DES Algorithm

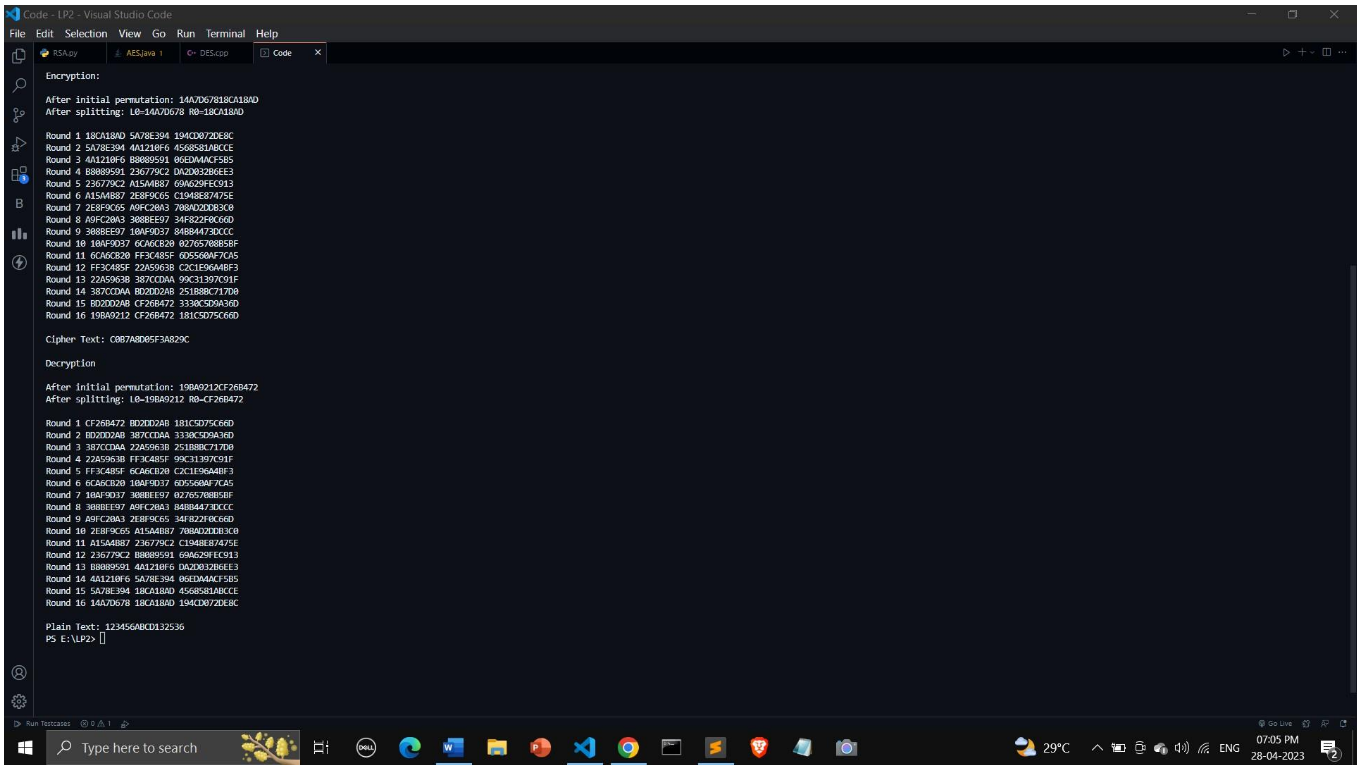
```
#include <bits/stdc++.h>
using namespace std;
string hex2bin(string s)
{
    // hexadecimal to binary conversion
    unordered_map<char, string> mp;
    mp['0'] = "0000";
    mp['1'] = "0001";
    mp['2'] = "0010";
    mp['3'] = "0011";
    mp['4'] = "0100";
    mp['5'] = "0101";
    mp['6'] = "0110";
    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)
{
    // binary to hexadecimal conversion
    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)
{
    // Hexadecimal to binary
    pt = hex2bin(pt);

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

    // Splitting
    string left = pt.substr(0, 32);
    string right = pt.substr(32, 32);
    cout << "After splitting: L0=" << bin2hex(left)
         << " R0=" << bin2hex(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 << " " << bin2hex(left) << " "
             << bin2hex(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 = bin2hex(permute(combine, final_perm, 64));
    return cipher;
}
int main()
{
    // pt is plain text
    string pt, key;
    /*cout<<"Enter plain text(in hexadecimal): ";
    cin>>pt;
    cout<<"Enter key(in hexadecimal): ";
    cin>>key;*/
```

```
pt = "123456ABCD132536";
key = "AABB09182736CCDD";
// Key Generation

// Hex to binary
key = hex2bin(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
vector<string> rk; // rk for RoundKeys in hexadecimal
for (int i = 0; i < 16; i++) {
    // Shifting
    left = shift_left(left, shift_table[i]);
    right = shift_left(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(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:



```
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
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
PS E:\LP2> 
```