Walchand College Of Engineering, Sangli

Department of Computer Science and Engineering

Subject: C&NS Lab

Batch: B4

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Assignment 6

Title: Data encryption standard

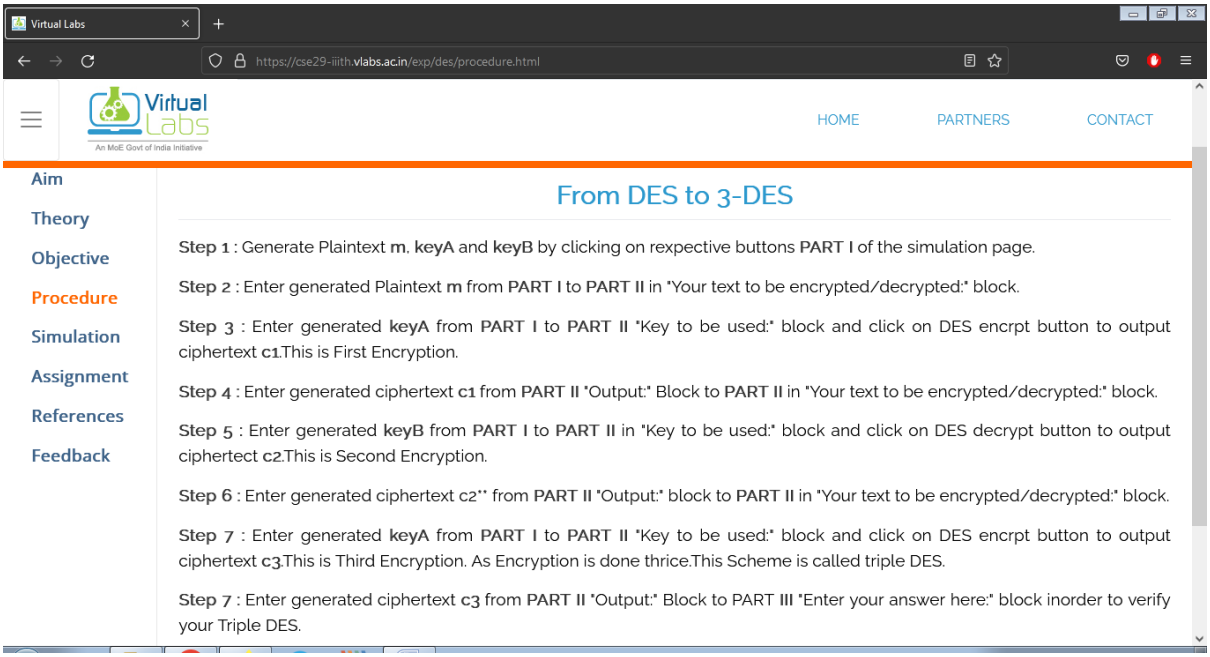
Theory:

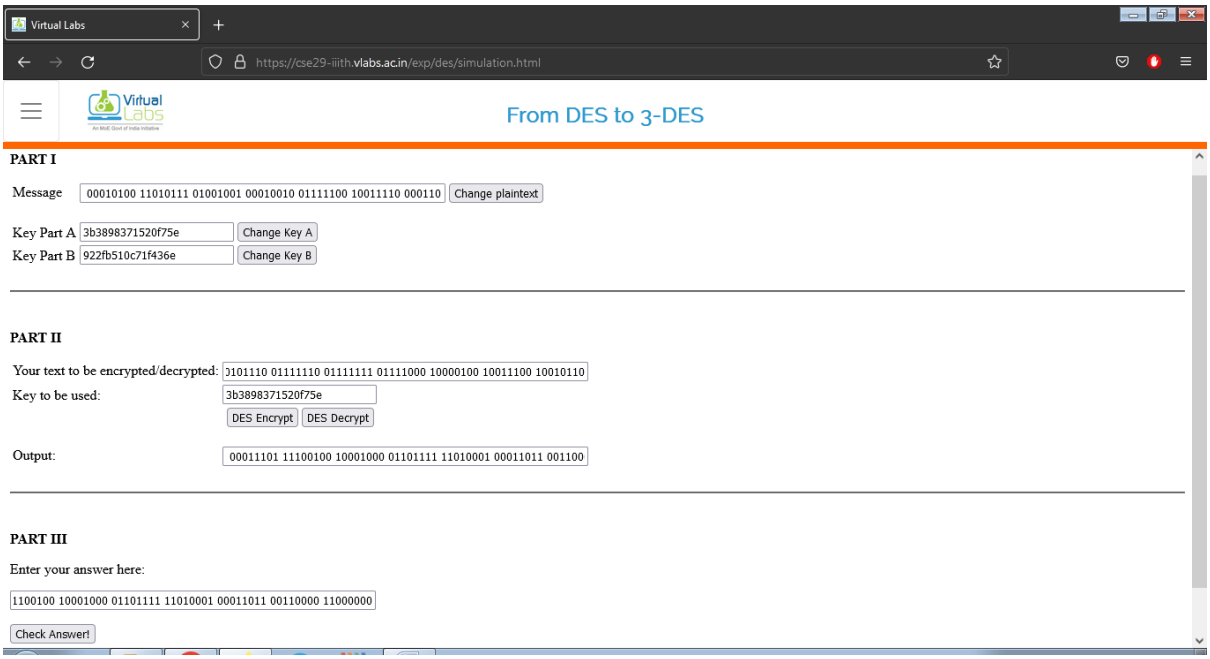
The Data Encryption Standard (DES) is a symmetric-key block cipher published by the National Institute of Standards and Technology (NIST). DES is an implementation of a Feistel Cipher. It uses 16 round Feistel structure. The block size is 64-bit. Though, key length is 64-bit, DES has an effective key length of 56 bits, since 8 of the 64 bits of the key are not used by the encryption algorithm**.**

Procedure:

1) In the first step, the 64-bit plain text block is handed over to an initial Permutation (IP) function.
2) The initial permutation is performed on plain text.
3) Next, the initial permutation (IP) produces two halves of the permuted block; saying Left Plain Text (LPT) and Right Plain Text (RPT).
4) Now each LPT and RPT go through 16 rounds of the encryption process.
5) In the end, LPT and RPT are rejoined and a Final Permutation (FP) is performed on the combined block
6) The result of this process produces 64-bit ciphertext.

Virtual Lab:





Code:

```
#include <bits/stdc++.h>

using namespace std;
```

```
string hex2bin(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";
    string bin = "";
    for (int i = 0; i < s.size(); i++)
    {
        bin += mp[s[i]];
    }
    return bin;
}
string bin2hex(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";
    string hex = "";
    for (int i = 0; i < s.length(); i += 4)
    {
        string ch = "";
        ch += s[i];
        ch += s[i + 1];
        ch += s[i + 2];
        ch += s[i + 3];
        hex += mp[ch];
    }
    return hex;
}
```

```
string permute(string k, int *arr, int n)
{
    string per = "";
    for (int i = 0; i < n; i++)
    {
        per += k[arr[i] - 1];
    }
    return per;
}

string shift_left(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)
{
    string ans = "";
```

```
    for (int i = 0; i < a.size(); i++)
    {
        if (a[i] == b[i])
        {
            ans += "0";
        }
        else
        {
            ans += "1";
        }
    }
    return ans;
}
string encrypt(string pt, vector<string> rkb,
               vector<string> rk)
{
    pt = hex2bin(pt);

    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};
    pt = permute(pt, initial_perm, 64);
    cout << "After initial permutation: " << bin2hex(pt)
         << endl;

    string left = pt.substr(0, 32);
```

```
    string right = pt.substr(32, 32);
    cout << "After splitting: L0=" << bin2hex(left)
         << " R0=" << bin2hex(right) << endl;

    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};

    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}};

    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;
```

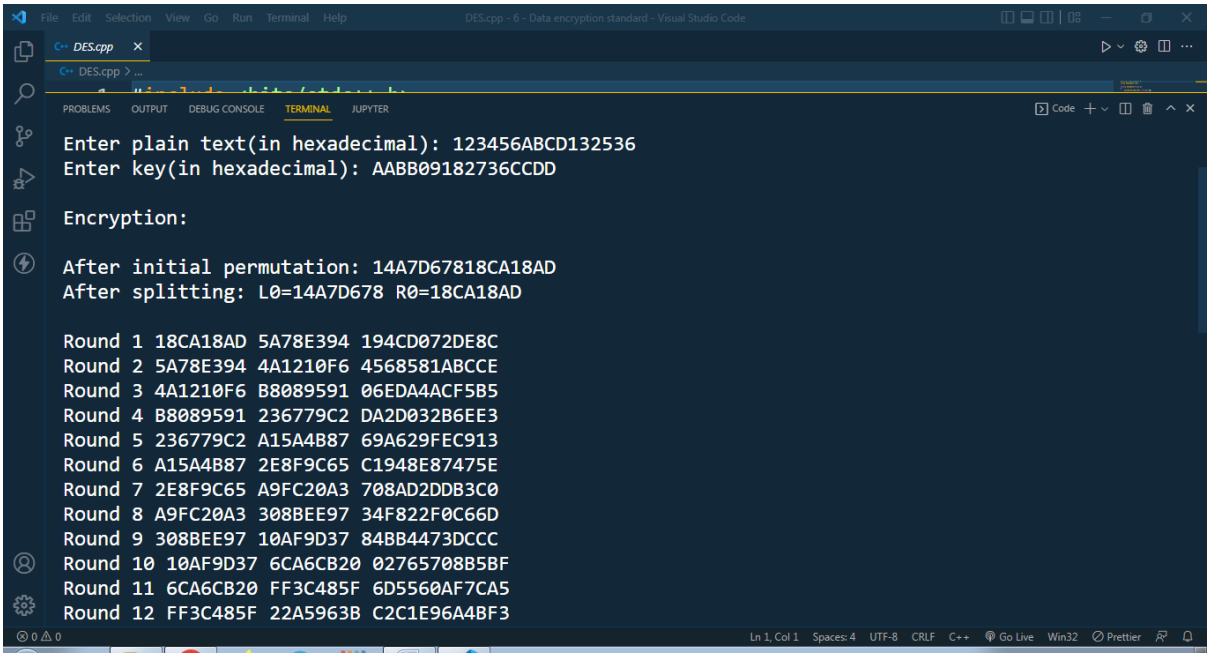
```
    for (int i = 0; i < 16; i++)
    {
        string right_expanded = permute(right, exp_d, 48);

        string x = xor_(rkb[i], right_expanded);

        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');
        }
        op = permute(op, per, 32);

        x = xor_(op, left);

        left = x;

        if (i != 15)
        {
```

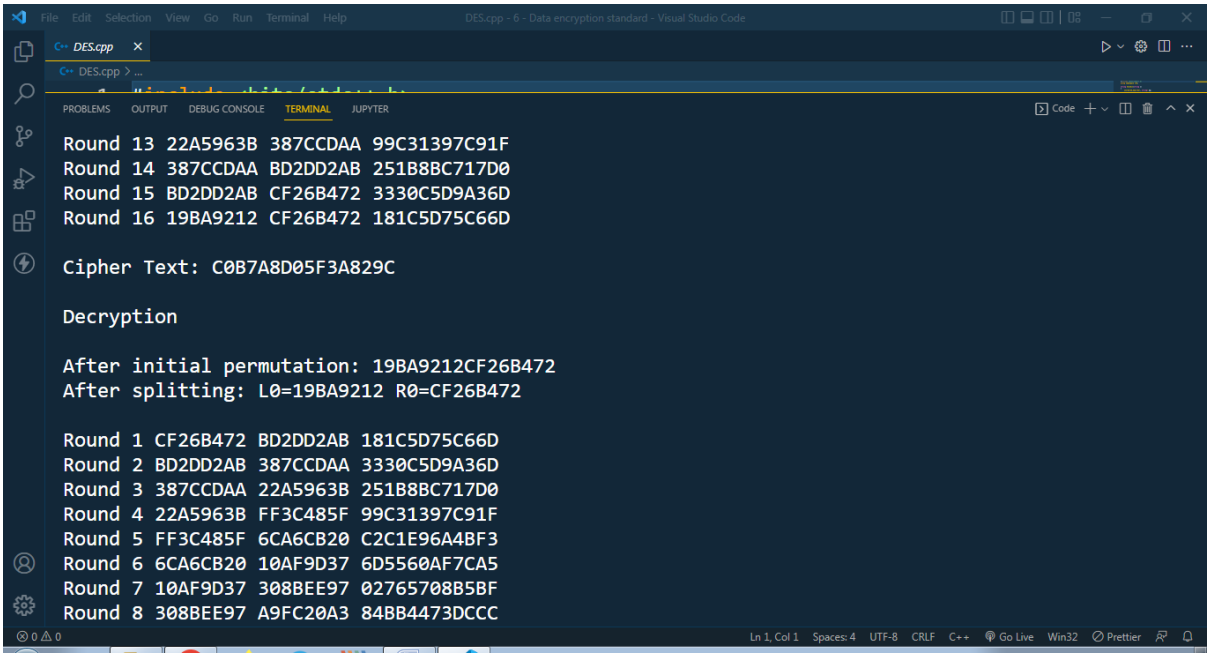
```
            swap(left, right);
        }
        cout << "Round " << i + 1 << " " << bin2hex(left)
             << " " << bin2hex(right) << " " << rk[i]
             << endl;
    }

    string combine = left + right;

    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};

    string cipher = bin2hex(permute(combine, final_perm, 64));
    return cipher;
}

int main()
{
    string pt, key;
    cout << "Enter plain text(in hexadecimal): ";
    cin >> pt;
    cout << "Enter key(in hexadecimal): ";
    cin >> key;

    key = hex2bin(key);
```

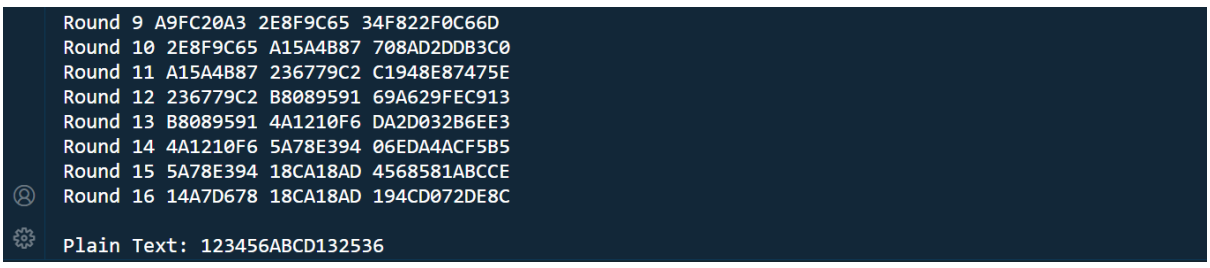
```
int keyp[56] = {57, 49, 41, 33, 25, 17, 9, 1, 58, 50, 42, 34,
                26, 18, 10, 2, 59, 51, 43, 35, 27, 19, 11, 3,
                60, 52, 44, 36, 63, 55, 47, 39, 31, 23, 15, 7,
                62, 54, 46, 38, 30, 22, 14, 6, 61, 53, 45, 37,
                29, 21, 13, 5, 28, 20, 12, 4};

key = permute(key, keyp, 56);

int shift_table[16] = {1, 1, 2, 2, 2, 2, 2, 2,
                       1, 2, 2, 2, 2, 2, 2, 1};

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};

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

vector<string> rkb;
vector<string> rk;
for (int i = 0; i < 16; i++)
{
    left = shift_left(left, shift_table[i]);
    right = shift_left(right, shift_table[i]);
```

```
        string combine = left + right;


        string RoundKey = permute(combine, key_comp, 48);


        rkb.push_back(RoundKey);
        rk.push_back(bin2hex(RoundKey));
    }


    cout << "\nEncryption:\n\n";
    string cipher = encrypt(pt, 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:


DES.cpp - 6 - Data encryption standard - Visual Studio Code
DES.cpp
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL JUPYTER
Enter plain text(in hexadecimal): 123456ABCD132536
Enter key(in hexadecimal): AABB09182736CCDD
Encryption:
After initial permutation: 14A7D67818CA18AD
After splitting: L0=14A7D678 R0=18CA18AD
Round 1 18CA18AD 5A78E394 194CD072DE8C
Round 2 5A78E394 4A1210F6 4568581ABCCE
Round 3 4A1210F6 B8089591 06EDA4ACF5B5
Round 4 B8089591 236779C2 DA2D032B6EE3
Round 5 236779C2 A15A4B87 69A629FEC913
Round 6 A15A4B87 2E8F9C65 C1948E87475E
Round 7 2E8F9C65 A9FC20A3 708AD2DDB3C0
Round 8 A9FC20A3 308BEE97 34F822F0C66D
Round 9 308BEE97 10AF9D37 84BB4473DCCC
Round 10 10AF9D37 6CA6CB20 02765708B5BF
Round 11 6CA6CB20 FF3C485F 6D5560AF7CA5
Round 12 FF3C485F 22A5963B C2C1E96A4BF3


DES.cpp - 6 - Data encryption standard - Visual Studio Code
DES.cpp
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL JUPYTER
Round 13 22A5963B 387CCDAA 99C31397C91F
Round 14 387CCDAA BD2DD2AB 251B8BC717D0
Round 15 BD2DD2AB CF26B472 3330C5D9A36D
Round 16 19BA9212 CF26B472 181C5D75C66D
Cipher Text: C0B7A8D05F3A829C
Decryption
After initial permutation: 19BA9212CF26B472
After splitting: L0=19BA9212 R0=CF26B472
Round 1 CF26B472 BD2DD2AB 181C5D75C66D
Round 2 BD2DD2AB 387CCDAA 3330C5D9A36D
Round 3 387CCDAA 22A5963B 251B8BC717D0
Round 4 22A5963B FF3C485F 99C31397C91F
Round 5 FF3C485F 6CA6CB20 C2C1E96A4BF3
Round 6 6CA6CB20 10AF9D37 6D5560AF7CA5
Round 7 10AF9D37 308BEE97 02765708B5BF
Round 8 308BEE97 A9FC20A3 84BB4473DCCC


Round 9 A9FC20A3 2E8F9C65 34F822F0C66D
Round 10 2E8F9C65 A15A4B87 708AD2DDB3C0
Round 11 A15A4B87 236779C2 C1948E87475E
Round 12 236779C2 B8089591 69A629FEC913
Round 13 B8089591 4A1210F6 DA2D032B6EE3
Round 14 4A1210F6 5A78E394 06EDA4ACF5B5
Round 15 5A78E394 18CA18AD 4568581ABCCE
Round 16 14A7D678 18CA18AD 194CD072DE8C
Plain Text: 123456ABCD132536

Conclusion:

The DES satisfies both the desired properties of block cipher. These two properties make cipher very strong.

1) Avalanche effect − A small change in plaintext results in a great change in the ciphertext.
2) Completeness − Each bit of ciphertext depends on many bits of plaintext.