密码学实验报告——分组密码算法DES

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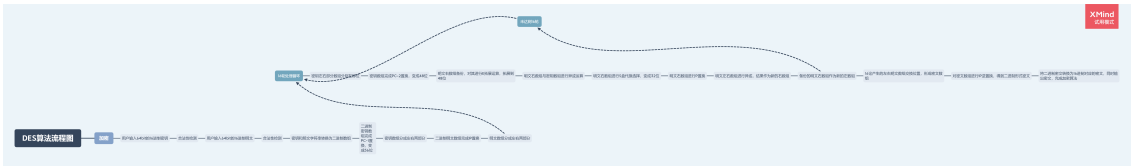
(实验环境 win10 dev c++)

1. 实验目的

   通过DES算法的编程实验加深对DES算法运行原理的理解，以及理解分组密码的加密算法设计和解密算法设计

2. 实验原理

   由于Xmind使用的不太顺手，可能图片较长不太清晰，已经将xmind文件和png原文件放在文件夹内



3. DES加密

   具体代码见程序代码文件夹或报告底部，展示效果如下：

```
{ 1, 1,      { 0x10, 0x31, 0x6E, 0x02, 0x8C, 0x8F, 0x3B, 0x4A },
             { 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00 },
             { 0x82, 0xDC, 0xBA, 0xFB, 0xDE, 0xAB, 0x66, 0x02 } };
```

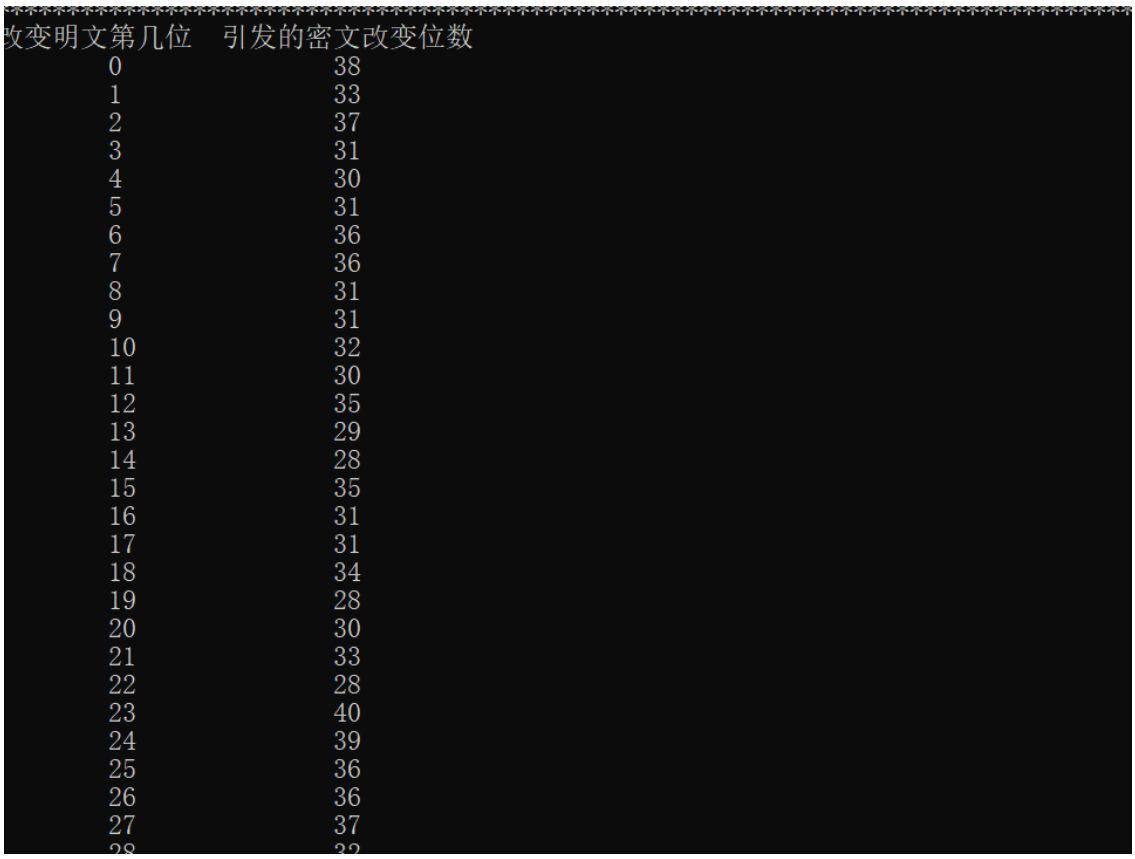
```
输入64bit密钥：10316E028C8F3B4A
您输入的密钥为：10316E028C8F3B4A
输入64bit明文：0
您输入的明文为：0000000000000000
加密！！！！！


二进制结果密文为：1000001011011100101110101111101111011110101010110110011000000010
十六进制结果————————————————————————————————
密钥10316E028C8F3B4A
明文0000000000000000
密文82DCBAFBDEAB6602
```

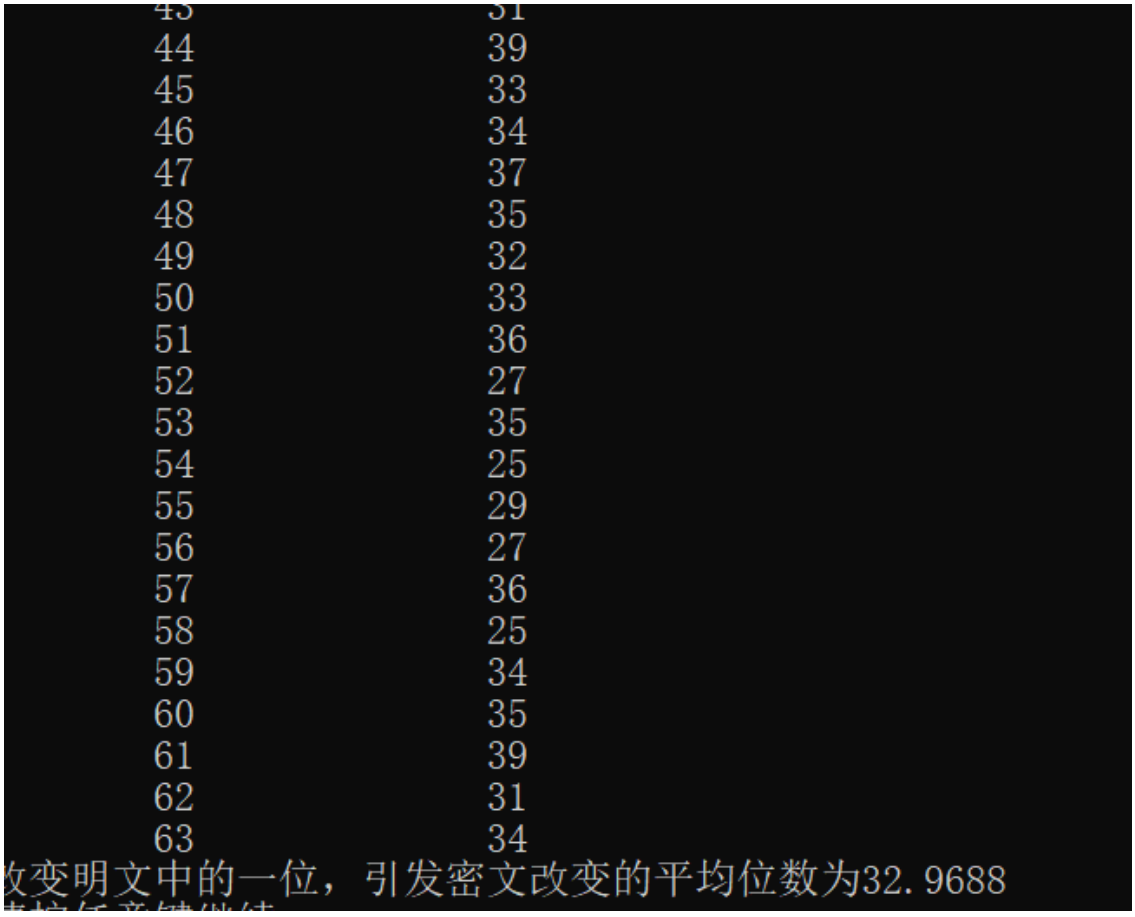
4. DES解密

   具体代码见程序代码文件夹或报告底部，展示效果如下：

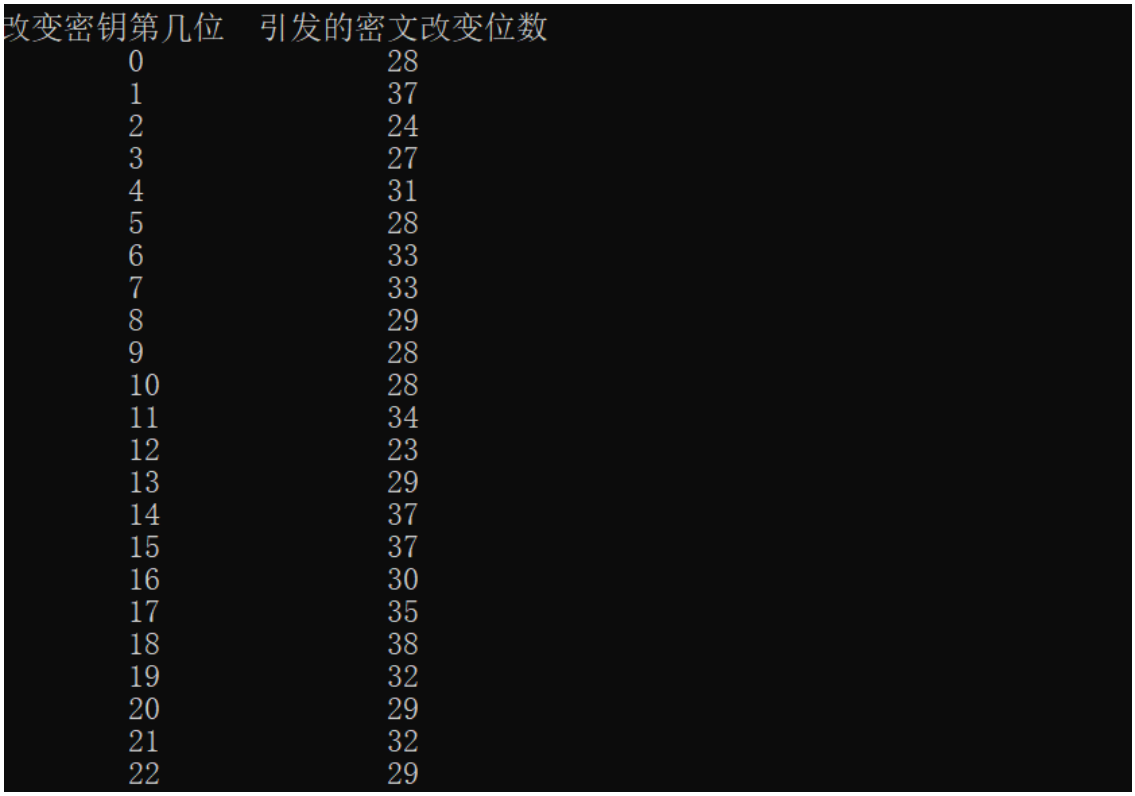
```
输入64bit密钥：10316E028C8F3B4A
64bit 密钥为：10316E028C8F3B4A
输入64bit密文：82DCBAFBDEAB6602
64bit 密文为：82DCBAFBDEAB6602
解密！！！！！


二进制初始密钥为：0001000000110001011011100000001010001100100011110011101101001010
二进制输入密文为：1000001011011100101110101111101111011110101010110110011000000010
二进制结果明文为：0000000000000000000000000000000000000000000000000000000000000000
********************************************************************************
十六进制 密钥为：10316E028C8F3B4A
十六进制 密文为：82DCBAFBDEAB6602
十六进制 明文为：0000000000000000
********************************************************************************
请按任意键继续. . .
```

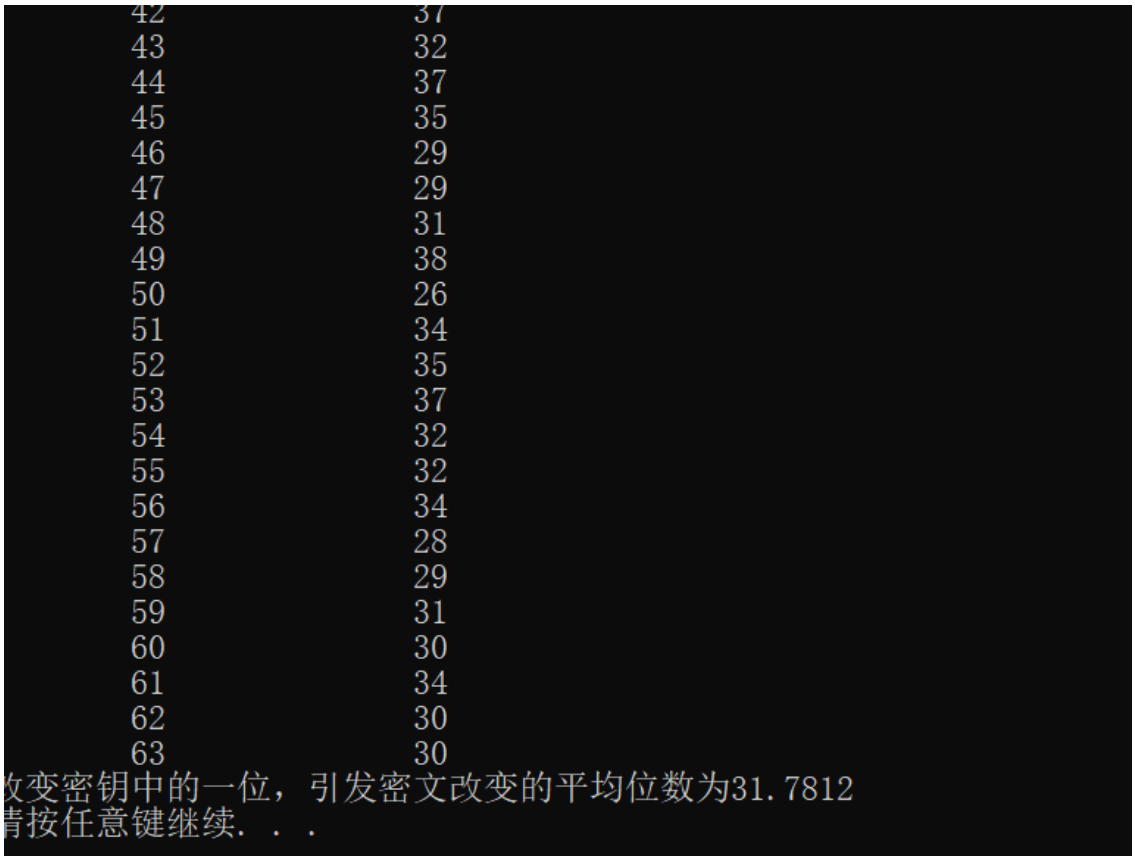
5. 雪崩效应——改变明文


改变明文第几位 引发的密文改变位数
0 38
1 33
2 37
3 31
4 30
5 31
6 36
7 36
8 31
9 31
10 32
11 30
12 35
13 29
14 28
15 35
16 31
17 31
18 34
19 28
20 30
21 33
22 28
23 40
24 39
25 36
26 36
27 37


44 39
45 33
46 34
47 37
48 35
49 32
50 33
51 36
52 27
53 35
54 25
55 29
56 27
57 36
58 25
59 34
60 35
61 39
62 31
63 34
改变明文中的一位，引发密文改变的平均位数为32.9688

6. 雪崩效应——改变密钥





7. 相关代码解释

加密解密以及雪崩效应的代码都调用了个人所构造的des.h头文件

```
#include <iostream>
#include <string>
using namespace std;

//初始置换IP表
const static int IP_Table[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
};

//逆初始置换IPR表
const static int IPR_Table[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
};

//E扩展选择表
static const int E_Table[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
};

//P换位表
const static int P_Table[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
};

//PC1选位表(用于完成密钥置换PC-1)
const static int PC1_Table[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
};

//PC2选位表(用于完成密钥置换PC-2)
const static int PC2_Table[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
};

//左移位数表
const static int LOOP_Table[16] =
{
    1,1,2,2,2,2,2,2,1,2,2,2,2,2,2,1
};

// S盒
const static int S_Box[32][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} };

//获取string输入 补零后存入char*
char* get_text(string input){
    string text = input.substr(0,16);
    if(text.size() < 16){
        int temp = text.size();
        for(int i = 1;i <= 16 - temp ; i++){
            text = text + '0';
        }
    }
    char* char_text = new char [17];
    text.copy(char_text,16,0);
    char_text[16] = '\0';
    return char_text;
}

//判断
bool is_input_valid(char* str){
    for(int i = 0;i<15;i++){
        if (!((str[i] >= 'A' && str[i] <= 'F') || (str[i] >= 'a' && str[i]
<= 'f') || (str[i] >= '0' && str[i] <= '9'))){
            return 0;
        }
    }
    return 1;
}

void hex_to_bin(char* hex,int* bin){
```

```
    for(int i = 0,k = 0; i<16 ;i++){
        int val = 0;
        if(hex[i] >= '0' && hex[i] <= '9'){
            val = hex[i] - '0';
        }
        else if (hex[i] >= 'A' && hex[i] <= 'F'){
            val = hex[i] - 'A' + 10;
        }
        else if (hex[i] >= 'a' && hex[i] <= 'f'){
            val = hex[i] - 'a' + 10;
        }
        for(k = 4*i+3;k>=4*i;k--){
            bin[k] = val%2;
            val /= 2;
        }
    }
}

void bin_to_hex(int* bin,char* hex){
    for(int i = 0,k = 0;i<16;i++){
        int val = 0;
        for(k = 4*i;k<=4*i+3;k++){
            val *= 2;
            val += bin[k];
        }
        if(val < 10){
            hex[i] = val + '0';
        }
        else if (val >= 10 && val <= 15){
            hex[i] = val - 10 + 'A';
        }
    }
    hex[16] = '\0';
}
```

```
//加密.cpp
#include "des.h"
int main(){
    string key_input;
    cout<<"输入64bit密钥：";
    cin>>key_input;
    char* char_key = get_text(key_input);
    if(is_input_valid(char_key)){
        cout<<"您输入的密钥为："<<char_key<<endl;
    }
    else{
        cout<<"输入16进制密钥不合法"<<endl;
        return 0;
    }
    string plain_input;
    cout<<"输入64bit明文：";
    cin>>plain_input;
    char* char_plain = get_text(plain_input);
    if(is_input_valid(char_plain)){
        cout<<"您输入的明文为："<<char_plain<<endl;
    }
    else{
```

```
        cout<<"输入16进制明文不合法"<<endl;
        return 0;
    }
    cout<<"加密！！！！！"<<endl<<endl<<endl;
    int bit_key[64];
    hex_to_bin(char_key,bit_key);
    int bit_plain[64];
    hex_to_bin(char_plain,bit_plain);
    //PC-1置换后的二进制密钥数组
    int bit_key_aft_pc1[56];
    for(int i = 0;i<56;i++){
        bit_key_aft_pc1[i] = bit_key[PC1_Table[i] - 1];
    }
    //密钥分成两半
    int bit_key_l1[28],bit_key_r1[28];
    for(int i = 0;i<56;i++){
        if(i<28){
            bit_key_l1[i] = bit_key_aft_pc1[i];
        }
        else{
            bit_key_r1[i-28] = bit_key_aft_pc1[i];
        }
    }
    //明文完成初始IP置换
    int bit_plain_aft_ip[64];
    for(int i = 0;i<64;i++){
        bit_plain_aft_ip[i] = bit_plain[IP_Table[i] - 1];
    }
    //明文分成两半
    int bit_plain_l1[32],bit_plain_r1[32];
    for(int i = 0;i<64;i++){
        if(i < 32){
            bit_plain_l1[i] = bit_plain_aft_ip[i];
        }
        else{
            bit_plain_r1[i-32] = bit_plain_aft_ip[i];
        }
    }
    //每轮子密钥
    int round_key_store[16][48];
    //移位后的左右密钥
    int bit_key_l2[28],bit_key_r2[28];
    //左右明文
    int bit_plain_l2[32],bit_plain_r2[32];
    int bit_plain_l3[32],bit_plain_r3[32];

    for(int round = 0;round <16;round ++){
        //密钥左移位
        for(int m = 0;m<28;m++){
            bit_key_l2[m] = bit_key_l1[(m + LOOP_Table[round]) %28];
            bit_key_r2[m] = bit_key_r1[(m + LOOP_Table[round]) %28];
        }
        //更新左右密钥
        for(int m = 0;m<28;m++){
            bit_key_l1[m] = bit_key_l2[m];
            bit_key_r1[m] = bit_key_r2[m];
        }
        //密钥完成PC-2置换
```

```
        for(int m = 0;m<48;m++){
            if(PC2_Table[m] < 28){
                round_key_store[round][m] = bit_key_l2[PC2_Table[m]-1];
            }
            else{
                round_key_store[round][m] = bit_key_r2[PC2_Table[m] - 29];
            }
        }
        //备份右明文
        for(int m = 0;m<32;m++){
            bit_plain_r2[m] = bit_plain_r1[m];
        }
        //对右明文进行E拓展运算
        for(int m = 0;m<48;m++){
            bit_plain_r3[m] = bit_plain_r1[E_Table[m] - 1];
        }
        //右明文于密钥做异或运算
        for(int m = 0;m<48;m++){
            bit_plain_r3[m] = bit_plain_r3[m] ^ round_key_store[round][m];
        }
        //右明文S盒代换
        for(int m = 0;m < 8;m++){
            int s ;
            //根据右明文的值从S_Box中选值
            s = S_Box[(bit_plain_r3[m * 6] * 2 + bit_plain_r3[5 + m * 6]) +
m * 4][bit_plain_r3[1 + m * 6] * 8 + bit_plain_r3[2 + m * 6] * 4 +
bit_plain_r3[3 + m * 6] * 2 + bit_plain_r3[4 + m * 6]];
            //将S_Box中选中的值表示为二进制 并 赋值到bit_plain_r3中
            for(int n = 1;n<=4;n++){
                bit_plain_r3[(4-n) + 4*m] = s % 2;
                s = s/2;
            }
        }
        //右明文完成P置换，与左明文异或，将备份的本轮原始右明文传给左明文
        for(int m = 0 ;m<32;m++){
            bit_plain_r1[m] = bit_plain_r3[P_Table[m] - 1] ^
bit_plain_l1[m];
            bit_plain_l1[m] = bit_plain_r2[m];
        }
    }
    //逆初始置换IPR置换前后的二进制明文数组
    int bit_cipher_bfr_ipr[64];
    int bit_cipher_aft_ipr[64];
    //16轮明文左右交换得到密文
    for(int m = 0;m<64;m++){
        if(m < 32){
            bit_cipher_bfr_ipr[m] = bit_plain_r1[m];
        }
        else{
            bit_cipher_bfr_ipr[m] = bit_plain_l1[m - 32];
        }
    }
    //密文完成逆初始置换
    for(int m = 0;m<64;m++){
        bit_cipher_aft_ipr[m] = bit_cipher_bfr_ipr[IPR_Table[m] - 1];
    }
    cout<<"二进制结果密文为：";
    for(int m = 0;m<64;m++){
```

```
        cout<<bit_cipher_aft_ipr[m];
    }
    cout<<endl;
    char char_cipher[17];
    bin_to_hex(bit_cipher_aft_ipr,char_cipher);
    cout<<"十六进制结果----------"<<endl;
    cout<<"密钥"<<char_key<<endl;
    cout<<"明文"<<char_plain<<endl;
    cout<<"密文"<<char_cipher<<endl;
    return 0;
}
```

```
//解密.cpp
#include "des.h"

int main()
{
    //用户输入密钥
    string key_input;
    cout <<"输入64bit密钥: " ;
    cin >> key_input;
    char * char_key = get_text(key_input);
    if(is_input_valid(char_key))
    {
        cout<<"64bit 密钥为: "<< char_key<<endl;
    }
    else
    {
        cout<<"输入16进制数不合法"<<endl;
        return 0;
    }

    //用户输入密文
    string cipher_input;
    cout <<"输入64bit密文: " ;
    cin >> cipher_input;
    char * char_cipher = get_text(cipher_input);
    if(is_input_valid(char_cipher))
    {
        cout<<"64bit 密文为: "<< char_cipher<<endl;
    }
    else
    {
        cout<<"输入16进制数不合法"<<endl;
        return 0;
    }

    cout<<"解密！！！！！"<<endl<<endl<<endl;

    //用于保存用户输入的64bit二进制密钥
    int bit_key[64];

    //将输入的十六进制密钥char数组转换为二进制int数组
    hex_to_bin(char_key, bit_key);
    cout<<"二进制初始密钥为: ";
    for(int i=0;i<64;i++)
        cout<<bit_key[i];
```

```
    cout<<endl;

    //用于保存用户输入的64bit二进制密文
    int bit_ciphertext_init[64];

    //将输入的十六进制密文char数组转换为二进制int数组
    hex_to_bin(char_cipher, bit_ciphertext_init);
    cout<<"二进制输入密文为：";
    for(int i=0;i<64;i++)
        cout<<bit_ciphertext_init[i];
    cout<<endl;

    //-----------------子密钥获取------------------------------
    //先要获得16轮子密钥

    //PC-1置换后的二进制密钥数组(56bit)
    int bit_key_aft_PC1[56];

    //密钥完成初始置换PC-1
    for(int m=0;m<56;m++)
    {
        bit_key_aft_PC1[m]=bit_key[PC1_Table[m]-1];
    }

    //把密钥分为左右两半
    int bit_key_l1[28],bit_key_r1[28];
    for(int m=0;m<56;m++)
    {
        if(m<28)
            bit_key_l1[m]=bit_key_aft_PC1[m];
        else
            bit_key_r1[m-28]=bit_key_aft_PC1[m];
    }

    //存储每轮子密钥用于解密
    int round_key_store[16][48];

    //存储每轮移位后的左右密钥
    int bit_key_l2[28],bit_key_r2[28];

    //16轮次结构
    for(int round=0;round<16;round++)
    {
        //密钥左移位
        for(int m=0;m<28;m++)
        {
            bit_key_l2[m]=bit_key_l1[(m+LOOP_Table[round])%28];
            bit_key_r2[m]=bit_key_r1[(m+LOOP_Table[round])%28];
        }

        //更新左右密钥，用于下次循环使用
        for(int m=0;m<28;m++)
        {
            bit_key_l1[m]=bit_key_l2[m];
            bit_key_r1[m]=bit_key_r2[m];
        }

        //密钥完成PC-2置换
```

```
        for(int m=0;m<48;m++)
        {
            if(PC2_Table[m]<29)
            {
                round_key_store[round][m]=bit_key_l2[PC2_Table[m]-1];
            }
            else
            {
                round_key_store[round][m]=bit_key_r2[PC2_Table[m]-29];
            }
        }
    }
    //-----------------子密钥获取结束-------------------------


    //IP置换后的二进制密文数组(64bit)
    int bit_ciphertext_aft_IP[64];

    //密文完成初始IP置换
    for(int m=0;m<64;m++)
    {
        bit_ciphertext_aft_IP[m]=bit_ciphertext_init[IP_Table[m]-1];
    }

    //把密文分为左右两半
    int bit_ciphertext_l1[32],bit_ciphertext_r1[32];
    for(int m=0;m<64;m++)
    {
        if(m<32)
            bit_ciphertext_l1[m]=bit_ciphertext_aft_IP[m];
        else
            bit_ciphertext_r1[m-32]=bit_ciphertext_aft_IP[m];
    }

    //存储左右明文
    int bit_ciphertext_l2[32],bit_ciphertext_r2[32];
    int bit_ciphertext_l3[32],bit_ciphertext_r3[48];

    //16轮次结构
    for(int round=0;round<16;round++)
    {

        //对右明文备份
        for(int m=0;m<32;m++)
        {
            bit_ciphertext_r2[m]=bit_ciphertext_r1[m];
        }

        //对右明文进行E扩展运算
        for(int m=0;m<48;m++)
        {
            bit_ciphertext_r3[m]=bit_ciphertext_r1[E_Table[m]-1];
        }

        //右明文与对应的轮密钥做异或运算
        for(int m=0;m<48;m++)
        {
```

```
            bit_ciphertext_r3[m]=bit_ciphertext_r3[m]^round_key_store[15-
round][m];
        }

        //右明文S盒代换
        for(int m=0;m<8;m++)
        {
            //根据右明文的值从S_Box中选出值
            int s;
            s=S_Box[(bit_ciphertext_r3[m*6]*2+bit_ciphertext_r3[5+m*6])+m*4]
[bit_ciphertext_r3[1+m*6]*8+bit_ciphertext_r3[2+m*6]*4+bit_ciphertext_r3[3+m
*6]*2+bit_ciphertext_r3[4+m*6]];


            //将S_Box中选中的值表示为二进制 并 赋值到bit_plaintext_r3中
            for(int n=1;n<=4;n++)
            {
                bit_ciphertext_r3[(4-n)+4*m]=s%2;
                s=s/2;
            }
        }

        //右明文完成P置换,与左明文异或,并将备份的本轮原始右明文传给左明文，用于下次循环使
用
        for(int m=0;m<32;m++)
        {

bit_ciphertext_r1[m]=bit_ciphertext_r3[P_Table[m]-1]^bit_ciphertext_l1[m];
            bit_ciphertext_l1[m]=bit_ciphertext_r2[m];
        }
    }

    //逆初始置换IPR置换前的二进制明文数组(64bit)
    int bit_plaintext_bfr_IPR[64];

    //16轮后密文左右交换得到明文
    for(int m=0;m<64;m++)
    {
        if(m<32)
            bit_plaintext_bfr_IPR[m]=bit_ciphertext_r1[m];
        else
            bit_plaintext_bfr_IPR[m]=bit_ciphertext_l1[m-32];
    }

    //逆初始置换IPR置换后的二进制明文数组(64bit)
    int bit_plaintext_aft_IPR[64];

    //明文完成逆初始置换
    for(int m=0;m<64;m++)
    {
        bit_plaintext_aft_IPR[m]=bit_plaintext_bfr_IPR[IPR_Table[m]-1];
    }

    cout<<"二进制结果明文为: ";
    for(int m=0;m<64;m++)
    {
        cout<<bit_plaintext_aft_IPR[m];
    }
```

```
    cout<<endl;

    //存储明文十六进制char数组
    char char_plaintext[17];

    //将得到的二进制明文int数组转化为十六进制char数组
    bin_to_hex(bit_plaintext_aft_IPR, char_plaintext);

    //输出16进制密钥、明文、密文，方便对比结果

cout<<"*********************************************************************
*****************************"<<endl;

    //输出密钥
    cout<<"十六进制 密钥为："<<char_key<<endl;

    //输出密文
    cout<<"十六进制 密文为："<<char_cipher<<endl;

    //输出明文
    cout<<"十六进制 明文为："<<char_plaintext<<endl;


cout<<"*********************************************************************
*****************************"<<endl;
    system("pause");
    return 0;
}
```

```
//本程序文件用于测试改变明文中的1位引发的雪崩效应
#include "des.h"

int main()
{

    cout<<"开始加密处理"<<endl;

    //用于保存原本的64bit二进制密文
    int bit_ciphertext_aft_IPR_form[64] =
{1,0,0,0,0,0,1,0,1,1,0,1,1,1,0,0,1,0,1,1,1,0,1,0,1,1,1,1,1,0,1,1,1,1,0,1,1,1
,1,0,1,0,1,0,1,0,1,1,0,1,1,0,0,1,1,0,0,0,0,0,0,0,1,0};


    //实际使用的密钥
    int bit_key_init[64] = {
0,0,0,1,0,0,0,0,0,0,1,1,0,0,0,1,0,1,1,0,1,1,1,0,0,0,0,0,0,0,1,0,1,0,0,0,1,1,
0,0,1,0,0,0,1,1,1,1,0,0,1,1,1,0,1,1,0,1,0,0,1,0,1,0} ;

    //实际使用的明文
    int bit_plaintext_init[64] =
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0};

    //--------------------下面测试明文改变一位引发的雪崩效应：依次改变明文中的每一位，统
计密文发生改变的位数--------------------

    cout<<"开始测试明文改变一位引发的雪崩效应："<<endl;
```

```
    //改变的是明文的第几位
    int plaintext_changedbit = 0;

    //记录改变明文每一位后密文发生变化的位数
    int avalanche_record_plaintext[64] = {0};

    //依次改变明文的第0位--第63位，统计密文改变的位数
    for(;plaintext_changedbit<64;plaintext_changedbit++)
    {
        //反转第plaintext_changedbit位
        bit_plaintext_init[plaintext_changedbit] = 1-
bit_plaintext_init[plaintext_changedbit];

        //PC-1置换后的二进制密钥数组(56bit)
        int bit_key_aft_PC1[56];

        //密钥完成初始置换PC-1
        for(int m=0;m<56;m++)
        {
            bit_key_aft_PC1[m]=bit_key_init[PC1_Table[m]-1];
        }

        //把密钥分为左右两半
        int bit_key_l1[28],bit_key_r1[28];
        for(int m=0;m<56;m++)
        {
            if(m<28)
                bit_key_l1[m]=bit_key_aft_PC1[m];
            else
                bit_key_r1[m-28]=bit_key_aft_PC1[m];
        }

        //IP置换后的二进制明文数组(64bit)
        int bit_plaintext_aft_IP[64];

        //明文完成初始IP置换
        for(int m=0;m<64;m++)
        {
            bit_plaintext_aft_IP[m]=bit_plaintext_init[IP_Table[m]-1];
        }

        //把明文分为左右两半
        int bit_plaintext_l1[32],bit_plaintext_r1[32];
        for(int m=0;m<64;m++)
        {
            if(m<32)
                bit_plaintext_l1[m]=bit_plaintext_aft_IP[m];
            else
                bit_plaintext_r1[m-32]=bit_plaintext_aft_IP[m];
        }

        //存储每轮子密钥用于解密
        int round_key_store[16][48];

        //存储每轮移位后的左右密钥
        int bit_key_l2[28],bit_key_r2[28];
```

```
        //存储左右明文
        int bit_plaintext_l2[32],bit_plaintext_r2[32];
        int bit_plaintext_l3[32],bit_plaintext_r3[48];

        //16轮次结构
        for(int round=0;round<16;round++)
        {
            //密钥左移位
            for(int m=0;m<28;m++)
            {
                bit_key_l2[m]=bit_key_l1[(m+LOOP_Table[round])%28];
                bit_key_r2[m]=bit_key_r1[(m+LOOP_Table[round])%28];
            }

            //更新左右密钥，用于下次循环使用
            for(int m=0;m<28;m++)
            {
                bit_key_l1[m]=bit_key_l2[m];
                bit_key_r1[m]=bit_key_r2[m];
            }

            //密钥完成PC-2置换
            for(int m=0;m<48;m++)
            {
                if(PC2_Table[m]<29)
                {
                    round_key_store[round][m]=bit_key_l2[PC2_Table[m]-1];
                }
                else
                {
                    round_key_store[round][m]=bit_key_r2[PC2_Table[m]-29];
                }
            }

            //对右明文备份
            for(int m=0;m<32;m++)
            {
                bit_plaintext_r2[m]=bit_plaintext_r1[m];
            }

            //对右明文进行E扩展运算
            for(int m=0;m<48;m++)
            {
                bit_plaintext_r3[m]=bit_plaintext_r1[E_Table[m]-1];
            }

            //右明文与密钥做异或运算
            for(int m=0;m<48;m++)
            {

bit_plaintext_r3[m]=bit_plaintext_r3[m]^round_key_store[round][m];
            }

            //右明文S盒代换
            for(int m=0;m<8;m++)
            {
                //根据右明文的值从S_Box中选出值
                int s;
```

```
s=S_Box[(bit_plaintext_r3[m*6]*2+bit_plaintext_r3[5+m*6])+m*4]
[bit_plaintext_r3[1+m*6]*8+bit_plaintext_r3[2+m*6]*4+bit_plaintext_r3[3+m*6]
*2+bit_plaintext_r3[4+m*6]];


                //将S_Box中选中的值表示为二进制 并 赋值到bit_plaintext_r3中
                for(int n=1;n<=4;n++)
                {
                    bit_plaintext_r3[(4-n)+4*m]=s%2;
                    s=s/2;
                }
            }

            //右明文完成P置换,与左明文异或,并将备份的本轮原始右明文传给左明文，用于下次
循环使用
            for(int m=0;m<32;m++)
            {

bit_plaintext_r1[m]=bit_plaintext_r3[P_Table[m]-1]^bit_plaintext_l1[m];
                bit_plaintext_l1[m]=bit_plaintext_r2[m];
            }
        }

        //逆初始置换IPR置换前的二进制密文数组(64bit)
        int bit_ciphertext_bfr_IPR[64];

        //16轮后明文左右交换形成密文
        for(int m=0;m<64;m++)
        {
            if(m<32)
                bit_ciphertext_bfr_IPR[m]=bit_plaintext_r1[m];
            else
                bit_ciphertext_bfr_IPR[m]=bit_plaintext_l1[m-32];
        }

        //逆初始置换IPR置换后的二进制密文数组(64bit)
        int bit_ciphertext_aft_IPR[64];

        //密文完成逆初始置换
        for(int m=0;m<64;m++)
        {

bit_ciphertext_aft_IPR[m]=bit_ciphertext_bfr_IPR[IPR_Table[m]-1];
        }

        int changedbit_temp = 0;

        for(int m=0;m<64;m++)
        {
            if(bit_ciphertext_aft_IPR[m] != bit_ciphertext_aft_IPR_form[m])
                changedbit_temp++;
        }

        //变化位数记录到avalanche_record_plaintext数组里
        avalanche_record_plaintext[plaintext_changedbit] = changedbit_temp;
```

```
        cout<<"-------------------------------------------------------------------
-------------------------------------"<<endl;
        cout<<"改变明文第"<<plaintext_changedbit<<"位"<<endl;

        cout<<"新密文为: ";
        for(int m=0;m<64;m++)
        {
            cout<<bit_ciphertext_aft_IPR[m];
        }
        cout<<endl;

        cout<<"原密文为: ";
        for(int m=0;m<64;m++)
        {
            cout<<bit_ciphertext_aft_IPR_form[m];
        }
        cout<<endl;

        cout<<"密文改变位数为: "
<<avalanche_record_plaintext[plaintext_changedbit]<<endl;


cout<<"*************************************************************************
*****************************"<<endl;
    }

    cout<<"改变明文第几位"<<'\t'<<"引发的密文改变位数"<<'\t'<<endl;
    for(int m=0;m<64;m++)
    {
        cout<<'\t'<<m<<'\t'<<'\t'<<avalanche_record_plaintext[m]
<<'\t'<<endl;
    }

    double average_changed =0;
    for(int m=0;m<64;m++)
    {
        average_changed+=avalanche_record_plaintext[m];
    }
    average_changed /=64;

    cout<<"改变明文中的一位，引发密文改变的平均位数为"<<average_changed<<endl;

    system("pause");
    return 0;
}
```

```
//本程序文件用于测试改变密钥中的1位引发的雪崩效应
#include "des.h"

int main()
{
    cout<<"开始加密处理"<<endl;

    //用于保存原本的64bit二进制密文
    int bit_ciphertext_aft_IPR_former[64] =
{1,0,0,0,0,0,1,0,1,1,0,1,1,1,0,0,1,0,1,1,1,0,1,0,1,1,1,1,1,0,1,1,1,1,0,1,1,1
,1,0,1,0,1,0,1,0,1,1,0,1,1,0,0,1,1,0,0,0,0,0,0,0,1,0};
```

```
    //实际使用的密钥
    int bit_key_init[64] = {
0,0,0,1,0,0,0,0,0,0,1,1,0,0,0,1,0,1,1,0,1,1,1,0,0,0,0,0,0,0,1,0,1,0,0,0,1,1,
0,0,1,0,0,0,1,1,1,1,0,0,1,1,1,0,1,1,0,1,0,0,1,0,1,0} ;

    //实际使用的明文
    int bit_plaintext_init[64] =
{0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0};

    //-------------------下面测试密钥改变一位引发的雪崩效应，依次改变明文中的每一位，统
计密文发生改变的位数-------------------

    cout<<"开始测试密钥改变一位引发的雪崩效应："<<endl;

    //改变的是密钥的第几位
    int key_changedbit = 0;

    //记录改变密钥每一位后密文发生变化的位数
    int avalanche_record_key[64] = {0};

    //依次改变密钥的第0位--第63位，统计密文改变的位数
    for(;key_changedbit<64;key_changedbit++)
    {
        //反转第key_changedbit位
        bit_key_init[key_changedbit] = 1-bit_key_init[key_changedbit];

        //PC-1置换后的二进制密钥数组(56bit)
        int bit_key_aft_PC1[56];

        //密钥完成初始置换PC-1
        for(int m=0;m<56;m++)
        {
            bit_key_aft_PC1[m]=bit_key_init[PC1_Table[m]-1];
        }

        //把密钥分为左右两半
        int bit_key_l1[28],bit_key_r1[28];
        for(int m=0;m<56;m++)
        {
            if(m<28)
                bit_key_l1[m]=bit_key_aft_PC1[m];
            else
                bit_key_r1[m-28]=bit_key_aft_PC1[m];
        }

        //IP置换后的二进制明文数组(64bit)
        int bit_plaintext_aft_IP[64];

        //明文完成初始IP置换
        for(int m=0;m<64;m++)
        {
            bit_plaintext_aft_IP[m]=bit_plaintext_init[IP_Table[m]-1];
        }

        //把明文分为左右两半
```

```
        int bit_plaintext_l1[32],bit_plaintext_r1[32];
        for(int m=0;m<64;m++)
        {
            if(m<32)
                bit_plaintext_l1[m]=bit_plaintext_aft_IP[m];
            else
                bit_plaintext_r1[m-32]=bit_plaintext_aft_IP[m];
        }

        //存储每轮子密钥用于解密
        int Round_key_Store[16][48];

        //存储每轮移位后的左右密钥
        int bit_key_l2[28],bit_key_r2[28];

        //存储左右明文
        int bit_plaintext_l2[32],bit_plaintext_r2[32];
        int bit_plaintext_l3[32],bit_plaintext_r3[48];

        //16轮次结构
        for(int round=0;round<16;round++)
        {
            //密钥左移位
            for(int m=0;m<28;m++)
            {
                bit_key_l2[m]=bit_key_l1[(m+LOOP_Table[round])%28];
                bit_key_r2[m]=bit_key_r1[(m+LOOP_Table[round])%28];
            }

            //更新左右密钥，用于下次循环使用
            for(int m=0;m<28;m++)
            {
                bit_key_l1[m]=bit_key_l2[m];
                bit_key_r1[m]=bit_key_r2[m];
            }

            //密钥完成PC-2置换
            for(int m=0;m<48;m++)
            {
                if(PC2_Table[m]<29)
                {
                    Round_key_Store[round][m]=bit_key_l2[PC2_Table[m]-1];
                }
                else
                {
                    Round_key_Store[round][m]=bit_key_r2[PC2_Table[m]-29];
                }
            }

            //对右明文备份
            for(int m=0;m<32;m++)
            {
                bit_plaintext_r2[m]=bit_plaintext_r1[m];
            }

            //对右明文进行E扩展运算
            for(int m=0;m<48;m++)
            {
```

```
                bit_plaintext_r3[m]=bit_plaintext_r1[E_Table[m]-1];
            }

            //右明文与密钥做异或运算
            for(int m=0;m<48;m++)
            {

bit_plaintext_r3[m]=bit_plaintext_r3[m]^Round_key_Store[round][m];
            }

            //右明文S盒代换
            for(int m=0;m<8;m++)
            {
                //根据右明文的值从S_Box中选出值
                int s;

s=S_Box[(bit_plaintext_r3[m*6]*2+bit_plaintext_r3[5+m*6])+m*4]
[bit_plaintext_r3[1+m*6]*8+bit_plaintext_r3[2+m*6]*4+bit_plaintext_r3[3+m*6]
*2+bit_plaintext_r3[4+m*6]];


                //将S_Box中选中的值表示为二进制 并 赋值到bit_plaintext_r3中
                for(int n=1;n<=4;n++)
                {
                    bit_plaintext_r3[(4-n)+4*m]=s%2;
                    s=s/2;
                }
            }

            //右明文完成P置换,与左明文异或,并将备份的本轮原始右明文传给左明文，用于下次
循环使用
            for(int m=0;m<32;m++)
            {

bit_plaintext_r1[m]=bit_plaintext_r3[P_Table[m]-1]^bit_plaintext_l1[m];
                bit_plaintext_l1[m]=bit_plaintext_r2[m];
            }
        }

        //逆初始置换IPR置换前的二进制密文数组(64bit)
        int bit_ciphertext_bfr_IPR[64];

        //16轮后明文左右交换形成密文
        for(int m=0;m<64;m++)
        {
            if(m<32)
                bit_ciphertext_bfr_IPR[m]=bit_plaintext_r1[m];
            else
                bit_ciphertext_bfr_IPR[m]=bit_plaintext_l1[m-32];
        }

        //逆初始置换IPR置换后的二进制密文数组(64bit)
        int bit_ciphertext_aft_IPR[64];

        //密文完成逆初始置换
        for(int m=0;m<64;m++)
        {
```

```
bit_ciphertext_aft_IPR[m]=bit_ciphertext_bfr_IPR[IPR_Table[m]-1];
        }

        int changedbit_temp = 0;

        for(int m=0;m<64;m++)
        {
            if(bit_ciphertext_aft_IPR[m] !=
bit_ciphertext_aft_IPR_former[m])
                changedbit_temp++;
        }

        //变化位数记录到avalanche_record_key数组里
        avalanche_record_key[key_changedbit] = changedbit_temp;

        cout<<"-----------------------------------------------------------------
-----------------------------------"<<endl;
        cout<<"改变密钥第"<<key_changedbit<<"位"<<endl;

        cout<<"新密文为：";
        for(int m=0;m<64;m++)
        {
            cout<<bit_ciphertext_aft_IPR[m];
        }
        cout<<endl;

        cout<<"原密文为：";
        for(int m=0;m<64;m++)
        {
            cout<<bit_ciphertext_aft_IPR_former[m];
        }
        cout<<endl;

        cout<<"密文改变位数为："<<avalanche_record_key[key_changedbit]<<endl;


cout<<"*********************************************************************
*****************************"<<endl;
    }

    cout<<"改变密钥第几位"<<'\t'<<"引发的密文改变位数"<<'\t'<<endl;
    for(int m=0;m<64;m++)
    {
        cout<<'\t'<<m<<'\t'<<'\t'<<avalanche_record_key[m]<<'\t'<<endl;
    }

    double Average_changed =0;
    for(int m=0;m<64;m++)
    {
        Average_changed+=avalanche_record_key[m];
    }
    Average_changed /=64;

    cout<<"改变密钥中的一位，引发密文改变的平均位数为"<<Average_changed<<endl;

    system("pause");
    return 0;
```

```
}
```