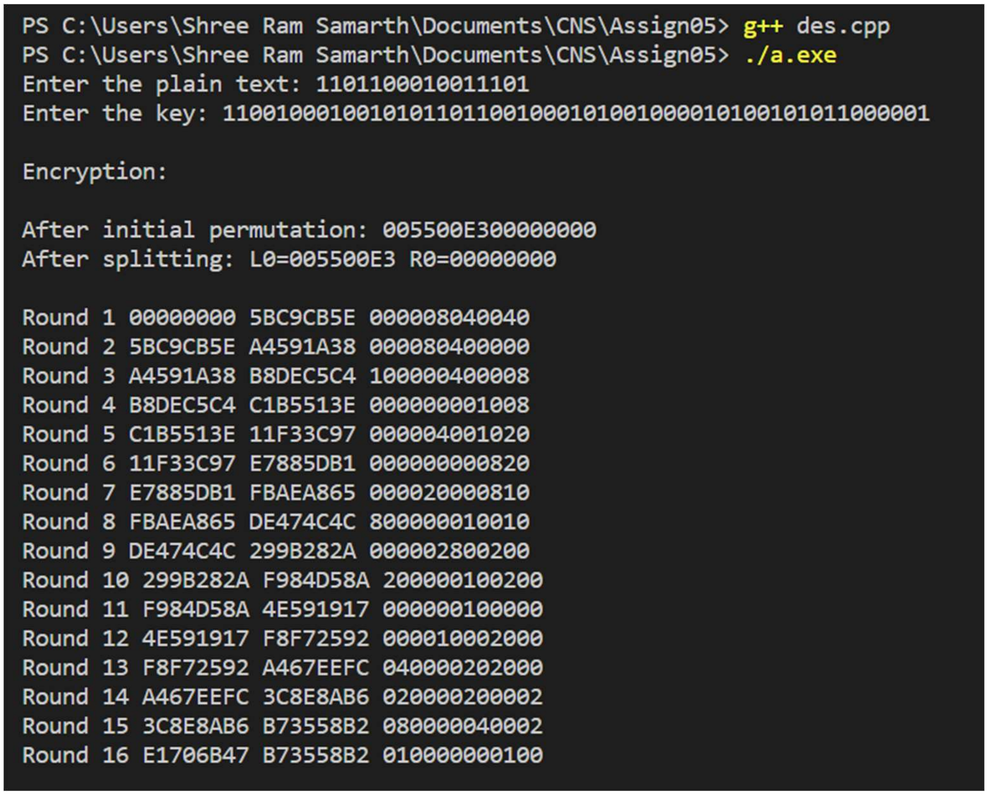


```
    // key = "this is a test";
    // Key Generation

    cout << "Enter the plain text: ";
    getline(cin, plain);
    cout << "Enter the key: ";
    getline(cin, key);

    // Hex to binary
    key = hexToBin(key);

    // Parity bit drop table
    int keyp[56] = {57, 49, 41, 33, 25, 17, 9,
                    1, 58, 50, 42, 34, 26, 18,
                    10, 2, 59, 51, 43, 35, 27,
                    19, 11, 3, 60, 52, 44, 36,
                    63, 55, 47, 39, 31, 23, 15,
                    7, 62, 54, 46, 38, 30, 22,
                    14, 6, 61, 53, 45, 37, 29,
                    21, 13, 5, 28, 20, 12, 4};

    // getting 56 bit key from 64 bit using the parity bits
    key = permute(key, keyp, 56); // key without parity

    // Number of bit shifts
    int shift_table[16] = {1, 1, 2, 2,
                           2, 2, 2, 2,
                           1, 2, 2, 2,
                           2, 2, 2, 1};

    // Key- Compression Table
    int key_comp[48] = {14, 17, 11, 24, 1, 5,
                        3, 28, 15, 6, 21, 10,
                        23, 19, 12, 4, 26, 8,
                        16, 7, 27, 20, 13, 2,
                        41, 52, 31, 37, 47, 55,
                        30, 40, 51, 45, 33, 48,
                        44, 49, 39, 56, 34, 53,
                        46, 42, 50, 36, 29, 32};

    // Splitting
    string left = key.substr(0, 28);
    string right = key.substr(28, 28);

    vector<string> rkb; // rkb for RoundKeys in binary
```

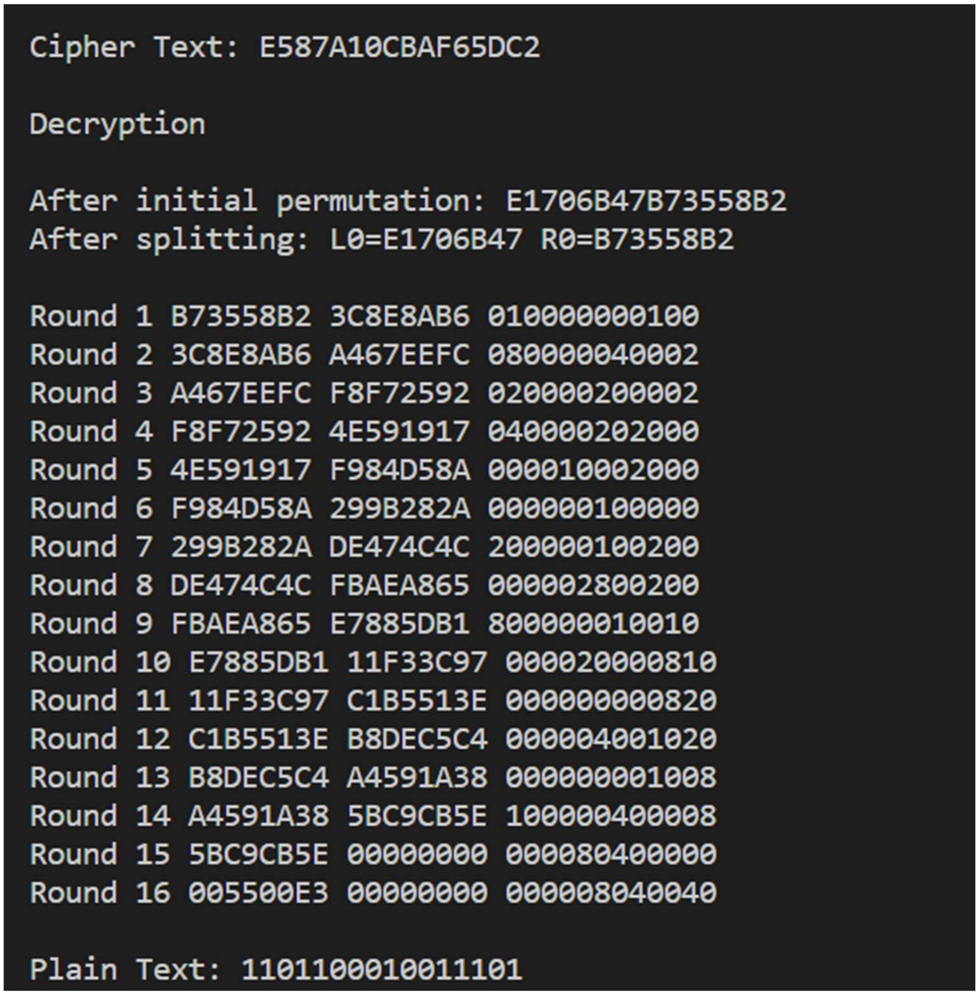


```cpp
    vector<string> rk;  // rk for RoundKeys in hexadecimal
    for (int i = 0; i < 16; i++)
    {
        // Shifting
        left = shiftLeft(left, shift_table[i]);
        right = shiftLeft(right, shift_table[i]);

        // Combining
        string combine = left + right;

        // Key Compression
        string RoundKey = permute(combine, key_comp, 48);

        rkb.push_back(RoundKey);
        rk.push_back(binToHex(RoundKey));
    }
    cout << "\nEncryption:\n\n";
    string cipher = encrypt(plain, rkb, rk);
    cout << "\nCipher Text: " << cipher << endl;
    cout << "\nDecryption\n\n";
    reverse(rkb.begin(), rkb.end());
    reverse(rk.begin(), rk.end());
    string text = encrypt(cipher, rkb, rk);
    cout << "\nPlain Text: " << text << endl;
}
```

Output :



```
PS C:\Users\Shree Ram Samarth\Documents\CNS\Assign05> g++ des.cpp
PS C:\Users\Shree Ram Samarth\Documents\CNS\Assign05> ./a.exe
Enter the plain text: 1101100010011101
Enter the key: 11001000100101011011001000101001000010100101011000001

Encryption:

After initial permutation: 005500E300000000
After splitting: L0=005500E3 R0=00000000

Round 1 00000000 5BC9CB5E 000008040040
Round 2 5BC9CB5E A4591A38 000080400000
Round 3 A4591A38 B8DEC5C4 100000400008
Round 4 B8DEC5C4 C1B5513E 000000001008
Round 5 C1B5513E 11F33C97 000004001020
Round 6 11F33C97 E7885DB1 000000000820
Round 7 E7885DB1 FBAEA865 000020000810
Round 8 FBAEA865 DE474C4C 800000010010
Round 9 DE474C4C 299B282A 000002800200
Round 10 299B282A F984D58A 200000100200
Round 11 F984D58A 4E591917 000000100000
Round 12 4E591917 F8F72592 000010002000
Round 13 F8F72592 A467EEFC 040000202000
Round 14 A467EEFC 3C8E8AB6 020000200002
Round 15 3C8E8AB6 B73558B2 080000040002
Round 16 E1706B47 B73558B2 010000000100
```



```
Cipher Text: E587A10CBAF65DC2

Decryption

After initial permutation: E1706B47B73558B2
After splitting: L0=E1706B47 R0=B73558B2

Round 1 B73558B2 3C8E8AB6 010000000100
Round 2 3C8E8AB6 A467EEFC 080000040002
Round 3 A467EEFC F8F72592 020000200002
Round 4 F8F72592 4E591917 040000202000
Round 5 4E591917 F984D58A 000010002000
Round 6 F984D58A 299B282A 000000100000
Round 7 299B282A DE474C4C 200000100200
Round 8 DE474C4C FBAEA865 000002800200
Round 9 FBAEA865 E7885DB1 800000010010
Round 10 E7885DB1 11F33C97 000020000810
Round 11 11F33C97 C1B5513E 000000000820
Round 12 C1B5513E B8DEC5C4 000004001020
Round 13 B8DEC5C4 A4591A38 000000001008
Round 14 A4591A38 5BC9CB5E 100000400008
Round 15 5BC9CB5E 00000000 000080400000
Round 16 005500E3 00000000 000008040040

Plain Text: 1101100010011101
```

Limitations:

DES uses a fixed key length of 56 bits. With advances in computing power, particularly the advent of distributed computing and specialized hardware, a 56-bit key length became insufficient to withstand brute-force attacks. It's now considered relatively easy to break DES encryption by trying all possible keys