Afterword by Matt Blaze

One of the most dangerous aspects of cryptology (and, by extension, of this book), is that you can almost measure it. Knowledge of key lengths, factoring methods, and cryptanalytic techniques makes it possible to estimate (in the absence of a real theory of cipher design) the "work factor" required to break a particular cipher. It's all too tempting to misuse these estimates as if they were overall security metrics for the systems in which they are used. The real world offers the attacker a richer menu of options than mere cryptanalysis. Often more worrisome are protocol attacks, Trojan horses, viruses, electromagnetic monitoring, physical compromise, blackmail and intimidation of key holders, operating system bugs, application program bugs, hardware bugs, user errors, physical eavesdropping, social engineering, and dumpster diving, to name just a few.

High-quality ciphers and protocols are important tools, but by themselves make poor substitutes for realistic, critical thinking about what is actually being protected and how various defenses might fail (attackers, after all, rarely restrict themselves to the clean, well-defined threat models of the academic world). Ross Anderson gives examples of cryptographically strong systems (in the banking industry) that fail when exposed to the threats of the real world [43,44]. Even when the attacker has access only to ciphertext, seemingly minor breaches in other parts of the system can leak enough information to render good cryptosystems useless. The Allies in World War II broke the German Enigma traffic largely by carefully exploiting operator errors [1587].

An NSA-employed acquaintance, when asked whether the government can crack DES traffic, quipped that real systems are so insecure that they never need to bother. Unfortunately, there are no easy recipes for making a system secure, no substitute for careful design and critical, ongoing scrutiny. Good cryptosystems have the nice property of making life much harder for the attacker than for the legitimate user; this is not the case for almost every other aspect of computer and communication

security. Consider the following (quite incomplete) "Top Ten Threats to Security in Real Systems" list; all are easier to exploit than to prevent.

1. The sorry state of software. Everyone knows that nobody knows how to write software. Modern systems are complex, with hundreds of thousands of lines of code; any one of them has the chance to compromise security. Fatal bugs may even be far-removed from the security portion of the software.
2. Ineffective protection against denial-of-service attacks. Some cryptographic protocols allow anonymity. It may be especially dangerous to deploy anonymous protocols if they increase the opportunities for unidentified vandals to disrupt service; anonymous systems therefore need to be especially resistant to denial-of-service attacks. Robust networks can more easily support anonymity; consider that hardly anyone worries very much about the millions of anonymous entry points to more robust networks like the telephone system or the postal service, where it's relatively difficult (or expensive) for an individual to cause large-scale failures.
3. No place to store secrets. Cryptosystems protect large secrets with smaller ones (keys). Unfortunately, modern computers aren't especially good at protecting even the smallest secrets. Multi-user networked workstations can be broken into and their memories compromised. Standalone, single-user machines can be stolen or compromised through viruses that leak secrets asynchronously. Remote servers, where there may be no user available to enter a passphrase (but see threat #5), are an especially hard problem.
4. Poor random-number generation. Keys and session variables need good sources of unpredictable bits. A running computer has a lot of entropy in it but rarely provides applications with a convenient or reliable way to exploit it. A number of techniques have been proposed for getting true random numbers in software (taking advantage of unpredictability in things like I/O interarrival timing, clock and timer skew, and even air turbulence inside disk enclosures), but all these are very sensitive to slight changes in the environments in which they are used.
5. Weak passphrases. Most cryptographic software addresses the key storage and key generation problems by relying on user-generated passphrase strings, which are presumed to be unpredictable enough to produce good key material and are also easy enough to remember that they do not require secure storage. While dictionary attacks are a well-known problem with short passwords, much less is known about lines of attack against user-selected passphrase-based keys. Shannon tells us that English text has only just over 1 bit of entropy per character, which would seem to leave most passphrases well within reach of brute-force search. Less is known, however, about good techniques for enumerating passphrases in order to exploit this. Until we have a better understanding of how to attack passphrases, we really have no idea how weak or strong they are.

6. Mismatched trust. Almost all currently available cryptographic software assumes that the user is in direct control over the systems on which it runs and has a secure path to it. For example, the interfaces to programs like PGP assume that their passphrase input always comes from the user over a secure path like the local console. This is not always the case, of course; consider the problem of reading your encrypted mail when logged in over a network connection. What the system designer assumes is trusted may not match the needs or expectations of the real users, especially when software can be controlled remotely over insecure networks.
7. Poorly understood protocol and service interactions. As systems get bigger and more complex, benign features frequently come back to haunt us, and it's hard to know even where to look when things fail. The Internet worm was propagated via an obscure and innocent-looking feature in the sendmail program; how many more features in how many more programs have unexpected consequences just waiting to be discovered?
8. Unrealistic threat and risks assessment. Security experts tend to focus on the threats they know how to model and prevent. Unfortunately, attackers focus on what they know how to exploit, and the two are rarely exactly the same. Too many "secure" systems are designed without considering what the attacker is actually likely to do.
9. Interfaces that make security expensive and special. If security features are to be used, they must be convenient and transparent enough that people actually turn them on. It's easy to design encryption mechanisms that come only at the expense of performance or ease of use, and even easier to design mechanisms that invite mistakes. Security should be harder to turn off than on; unfortunately, few systems actually work this way.
10. Little broad-based demand for security. This is a well-known problem among almost everyone who has tied his or her fortune to selling security products and services. Until there is widespread demand for transparent security, the tools and infrastructure needed to support it will be expensive and inaccessible to many applications. This is partly a problem of understanding and exposing the threats and risks in real applications and partly a problem of not designing systems that include security as a basic feature rather than as a later add-on.

A more complete list and discussion of these kinds of threats could easily fill a book of this size and barely scratch the surface. What makes them especially difficult and dangerous is that there are no magic techniques, beyond good engineering and ongoing scrutiny, for avoiding them. The lesson for the aspiring cryptographer is to respect the limits of the art.

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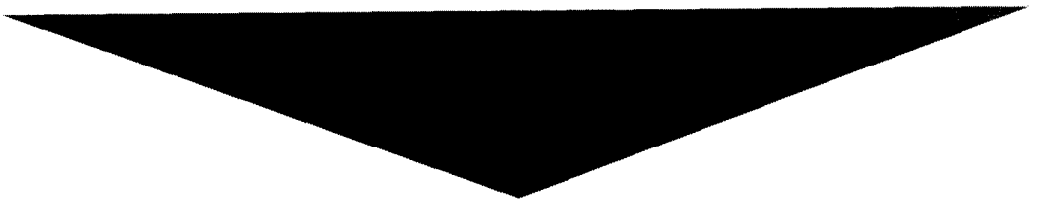
PART V



1. DES
2. LOKI91
3. IDEA
4. GOST
5. BLOWFISH
6. 3-Way
7. RC5
8. A5
9. SEAL

DES

```
#define ENO   0       /* MODE == encrypt */
#define DE1   1       /* MODE == decrypt */

typedef struct {
        unsigned long ek[32];
        unsigned long dk[32];
} des_ctx;

extern void deskey(unsigned char *, short);
/*                  hexkey[8]     MODE
 * Sets the internal key register according to the hexadecimal
 * key contained in the 8 bytes of hexkey, according to the DES,
 * for encryption or decryption according to MODE.
 */

extern void usekey(unsigned long *);
/*                cookedkey[32]
```

```
 * Loads the internal key register with the data in cookedkey.
 */

extern void cpkey(unsigned long *);
/*              cookedkey[32]
 * Copies the contents of the internal key register into the storage
 * located at &cookedkey[0].
 */

extern void des(unsigned char *, unsigned char *);
/*               from[8]         to[8]
 * Encrypts/Decrypts (according to the key currently loaded in the
 * internal key register) one block of eight bytes at address 'from'
 * into the block at address 'to'.  They can be the same.
 */

static void scrunch(unsigned char *, unsigned long *);
static void unscrun(unsigned long *, unsigned char *);
static void desfunc(unsigned long *, unsigned long *);
static void cookey(unsigned long *);

static unsigned long KnL[32] = { 0L };
static unsigned long KnR[32] = { 0L };
static unsigned long Kn3[32] = { 0L };
static unsigned char Df_Key[24] = {
       0x01,0x23,0x45,0x67,0x89,0xab,0xcd,0xef,
       0xfe,0xdc,0xba,0x98,0x76,0x54,0x32,0x10,
       0x89,0xab,0xcd,0xef,0x01,0x23,0x45,0x67 };

static unsigned short bytebit[8]    = {
       0200, 0100, 040, 020, 010, 04, 02, 01 };

static unsigned long bigbyte[24] = {
       0x800000L,     0x400000L,     0x200000L,     0x100000L,
       0x80000L,      0x40000L,      0x20000L,      0x10000L,
       0x8000L,       0x4000L,       0x2000L,       0x1000L,
       0x800L,               0x400L,               0x200L,               0x100L,
       0x80L,                0x40L,                0x20L,                0x10L,
       0x8L,          0x4L,          0x2L,          0x1L    };

/* Use the key schedule specified in the Standard (ANSI X3.92-1981). */

static unsigned char pc1[56] = {
       56, 48, 40, 32, 24, 16,  8,   0, 57, 49, 41, 33, 25, 17,
        9,  1, 58, 50, 42, 34, 26,  18, 10,  2, 59, 51, 43, 35,
       62, 54, 46, 38, 30, 22, 14,   6, 61, 53, 45, 37, 29, 21,
       13,  5, 60, 52, 44, 36, 28,  20, 12,  4, 27, 19, 11,  3 };

static unsigned char totrot[16] = {
       1,2,4,6,8,10,12,14,15,17,19,21,23,25,27,28 };

static unsigned char pc2[48] = {
       13, 16, 10, 23,  0,  4,       2, 27, 14,  5, 20,  9,
       22, 18, 11,  3, 25,  7,      15,  6, 26, 19, 12,  1,
       40, 51, 30, 36, 46, 54,      29, 39, 50, 44, 32, 47,
       43, 48, 38, 55, 33, 52,      45, 41, 49, 35, 28, 31 };
```

```
void deskey(key, edf)       /* Thanks to James Gillogly & Phil Karn! */
unsigned char *key;
short edf;
{
        register int i, j, l, m, n;
        unsigned char pc1m[56], pcr[56];
        unsigned long kn[32];

        for ( j = 0; j < 56; j++ ) {
                l = pc1[j];
                m = l & 07;
                pc1m[j] = (key[l >> 3] & bytebit[m]) ? 1 : 0;
                }
        for( i = 0; i < 16; i++ ) {
                if( edf == DE1 ) m = (15 - i) << 1;
                else m = i << 1;
                n = m + 1;
                kn[m] = kn[n] = 0L;
                for( j = 0; j < 28; j++ ) {
                        l = j + totrot[i];
                        if( l < 28 ) pcr[j] = pc1m[l];
                        else pcr[j] = pc1m[l - 28];
                        }
                for( j = 28; j < 56; j++ ) {
                    l = j + totrot[i];
                    if( l < 56 ) pcr[j] = pc1m[l];
                    else pcr[j] = pc1m[l - 28];
                    }
                for( j = 0; j < 24; j++ ) {
                        if( pcr[pc2[j]] ) kn[m] |= bigbyte[j];
                        if( pcr[pc2[j+24]] ) kn[n] |= bigbyte[j];
                        }
                }
        cookey(kn);
        return;
}

static void cookey(raw1)
register unsigned long *raw1;
{
        register unsigned long *cook, *raw0;
        unsigned long dough[32];
        register int i;

        cook = dough;
        for( i = 0; i < 16; i++, raw1++ ) {
                raw0 = raw1++;
                *cook    = (*raw0 & 0x00fc0000L) << 6;
                *cook   |= (*raw0 & 0x00000fc0L) << 10;
                *cook   |= (*raw1 & 0x00fc0000L) >> 10;
                *cook++         |= (*raw1 & 0x00000fc0L) >> 6;
                *cook    = (*raw0 & 0x0003f000L) << 12;
                *cook   |= (*raw0 & 0x0000003fL) << 16;
                *cook   |= (*raw1 & 0x0003f000L) >> 4;
                *cook++         |= (*raw1 & 0x0000003fL);
```

```
                }
        usekey(dough);
        return;
}

void cpkey(into)
register unsigned long *into;
{
        register unsigned long *from, *endp;

        from = KnL, endp = &KnL[32];
        while( from < endp ) *into++ = *from++;
        return;
}

void usekey(from)
register unsigned long *from;
{
        register unsigned long *to, *endp;

        to = KnL, endp = &KnL[32];
        while( to < endp ) *to++ = *from++;
        return;
}

void des(inblock, outblock)
unsigned char *inblock, *outblock;
{
        unsigned long work[2];

        scrunch(inblock, work);
        desfunc(work, KnL);
        unscrun(work, outblock);
        return;
}

static void scrunch(outof, into)
register unsigned char *outof;
register unsigned long *into;
{
        *into   = (*outof++ & 0xffL) << 24;
        *into  |= (*outof++ & 0xffL) << 16;
        *into  |= (*outof++ & 0xffL) << 8;
        *into++ |= (*outof++ & 0xffL);
        *into   = (*outof++ & 0xffL) << 24;
        *into  |= (*outof++ & 0xffL) << 16;
        *into  |= (*outof++ & 0xffL) << 8;
        *into  |= (*outof   & 0xffL);
        return;
}

static void unscrun(outof, into)
register unsigned long *outof;
register unsigned char *into;
{
```

```
        *into++ = (*outof >> 24) & 0xffL;
        *into++ = (*outof >> 16) & 0xffL;
        *into++ = (*outof >>  8) & 0xffL;
        *into++ =  *outof++           & 0xffL;
        *into++ = (*outof >> 24) & 0xffL;
        *into++ = (*outof >> 16) & 0xffL;
        *into++ = (*outof >>  8) & 0xffL;
        *into   =  *outof     & 0xffL;
        return;
}

static unsigned long SP1[64] = {
        0x01010400L, 0x00000000L, 0x00010000L, 0x01010404L,
        0x01010004L, 0x00010404L, 0x00000004L, 0x00010000L,
        0x00000400L, 0x01010400L, 0x01010404L, 0x00000400L,
        0x01000404L, 0x01010004L, 0x01000000L, 0x00000004L,
        0x00000404L, 0x01000400L, 0x01000400L, 0x00010400L,
        0x00010400L, 0x01010000L, 0x01010000L, 0x01000404L,
        0x00010004L, 0x01000004L, 0x01000004L, 0x00010004L,
        0x00000000L, 0x00000404L, 0x00010404L, 0x01000000L,
        0x00010000L, 0x01010404L, 0x00000004L, 0x01010000L,
        0x01010400L, 0x01000000L, 0x01000000L, 0x00000400L,
        0x01010004L, 0x00010000L, 0x00010400L, 0x01000004L,
        0x00000400L, 0x00000004L, 0x01000404L, 0x00010404L,
        0x01010404L, 0x00010004L, 0x01010000L, 0x01000404L,
        0x01000004L, 0x00000404L, 0x00010404L, 0x01010400L,
        0x00000404L, 0x01000400L, 0x01000400L, 0x00000000L,
        0x00010004L, 0x00010400L, 0x00000000L, 0x01010004L };

static unsigned long SP2[64] = {
        0x80108020L, 0x80008000L, 0x00008000L, 0x00108020L,
        0x00100000L, 0x00000020L, 0x80100020L, 0x80008020L,
        0x80000020L, 0x80108020L, 0x80108000L, 0x80000000L,
        0x80008000L, 0x00100000L, 0x00000020L, 0x80100020L,
        0x00108000L, 0x00100020L, 0x80008020L, 0x00000000L,
        0x80000000L, 0x00008000L, 0x00108020L, 0x80100000L,
        0x00100020L, 0x80000020L, 0x00000000L, 0x00108000L,
        0x00008020L, 0x80108000L, 0x80100000L, 0x00008020L,
        0x00000000L, 0x00108020L, 0x80100020L, 0x00100000L,
        0x80008020L, 0x80100000L, 0x80108000L, 0x00008000L,
        0x80100000L, 0x80008000L, 0x00000020L, 0x80108020L,
        0x00108020L, 0x00000020L, 0x00008000L, 0x80000000L,
        0x00008020L, 0x80108000L, 0x00100000L, 0x80000020L,
        0x00100020L, 0x80008020L, 0x80000020L, 0x00100020L,
        0x00108000L, 0x00000000L, 0x80008000L, 0x00008020L,
        0x80000000L, 0x80100020L, 0x80108020L, 0x00108000L };

static unsigned long SP3[64] = {
        0x00000208L, 0x08020200L, 0x00000000L, 0x08020008L,
        0x08000200L, 0x00000000L, 0x00020208L, 0x08000200L,
        0x00020008L, 0x08000008L, 0x08000008L, 0x00020000L,
        0x08020208L, 0x00020008L, 0x08020000L, 0x00000208L,
        0x08000000L, 0x00000008L, 0x08020200L, 0x00000200L,
        0x00020200L, 0x08020000L, 0x08020008L, 0x00020208L,
```

```
        0x08000208L, 0x00020200L, 0x00020000L, 0x08000208L,
        0x00000008L, 0x08020208L, 0x00000200L, 0x08000000L,
        0x08020200L, 0x08000000L, 0x00020008L, 0x00000208L,
        0x00020000L, 0x08020200L, 0x08000200L, 0x00000000L,
        0x00000200L, 0x00020008L, 0x08020208L, 0x08000200L,
        0x08000008L, 0x00000200L, 0x00000000L, 0x08020008L,
        0x08000208L, 0x00020000L, 0x08000000L, 0x08020208L,
        0x00000008L, 0x00020208L, 0x00020200L, 0x08000008L,
        0x08020000L, 0x08000208L, 0x00000208L, 0x08020000L,
        0x00020208L, 0x00000008L, 0x08020008L, 0x00020200L };

static unsigned long SP4[64] = {
        0x00802001L, 0x00002081L, 0x00002081L, 0x00000080L,
        0x00802080L, 0x00800081L, 0x00800001L, 0x00002001L,
        0x00000000L, 0x00802000L, 0x00802000L, 0x00802081L,
        0x00000081L, 0x00000000L, 0x00800080L, 0x00800001L,
        0x00000001L, 0x00002000L, 0x00800000L, 0x00802001L,
        0x00000080L, 0x00800000L, 0x00002001L, 0x00002080L,
        0x00800081L, 0x00000001L, 0x00002080L, 0x00800080L,
        0x00002000L, 0x00802080L, 0x00802081L, 0x00000081L,
        0x00800080L, 0x00800001L, 0x00802000L, 0x00802081L,
        0x00000081L, 0x00000000L, 0x00000000L, 0x00802000L,
        0x00002080L, 0x00800080L, 0x00800081L, 0x00000001L,
        0x00802001L, 0x00002081L, 0x00002081L, 0x00000080L,
        0x00802081L, 0x00000081L, 0x00000001L, 0x00002000L,
        0x00800001L, 0x00002001L, 0x00802080L, 0x00800081L,
        0x00002001L, 0x00002080L, 0x00800000L, 0x00802001L,
        0x00000080L, 0x00800000L, 0x00002000L, 0x00802080L };

static unsigned long SP5[64] = {
        0x00000100L, 0x02080100L, 0x02080000L, 0x42000100L,
        0x00080000L, 0x00000100L, 0x40000000L, 0x02080000L,
        0x40080100L, 0x00080000L, 0x02000100L, 0x40080100L,
        0x42000100L, 0x42080000L, 0x00080100L, 0x40000000L,
        0x02000000L, 0x40080000L, 0x40080000L, 0x00000000L,
        0x40000100L, 0x42080100L, 0x42080100L, 0x02000100L,
        0x42080000L, 0x40000100L, 0x00000000L, 0x42000000L,
        0x02080100L, 0x02000000L, 0x42000000L, 0x00080100L,
        0x00080000L, 0x42000100L, 0x00000100L, 0x02000000L,
        0x40000000L, 0x02080000L, 0x42000100L, 0x40080100L,
        0x02000100L, 0x40000000L, 0x42080000L, 0x02080100L,
        0x40080100L, 0x00000100L, 0x02000000L, 0x42080000L,
        0x42080100L, 0x00080100L, 0x42000000L, 0x42080100L,
        0x02080000L, 0x00000000L, 0x40080000L, 0x42000000L,
        0x00080100L, 0x02000100L, 0x40000100L, 0x00080000L,
        0x00000000L, 0x40080000L, 0x02080100L, 0x40000100L };

static unsigned long SP6[64] = {
        0x20000010L, 0x20400000L, 0x00004000L, 0x20404010L,
        0x20400000L, 0x00000010L, 0x20404010L, 0x00400000L,
        0x20004000L, 0x00404010L, 0x00400000L, 0x20000010L,
        0x00400010L, 0x20004000L, 0x20000000L, 0x00004010L,
        0x00000000L, 0x00400010L, 0x20004010L, 0x00004000L,
        0x00404000L, 0x20004010L, 0x00000010L, 0x20400010L,
```

```
        0x20400010L, 0x00000000L, 0x00404010L, 0x20404000L,
        0x00004010L, 0x00404000L, 0x20404000L, 0x20000000L,
        0x20004000L, 0x00000010L, 0x20400010L, 0x00404000L,
        0x20404010L, 0x00400000L, 0x00004010L, 0x20000010L,
        0x00400000L, 0x20004000L, 0x20000000L, 0x00004010L,
        0x20000010L, 0x20404010L, 0x00404000L, 0x20400000L,
        0x00404010L, 0x20404000L, 0x00000000L, 0x20400010L,
        0x00000010L, 0x00004000L, 0x20400000L, 0x00404010L,
        0x00004000L, 0x00400010L, 0x20004010L, 0x00000000L,
        0x20404000L, 0x20000000L, 0x00400010L, 0x20004010L };

static unsigned long SP7[64] = {
        0x00200000L, 0x04200002L, 0x04000802L, 0x00000000L,
        0x00000800L, 0x04000802L, 0x00200802L, 0x04200800L,
        0x04200802L, 0x00200000L, 0x00000000L, 0x04000002L,
        0x00000002L, 0x04000000L, 0x04200002L, 0x00000802L,
        0x04000800L, 0x00200802L, 0x00200002L, 0x04000800L,
        0x04000002L, 0x04200000L, 0x04200800L, 0x00200002L,
        0x04200000L, 0x00000800L, 0x00000802L, 0x04200802L,
        0x00200800L, 0x00000002L, 0x04000000L, 0x00200800L,
        0x04000000L, 0x00200800L, 0x00200000L, 0x04000802L,
        0x04000802L, 0x04200002L, 0x04200002L, 0x00000002L,
        0x00200002L, 0x04000000L, 0x04000800L, 0x00200000L,
        0x04200800L, 0x00000802L, 0x00200802L, 0x04200800L,
        0x00000802L, 0x04000002L, 0x04200802L, 0x04200000L,
        0x00200800L, 0x00000000L, 0x00000002L, 0x04200802L,
        0x00000000L, 0x00200802L, 0x04200000L, 0x00000800L,
        0x04000002L, 0x04000800L, 0x00000800L, 0x00200002L };

static unsigned long SP8[64] = {
        0x10001040L, 0x00001000L, 0x00040000L, 0x10041040L,
        0x10000000L, 0x10001040L, 0x00000040L, 0x10000000L,
        0x00040040L, 0x10040000L, 0x10041040L, 0x00041000L,
        0x10041000L, 0x00041040L, 0x00001000L, 0x00000040L,
        0x10040000L, 0x10000040L, 0x10001000L, 0x00001040L,
        0x00041000L, 0x00040040L, 0x10040040L, 0x10041000L,
        0x00001040L, 0x00000000L, 0x00000000L, 0x10040040L,
        0x10000040L, 0x10001000L, 0x00041040L, 0x00040000L,
        0x00041040L, 0x00040000L, 0x10041000L, 0x00001000L,
        0x00000040L, 0x10040040L, 0x00001000L, 0x00041040L,
        0x10001000L, 0x00000040L, 0x10000040L, 0x10040000L,
        0x10040040L, 0x10000000L, 0x00040000L, 0x10001040L,
        0x00000000L, 0x10041040L, 0x00040040L, 0x10000040L,
        0x10040000L, 0x10001000L, 0x10001040L, 0x00000000L,
        0x10041040L, 0x00041000L, 0x00041000L, 0x00001040L,
        0x00001040L, 0x00040040L, 0x10000000L, 0x10041000L };

static void desfunc(block, keys)
register unsigned long *block, *keys;
{
        register unsigned long fval, work, right, leftt;
        register int round;

        leftt = block[0];
```

```
right = block[1];
work = ((leftt >> 4) ^ right) & 0x0f0f0f0fL;
right ^= work;
leftt ^= (work << 4);
work = ((leftt >> 16) ^ right) & 0x0000ffffL;
right ^= work;
leftt ^= (work << 16);
work = ((right >> 2) ^ leftt) & 0x33333333L;
leftt ^= work;
right ^= (work << 2);
work = ((right >> 8) ^ leftt) & 0x00ff00ffL;
leftt ^= work;
right ^= (work << 8);
right = ((right << 1) | ((right >> 31) & 1L)) & 0xffffffffL;
work = (leftt ^ right) & 0xaaaaaaaaL;
leftt ^= work;
right ^= work;
leftt = ((leftt << 1) | ((leftt >> 31) & 1L)) & 0xffffffffL;

for( round = 0; round < 8; round++ ) {
       work  = (right << 28) | (right >> 4);
       work ^= *keys++;
       fval  = SP7[ work             & 0x3fL];
       fval |= SP5[(work >>  8) & 0x3fL];
       fval |= SP3[(work >> 16) & 0x3fL];
       fval |= SP1[(work >> 24) & 0x3fL];
       work  = right ^ *keys++;
       fval |= SP8[ work             & 0x3fL];
       fval |= SP6[(work >>  8) & 0x3fL];
       fval |= SP4[(work >> 16) & 0x3fL];
       fval |= SP2[(work >> 24) & 0x3fL];
       leftt ^= fval;
       work  = (leftt << 28) | (leftt >> 4);
       work ^= *keys++;
       fval  = SP7[ work             & 0x3fL];
       fval |= SP5[(work >>  8) & 0x3fL];
       fval |= SP3[(work >> 16) & 0x3fL];
       fval |= SP1[(work >> 24) & 0x3fL];
       work  = leftt ^ *keys++;
       fval |= SP8[ work             & 0x3fL];
       fval |= SP6[(work >>  8) & 0x3fL];
       fval |= SP4[(work >> 16) & 0x3fL];
       fval |= SP2[(work >> 24) & 0x3fL];
       right ^= fval;
       }

right = (right << 31) | (right >> 1);
work = (leftt ^ right) & 0xaaaaaaaaL;
leftt ^= work;
right ^= work;
leftt = (leftt << 31) | (leftt >> 1);
work = ((leftt >> 8) ^ right) & 0x00ff00ffL;
right ^= work;
leftt ^= (work << 8);
```

```
        work = ((leftt >> 2) ^ right) & 0x33333333L;
        right ^= work;
        leftt ^= (work << 2);
        work = ((right >> 16) ^ leftt) & 0x0000ffffL;
        leftt ^= work;
        right ^= (work << 16);
        work = ((right >> 4) ^ leftt) & 0x0f0f0f0fL;
        leftt ^= work;
        right ^= (work << 4);
        *block++ = right;
        *block = leftt;
        return;
}

/* Validation sets:
 *
 * Single-length key, single-length plaintext -
 * Key     : 0123 4567 89ab cdef
 * Plain   : 0123 4567 89ab cde7
 * Cipher : c957 4425 6a5e d31d
 *
 ********************************************************************/

void des_key(des_ctx *dc, unsigned char *key){
        deskey(key,EN0);
        cpkey(dc->ek);
        deskey(key,DE1);
        cpkey(dc->dk);
}

/* Encrypt several blocks in ECB mode.  Caller is responsible for
   short blocks. */
void des_enc(des_ctx *dc, unsigned char *data, int blocks){
        unsigned long work[2];
        int i;
        unsigned char *cp;

        cp = data;
        for(i=0;i<blocks;i++){
                scrunch(cp,work);
                desfunc(work,dc->ek);
                unscrun(work,cp);
                cp+=8;
        }
}

void des_dec(des_ctx *dc, unsigned char *data, int blocks){
        unsigned long work[2];
        int i;
        unsigned char *cp;

        cp = data;
        for(i=0;i<blocks;i++){
                scrunch(cp,work);
                desfunc(work,dc->dk);
```

```
                unscrun(work,cp);
                cp+=8;
        }
}

void main(void){
        des_ctx dc;
        int i;
        unsigned long data[10];
        char *cp,key[8] = {0x01,0x23,0x45,0x67,0x89,0xab,0xcd,0xef};
        char x[8] = {0x01,0x23,0x45,0x67,0x89,0xab,0xcd,0xe7};

        cp = x;

        des_key(&dc,key);
        des_enc(&dc,cp,1);
        printf("Enc(0..7,0..7) = ");
        for(i=0;i<8;i++) printf("%02x ", ((unsigned int) cp[i])&0x00ff);
        printf("\n");

        des_dec(&dc,cp,1);

        printf("Dec(above,0..7) = ");
        for(i=0;i<8;i++) printf("%02x ",((unsigned int)cp[i])&0x00ff);
        printf("\n");

        cp = (char *) data;
        for(i=0;i<10;i++)data[i]=i;

        des_enc(&dc,cp,5); /* Enc 5 blocks. */
        for(i=0;i<10;i+=2) printf("Block %01d = %08lx %08lx.\n",
                                i/2,data[i],data[i+1]);

        des_dec(&dc,cp,1);
        des_dec(&dc,cp+8,4);
        for(i=0;i<10;i+=2) printf("Block %01d = %08lx %08lx.\n",
                                i/2,data[i],data[i+1]);

}
```

LOKI91

```
#include <stdio.h>

#define LOKIBLK         8               /* No of bytes in a LOKI data-block          */
#define ROUNDS          16              /* No of LOKI rounds                        */

typedef unsigned long           Long;   /* type specification for aligned LOKI blocks
*/

extern Long     lokikey[2];     /* 64-bit key used by LOKI routines          */
extern char     *loki_lib_ver;          /* String with version no. & copyright       */

#ifdef __STDC__                         /* declare prototypes for library functions  */
extern void enloki(char *b);
```

```
extern void deloki(char *b);
extern void setlokikey(char key[LOKIBLK]);
#else                           /* else just declare library functions extern */
extern void enloki(), deloki(), setlokikey();
#endif __STDC__

char P[32] = {
        31, 23, 15, 7, 30, 22, 14, 6,
        29, 21, 13, 5, 28, 20, 12, 4,
        27, 19, 11, 3, 26, 18, 10, 2,
        25, 17, 9, 1, 24, 16, 8, 0
        };

typedef         struct {
        short   gen;            /* irreducible polynomial used in this field */
        short   exp;            /* exponent used to generate this s function */
        } sfn_desc;

sfn_desc sfn[] = {
        { /* 101110111 */ 375, 31}, { /* 101111011 */ 379, 31},
        { /* 110000111 */ 391, 31}, { /* 110001011 */ 395, 31},
        { /* 110001101 */ 397, 31}, { /* 110011111 */ 415, 31},
        { /* 110100011 */ 419, 31}, { /* 110101001 */ 425, 31},
        { /* 110110001 */ 433, 31}, { /* 110111101 */ 445, 31},
        { /* 111000011 */ 451, 31}, { /* 111001111 */ 463, 31},
        { /* 111010111 */ 471, 31}, { /* 111011101 */ 477, 31},
        { /* 111100111 */ 487, 31}, { /* 111110011 */ 499, 31},
        { 00, 00}       };

typedef struct {
        Long loki_subkeys[ROUNDS];
} loki_ctx;

static Long     f();                    /* declare LOKI function f */
static short    s();                    /* declare LOKI S-box fn s */

#define ROL12(b) b = ((b << 12) | (b >> 20));
#define ROL13(b) b = ((b << 13) | (b >> 19));

#ifdef  LITTLE_ENDIAN
#define bswap(cb) {                             \
        register char   c;                      \
        c = cb[0]; cb[0] = cb[3]; cb[3] = c;    \
        c = cb[1]; cb[1] = cb[2]; cb[2] = c;    \
        c = cb[4]; cb[4] = cb[7]; cb[7] = c;    \
        c = cb[5]; cb[5] = cb[6]; cb[6] = c;    \
}
#endif

void
setlokikey(loki_ctx *c, char *key)
{
        register        i;
        register Long   KL, KR;
```

```
#ifdef LITTLE_ENDIAN
        bswap(key);                     /* swap bytes round if little-endian */
#endif
        KL = ((Long *)key)[0];
        KR = ((Long *)key)[1];

        for (i=0; i<ROUNDS; i+=4) {             /* Generate the 16 subkeys */
            c->loki_subkeys[i] = KL;
            ROL12 (KL);
            c->loki_subkeys[i+1] = KL;
            ROL13 (KL);
            c->loki_subkeys[i+2] = KR;
            ROL12 (KR);
            c->loki_subkeys[i+3] = KR;
            ROL13 (KR);
        }

#ifdef LITTLE_ENDIAN
        bswap(key);                     /* swap bytes back if little-endian */
#endif
}

void
enloki (loki_ctx *c, char *b)
{
        register        i;
        register Long   L, R;           /* left & right data halves  */

#ifdef LITTLE_ENDIAN
        bswap(b);                       /* swap bytes round if little-endian */
#endif

        L = ((Long *)b)[0];
        R = ((Long *)b)[1];

        for (i=0; i<ROUNDS; i+=2) {             /* Encrypt with the 16 subkeys */
            L ^= f (R, c->loki_subkeys[i]);
            R ^= f (L, c->loki_subkeys[i+1]);
        }

        ((Long *)b)[0] = R;             /* Y = swap(LR) */
        ((Long *)b)[1] = L;

#ifdef LITTLE_ENDIAN
        bswap(b);                       /* swap bytes round if little-endian */
#endif
}

void
deloki(loki_ctx *c, char *b)
{
        register        i;
        register Long   L, R;                   /* left & right data halves  */

#ifdef LITTLE_ENDIAN
```

```
        bswap(b);                       /* swap bytes round if little-endian */
#endif

        L = ((Long *)b)[0];                     /* LR = X XOR K */
        R = ((Long *)b)[1];

        for (i=ROUNDS; i>0; i-=2) {                     /* subkeys in reverse order */
            L ^= f(R, c->loki_subkeys[i-1]);
            R ^= f(L, c->loki_subkeys[i-2]);
        }

        ((Long *)b)[0] = R;                     /* Y = LR XOR K */
        ((Long *)b)[1] = L;
}

#define MASK12          0x0fff                  /* 12 bit mask for expansion E */

static Long
f(r, k)
register Long  r;       /* Data value R(i-1) */
Long           k;       /* Key     K(i)   */
{
        Long   a, b, c;                 /* 32 bit S-box output, & P output */

        a = r ^ k;                      /* A = R(i-1) XOR K(i) */

        /* want to use slow speed/small size version */
        b = ((Long)s((a          & MASK12))       ) | /* B = S(E(R(i-1))^K(i)) */
            ((Long)s(((a >>  8) & MASK12)) <<  8) |
            ((Long)s(((a >> 16) & MASK12)) << 16) |
            ((Long)s((((a >> 24) | (a << 8)) & MASK12)) << 24);

        perm32(&c, &b, P);              /* C = P(S( E(R(i-1)) XOR K(i))) */

        return(c);                      /* f returns the result C */
}

static short s(i)
register Long i;        /* return S-box value for input i */
{
        register short r, c, v, t;
        short  exp8();                  /* exponentiation routine for GF(2^8) */

        r = ((i>>8) & 0xc) | (i & 0x3);                 /* row value-top 2 & bottom 2 */
        c = (i>>2) & 0xff;                              /* column value-middle 8 bits */
        t = (c + ((r * 17) ^ 0xff)) & 0xff;             /* base value for Sfn */
        v = exp8(t, sfn[r].exp, sfn[r].gen);            /* Sfn[r] = t ^ exp mod gen */
        return(v);
}

#define         MSB     0x80000000L             /* MSB of 32-bit word */

perm32(out, in , perm)
Long    *out;           /* Output 32-bit block to be permuted                */
```

```
Long    *in;            /* Input  32-bit block after permutation            */
char    perm[32];       /* Permutation array                                */
{
        Long   mask = MSB;                      /* mask used to set bit in output    */
        register int   i, o, b;         /* input bit no, output bit no, value */
        register char  *p = perm;       /* ptr to permutation array  */

        *out = 0;                       /* clear output block */
        for (o=0; o<32; o++) {                  /* For each output bit position o */
                i =(int)*p++;                   /* get input bit permuted to output o */
                b = (*in >> i) & 01;            /* value of input bit i */
                if (b)                  /* If the input bit i is set */
                        *out |= mask;                   /*  OR in mask to output i */
                mask >>= 1;                             /* Shift mask to next bit    */
        }
}

#define SIZE 256                /* 256 elements in GF(2^8) */

short mult8(a, b, gen)
short   a, b;           /* operands for multiply */
short   gen;            /* irreducible polynomial generating Galois Field */
{
        short  product = 0;             /* result of multiplication */

        while(b != 0) {                         /* while multiplier is non-zero */
                if (b & 01)
                        product ^= a;           /*   add multiplicand if LSB of b set */
                a <<= 1;                /*   shift multiplicand one place */
                if (a >= SIZE)
                        a ^= gen;       /*   and modulo reduce if needed */
                b >>= 1;                /*   shift multiplier one place  */
        }
        return(product);
}

short exp8(base, exponent, gen)
short   base;           /* base of exponentiation       */
short   exponent;       /* exponent                     */
short   gen;            /* irreducible polynomial generating Galois Field */
{
        short  accum = base;            /* superincreasing sequence of base */
        short  result = 1;      /* result of exponentiation        */

        if (base == 0)                  /* if zero base specified then      */
                return(0);      /* the result is "0" if base = 0    */

        while (exponent != 0) {         /* repeat while exponent non-zero */
                if (( exponent & 0x0001) == 0x0001)             /* multiply if exp 1 */
                        result = mult8(result, accum, gen);
                exponent >>= 1;                 /* shift exponent to next digit */
                accum = mult8(accum, accum, gen);               /* & square  */
        }
        return(result);
}
```

```
void loki_key(loki_ctx *c, unsigned char *key){
        setlokikey(c,key);
}

void loki_enc(loki_ctx *c, unsigned char *data, int blocks){
        unsigned char *cp;
        int i;

        cp = data;
        for(i=0;i<blocks;i++){
                enloki(c,cp);
                cp+=8;
        }
}

void loki_dec(loki_ctx *c, unsigned char *data, int blocks){
        unsigned char *cp;
        int i;

        cp = data;
        for(i=0;i<blocks;i++){
                deloki(c,cp);
                cp+=8;
        }
}

void main(void){
        loki_ctx lc;
        unsigned long data[10];
        unsigned char *cp;
        unsigned char key[] = {0,1,2,3,4,5,6,7};
        int i;

        for(i=0;i<10;i++) data[i]=i;

        loki_key(&lc,key);

        cp = (char *)data;
        loki_enc(&lc,cp,5);
        for(i=0;i<10;i+=2) printf("Block %01d = %08lx %08lx\n",
                        i/2,data[i],data[i+1]);
        loki_dec(&lc,cp,1);
        loki_dec(&lc,cp+8,4);
        for(i=0;i<10;i+=2) printf("Block %01d = %08lx %08lx\n",
                        i/2,data[i],data[i+1]);

}
```

IDEA

```
typedef unsigned char boolean;      /* values are TRUE or FALSE */
typedef unsigned char byte; /* values are 0-255 */
typedef byte *byteptr;      /* pointer to byte */
```

```
typedef char *string;/* pointer to ASCII character string */
typedef unsigned short word16;      /* values are 0-65535 */
typedef unsigned long word32;       /* values are 0-4294967295 */

#ifndef TRUE
#define FALSE 0
#define TRUE (!FALSE)
#endif /* if TRUE not already defined */

#ifndef min   /* if min macro not already defined */
#define min(a,b) ( (a)<(b) ? (a) : (b) )
#define max(a,b) ( (a)>(b) ? (a) : (b) )
#endif /* if min macro not already defined */

#define IDEAKEYSIZE 16
#define IDEABLOCKSIZE 8

#define IDEAROUNDS 8
#define IDEAKEYLEN (6*IDEAROUNDS+4)

typedef struct{
       word16 ek[IDEAKEYLEN],dk[IDEAKEYLEN];
}idea_ctx;

/* End includes for IDEA.C */
#ifdef IDEA32        /* Use >16-bit temporaries */
#define low16(x) ((x) & 0xFFFF)
typedef unsigned int uint16;/* at LEAST 16 bits, maybe more */
#else
#define low16(x) (x) /* this is only ever applied to uint16's */
typedef word16 uint16;
#endif

#ifdef SMALL_CACHE
static uint16
mul(register uint16 a, register uint16 b)
{
       register word32 p;

       p = (word32)a * b;
       if (p) {
              b = low16(p);
              a = p>>16;
              return (b - a) + (b < a);
       } else if (a) {
              return 1-b;
       } else {
              return 1-a;
       }
} /* mul */
#endif /* SMALL_CACHE */

static uint16
mulInv(uint16 x)
{
```

```
        uint16 t0, t1;
        uint16 q, y;

        if (x <= 1)
                return x;       /* 0 and 1 are self-inverse */
        t1 = 0x10001L / x;      /* Since x >= 2, this fits into 16 bits */
        y = 0x10001L % x;
        if (y == 1)
                return low16(1-t1);
        t0 = 1;
        do {
                q = x / y;
                x = x % y;
                t0 += q * t1;
                if (x == 1)
                        return t0;
                q = y / x;
                y = y % x;
                t1 += q * t0;
        } while (y != 1);
        return low16(1-t1);
} /* mukInv */

static void
ideaExpandKey(byte const *userkey, word16 *EK)
{
        int i,j;

        for (j=0; j<8; j++) {
                EK[j] = (userkey[0]<<8) + userkey[1];
                userkey += 2;
        }
        for (i=0; j < IDEAKEYLEN; j++) {
                i++;
                EK[i+7] = EK[i & 7] << 9 | EK[i+1 & 7] >> 7;
                EK += i & 8;
                i &= 7;
        }
} /* ideaExpandKey */

static void
ideaInvertKey(word16 const *EK, word16 DK[IDEAKEYLEN])
{
        int i;
        uint16 t1, t2, t3;
        word16 temp[IDEAKEYLEN];
        word16 *p = temp + IDEAKEYLEN;

        t1 = mulInv(*EK++);
        t2 = -*EK++;
        t3 = -*EK++;
        *--p = mulInv(*EK++);
        *--p = t3;
        *--p = t2;
```

```
        *--p = t1;

        for (i = 0; i < IDEAROUNDS-1; i++) {
                t1 = *EK++;
                *--p = *EK++;
                *--p = t1;

                t1 = mulInv(*EK++);
                t2 = -*EK++;
                t3 = -*EK++;
                *--p = mulInv(*EK++);
                *--p = t2;
                *--p = t3;
                *--p = t1;
        }
        t1 = *EK++;
        *--p = *EK++;
        *--p = t1;

        t1 = mulInv(*EK++);
        t2 = -*EK++;
        t3 = -*EK++;
        *--p = mulInv(*EK++);
        *--p = t3;
        *--p = t2;
        *--p = t1;
/* Copy and destroy temp copy */
        memcpy(DK, temp, sizeof(temp));
        for(i=0;i<IDEAKEYLEN;i++)temp[i]=0;
} /* ideaInvertKey */

#ifdef SMALL_CACHE
#define MUL(x,y) (x = mul(low16(x),y))
#else /* !SMALL_CACHE */
#ifdef AVOID_JUMPS
#define MUL(x,y) (x = low16(x-1), t16 = low16((y)-1), \
                t32 = (word32)x*t16 + x + t16 + 1, x = low16(t32), \
                t16 = t32>>16, x = (x-t16) + (x<t16) )
#else /* !AVOID_JUMPS (default) */
#define MUL(x,y) \
        ((t16 = (y)) ? \
                (x=low16(x)) ? \
                        t32 = (word32)x*t16, \
                        x = low16(t32), \
                        t16 = t32>>16, \
                        x = (x-t16)+(x<t16) \
                : \
                        (x = 1-t16) \
        : \
                (x = 1-x))
#endif
#endif

static void
```

```
ideaCipher(byte *inbuf, byte *outbuf, word16 *key)
{
        register uint16 x1, x2, x3, x4, s2, s3;
        word16 *in, *out;
#ifndef SMALL_CACHE
        register uint16 t16; /* Temporaries needed by MUL macro */
        register word32 t32;
#endif
        int r = IDEAROUNDS;

        in = (word16 *)inbuf;
        x1 = *in++;  x2 = *in++;
        x3 = *in++;  x4 = *in;
#ifndef HIGHFIRST
        x1 = (x1 >>8) | (x1<<8);
        x2 = (x2 >>8) | (x2<<8);
        x3 = (x3 >>8) | (x3<<8);
        x4 = (x4 >>8) | (x4<<8);
#endif
        do {
                MUL(x1,*key++);
                x2 += *key++;
                x3 += *key++;
                MUL(x4, *key++);

                s3 = x3;
                x3 ^= x1;
                MUL(x3, *key++);
                s2 = x2;
                x2 ^= x4;
                x2 += x3;
                MUL(x2, *key++);
                x3 += x2;

                x1 ^= x2;  x4 ^= x3;

                x2 ^= s3;  x3 ^= s2;
        } while (--r);
        MUL(x1, *key++);
        x3 += *key++;
        x2 += *key++;
        MUL(x4, *key);

        out = (word16 *)outbuf;
#ifdef HIGHFIRST
        *out++ = x1;
        *out++ = x3;
        *out++ = x2;
        *out = x4;
#else /* !HIGHFIRST */
        *out++ = (x1 >>8) | (x1<<8);
        *out++ = (x3 >>8) | (x3<<8);
        *out++ = (x2 >>8) | (x2<<8);
        *out = (x4 >>8) | (x4<<8);
```

```
#endif
} /* ideaCipher */

void idea_key(idea_ctx *c, unsigned char *key){
       ideaExpandKey(key,c->ek);
       ideaInvertKey(c->ek,c->dk);
}

void idea_enc(idea_ctx *c, unsigned char *data, int blocks){
       int i;
       unsigned char *d = data;

       for(i=0;i<blocks;i++){
              ideaCipher(d,d,c->ek);
              d+=8;
       }
}

void idea_dec(idea_ctx *c, unsigned char *data, int blocks){
       int i;
       unsigned char *d = data;

       for(i=0;i<blocks;i++){
              ideaCipher(d,d,c->dk);
              d+=8;
       }
}

#include <stdio.h>

#ifndef BLOCKS
#ifndef KBYTES
#define KBYTES 1024
#endif
#define BLOCKS (64*KBYTES)
#endif

int
main(void)
{      /* Test driver for IDEA cipher */
       int i, j, k;
       idea_ctx c;
       byte userkey[16];
       word16 EK[IDEAKEYLEN], DK[IDEAKEYLEN];
       byte XX[8], YY[8], ZZ[8];
       word32 long_block[10]; /* 5 blocks */
       long l;
       char *lbp;

       /* Make a sample user key for testing... */
       for(i=0; i<16; i++)
              userkey[i] = i+1;

       idea_key(&c,userkey);

       /* Make a sample plaintext pattern for testing... */
```

```
        for (k=0; k<8; k++)
                XX[k] = k;

        idea_enc(&c,XX,1); /* encrypt */

        lbp = (unsigned char *) long_block;
        for(i=0;i<10;i++) long_block[i] = i;
        idea_enc(&c,lbp,5);
        for(i=0;i<10;i+=2) printf("Block %01d = %08lx %08lx.\n",
                                i/2,long_block[i],long_block[i+1]);

        idea_dec(&c,lbp,3);
        idea_dec(&c,lbp+24,2);

        for(i=0;i<10;i+=2) printf("Block %01d = %08lx %08lx.\n",
                                i/2,long_block[i],long_block[i+1]);

        return 0;       /* normal exit */
} /* main */
```

GOST

```
typedef unsigned long u4;
typedef unsigned char byte;

typedef struct {
        u4 k[8];
        /* Constant s-boxes -- set up in gost_init(). */
        char k87[256],k65[256],k43[256],k21[256];
} gost_ctx;

/* Note:  encrypt and decrypt expect full blocks--padding blocks is
          caller's responsibility.  All bulk encryption is done in
          ECB mode by these calls.  Other modes may be added easily
          enough.                                                    */
void gost_enc(gost_ctx *, u4 *, int);
void gost_dec(gost_ctx *, u4 *, int);
void gost_key(gost_ctx *, u4 *);
void gost_init(gost_ctx *);
void gost_destroy(gost_ctx *);

#ifdef __alpha  /* Any other 64-bit machines? */
typedef unsigned int word32;
#else
typedef unsigned long word32;
#endif

kboxinit(gost_ctx *c)
{
        int i;

        byte k8[16] = {14,  4, 13,  1,  2, 15, 11,  8,  3, 10,  6,
                       12,  5,  9,  0,  7 };
        byte k7[16] = {15,  1,  8, 14,  6, 11,  3,  4,  9,  7,  2,
```

```
                    13, 12,  0,  5, 10 };
      byte k6[16] = {10,  0,  9, 14,  6,  3, 15,  5,  1, 13, 12,
                     7, 11,  4,  2,  8 };
      byte k5[16] = { 7, 13, 14,  3,  0,  6,  9, 10,  1,  2,  8,
                     5, 11, 12,  4, 15 };
      byte k4[16] = { 2, 12,  4,  1,  7, 10, 11,  6,  8,  5,  3,
                    15, 13,  0, 14,  9 };
      byte k3[16] = {12,  1, 10, 15,  9,  2,  6,  8,  0, 13,  3,
                     4, 14,  7,  5, 11 };
      byte k2[16] = { 4, 11,  2, 14, 15,  0,  8, 13,  3, 12,  9,
                     7,  5, 10,  6,  1 };
      byte k1[16] = {13,  2,  8,  4,  6, 15, 11,  1, 10,  9,  3,
                    14,  5,  0, 12,  7 };

    for (i = 0; i < 256; i++) {
            c->k87[i] = k8[i >> 4] << 4 | k7[i & 15];
            c->k65[i] = k6[i >> 4] << 4 | k5[i & 15];
            c->k43[i] = k4[i >> 4] << 4 | k3[i & 15];
            c->k21[i] = k2[i >> 4] << 4 | k1[i & 15];
    }
}

static word32
f(gost_ctx *c,word32 x)
{
      x = c->k87[x>>24 & 255] << 24 | c->k65[x>>16 & 255] << 16 |
          c->k43[x>> 8 & 255] <<  8 | c->k21[x & 255];

    /* Rotate left 11 bits */
    return x<<11 | x>>(32-11);
}

void gostcrypt(gost_ctx *c, word32 *d){
    register word32 n1, n2; /* As named in the GOST */

      n1 = d[0];
      n2 = d[1];

    /* Instead of swapping halves, swap names each round */
      n2 ^= f(c,n1+c->k[0]); n1 ^= f(c,n2+c->k[1]);
      n2 ^= f(c,n1+c->k[2]); n1 ^= f(c,n2+c->k[3]);
      n2 ^= f(c,n1+c->k[4]); n1 ^= f(c,n2+c->k[5]);
      n2 ^= f(c,n1+c->k[6]); n1 ^= f(c,n2+c->k[7]);

      n2 ^= f(c,n1+c->k[0]); n1 ^= f(c,n2+c->k[1]);
      n2 ^= f(c,n1+c->k[2]); n1 ^= f(c,n2+c->k[3]);
      n2 ^= f(c,n1+c->k[4]); n1 ^= f(c,n2+c->k[5]);
      n2 ^= f(c,n1+c->k[6]); n1 ^= f(c,n2+c->k[7]);

      n2 ^= f(c,n1+c->k[0]); n1 ^= f(c,n2+c->k[1]);
      n2 ^= f(c,n1+c->k[2]); n1 ^= f(c,n2+c->k[3]);
      n2 ^= f(c,n1+c->k[4]); n1 ^= f(c,n2+c->k[5]);
      n2 ^= f(c,n1+c->k[6]); n1 ^= f(c,n2+c->k[7]);

      n2 ^= f(c,n1+c->k[7]); n1 ^= f(c,n2+c->k[6]);
      n2 ^= f(c,n1+c->k[5]); n1 ^= f(c,n2+c->k[4]);
```

```
        n2 ^= f(c,n1+c->k[3]); n1 ^= f(c,n2+c->k[2]);
        n2 ^= f(c,n1+c->k[1]); n1 ^= f(c,n2+c->k[0]);

        d[0] = n2; d[1] = n1;
}

void
gostdecrypt(gost_ctx *c, u4 *d){
     register word32 n1, n2; /* As named in the GOST */

        n1 = d[0]; n2 = d[1];

        n2 ^= f(c,n1+c->k[0]); n1 ^= f(c,n2+c->k[1]);
        n2 ^= f(c,n1+c->k[2]); n1 ^= f(c,n2+c->k[3]);
        n2 ^= f(c,n1+c->k[4]); n1 ^= f(c,n2+c->k[5]);
        n2 ^= f(c,n1+c->k[6]); n1 ^= f(c,n2+c->k[7]);

        n2 ^= f(c,n1+c->k[7]); n1 ^= f(c,n2+c->k[6]);
        n2 ^= f(c,n1+c->k[5]); n1 ^= f(c,n2+c->k[4]);
        n2 ^= f(c,n1+c->k[3]); n1 ^= f(c,n2+c->k[2]);
        n2 ^= f(c,n1+c->k[1]); n1 ^= f(c,n2+c->k[0]);

        n2 ^= f(c,n1+c->k[7]); n1 ^= f(c,n2+c->k[6]);
        n2 ^= f(c,n1+c->k[5]); n1 ^= f(c,n2+c->k[4]);
        n2 ^= f(c,n1+c->k[3]); n1 ^= f(c,n2+c->k[2]);
        n2 ^= f(c,n1+c->k[1]); n1 ^= f(c,n2+c->k[0]);

        n2 ^= f(c,n1+c->k[7]); n1 ^= f(c,n2+c->k[6]);
        n2 ^= f(c,n1+c->k[5]); n1 ^= f(c,n2+c->k[4]);
        n2 ^= f(c,n1+c->k[3]); n1 ^= f(c,n2+c->k[2]);
        n2 ^= f(c,n1+c->k[1]); n1 ^= f(c,n2+c->k[0]);

        d[0] = n2; d[1] = n1;
}

void gost_enc(gost_ctx *c, u4 *d, int blocks){
        int i;

        for(i=0;i<blocks;i++){
                gostcrypt(c,d);
                d+=2;
        }
}

void gost_dec(gost_ctx *c, u4 *d, int blocks){
        int i;

        for(i=0;i<blocks;i++){
                gostdecrypt(c,d);
                d+=2;
        }
}

void gost_key(gost_ctx *c, u4 *k){
        int i;
        for(i=0;i<8;i++) c->k[i]=k[i];
```

```
}

void gost_init(gost_ctx *c){
        kboxinit(c);
}

void gost_destroy(gost_ctx *c){
        int i;
        for(i=0;i<8;i++) c->k[i]=0;
}

void main(void){
        gost_ctx gc;
        u4 k[8],data[10];
        int i;

        /* Initialize GOST context. */
        gost_init(&gc);

        /* Prepare key--a simple key should be OK, with this many rounds! */
        for(i=0;i<8;i++) k[i] = i;
        gost_key(&gc,k);

        /* Try some test vectors. */
        data[0] = 0; data[1] = 0;
        gostcrypt(&gc,data);
        printf("Enc of zero vector:  %08lx %08lx\n",data[0],data[1]);
        gostcrypt(&gc,data);
        printf("Enc of above:        %08lx %08lx\n",data[0],data[1]);
        data[0] = 0xffffffff; data[1] = 0xffffffff;
        gostcrypt(&gc,data);
        printf("Enc of ones vector:  %08lx %08lx\n",data[0],data[1]);
        gostcrypt(&gc,data);
        printf("Enc of above:        %08lx %08lx\n",data[0],data[1]);

        /* Does gost_dec() properly reverse gost_enc()?  Do
           we deal OK with single-block lengths passed in gost_dec()?
           Do we deal OK with different lengths passed in? */

        /* Init data */
        for(i=0;i<10;i++) data[i]=i;

        /* Encrypt data as 5 blocks. */
        gost_enc(&gc,data,5);

        /* Display encrypted data. */
        for(i=0;i<10;i+=2) printf("Block %02d = %08lx %08lx\n",
                                  i/2,data[i],data[i+1]);

        /* Decrypt in different sized chunks. */
        gost_dec(&gc,data,1);
        gost_dec(&gc,data+2,4);
        printf("\n");

        /* Display decrypted data. */
```

```
        for(i=0;i<10;i+=2) printf("Block %02d = %08lx %08lx\n",
                                  i/2,data[i],data[i+1]);

        gost_destroy(&gc);
}
```

BLOWFISH

```
#include <math.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

#ifdef little_endian   /* Eg: Intel */
   #include <alloc.h>
#endif

#include <ctype.h>

#ifdef little_endian   /* Eg: Intel */
   #include <dir.h>
   #include <bios.h>
#endif

#ifdef big_endian
   #include <Types.h>
#endif

typedef struct {
        unsigned long S[4][256],P[18];
} blf_ctx;

#define MAXKEYBYTES 56          /* 448 bits */
// #define little_endian 1              /* Eg: Intel */
#define big_endian 1            /* Eg: Motorola */

void Blowfish_encipher(blf_ctx *,unsigned long *xl, unsigned long *xr);
void Blowfish_decipher(blf_ctx *,unsigned long *xl, unsigned long *xr);

#define N               16
#define noErr            0
#define DATAERROR         -1
#define KEYBYTES         8

FILE*         SubkeyFile;

unsigned long F(blf_ctx *bc, unsigned long x)
{
   unsigned short a;
   unsigned short b;
   unsigned short c;
   unsigned short d;
   unsigned long  y;
```

```
    d = x & 0x00FF;
    x >>= 8;
    c = x & 0x00FF;
    x >>= 8;
    b = x & 0x00FF;
    x >>= 8;
    a = x & 0x00FF;
    //y = ((S[0][a] + S[1][b]) ^ S[2][c]) + S[3][d];
    y = bc->S[0][a] + bc->S[1][b];
    y = y ^ bc->S[2][c];
    y = y + bc->S[3][d];

    return y;
}

void Blowfish_encipher(blf_ctx *c,unsigned long *xl, unsigned long *xr)
{
    unsigned long  Xl;
    unsigned long  Xr;
    unsigned long  temp;
    short          i;

    Xl = *xl;
    Xr = *xr;

    for (i = 0; i < N; ++i) {
        Xl = Xl ^ c->P[i];
        Xr = F(c,Xl) ^ Xr;

        temp = Xl;
        Xl = Xr;
        Xr = temp;
    }

    temp = Xl;
    Xl = Xr;
    Xr = temp;

    Xr = Xr ^ c->P[N];
    Xl = Xl ^ c->P[N + 1];

    *xl = Xl;
    *xr = Xr;
}

void Blowfish_decipher(blf_ctx *c, unsigned long *xl, unsigned long *xr)
{
    unsigned long  Xl;
    unsigned long  Xr;
    unsigned long  temp;
    short          i;

    Xl = *xl;
    Xr = *xr;
```

```
    for (i = N + 1; i > 1; --i) {
        Xl = Xl ^ c->P[i];
        Xr = F(c,Xl) ^ Xr;

        /* Exchange Xl and Xr */
        temp = Xl;
        Xl = Xr;
        Xr = temp;
    }

    /* Exchange Xl and Xr */
    temp = Xl;
    Xl = Xr;
    Xr = temp;

    Xr = Xr ^ c->P[1];
    Xl = Xl ^ c->P[0];

    *xl = Xl;
    *xr = Xr;
}

short InitializeBlowfish(blf_ctx *c, char key[], short keybytes)
{
    short          i;
    short          j;
    short          k;
    short          error;
    short          numread;
    unsigned long  data;
    unsigned long  datal;
    unsigned long  datar;

unsigned long ks0[] = {
0xd1310ba6, 0x98dfb5ac, 0x2ffd72db, 0xd01adfb7, 0xb8e1afed, 0x6a267e96,
0xba7c9045, 0xf12c7f99, 0x24a19947, 0xb3916cf7, 0x0801f2e2, 0x858efc16,
0x636920d8, 0x71574e69, 0xa458fea3, 0xf4933d7e, 0x0d95748f, 0x728eb658,
0x718bcd58, 0x82154aee, 0x7b54a41d, 0xc25a59b5, 0x9c30d539, 0x2af26013,
0xc5d1b023, 0x286085f0, 0xca417918, 0xb8db38ef, 0x8e79dcb0, 0x603a180e,
0x6c9e0e8b, 0xb01e8a3e, 0xd71577c1, 0xbd314b27, 0x78af2fda, 0x55605c60,
0xe65525f3, 0xaa55ab94, 0x57489862, 0x63e81440, 0x55ca396a, 0x2aab10b6,
0xb4cc5c34, 0x1141e8ce, 0xa15486af, 0x7c72e993, 0xb3ee1411, 0x636fbc2a,
0x2ba9c55d, 0x741831f6, 0xce5c3e16, 0x9b87931e, 0xafd6ba33, 0x6c24cf5c,
0x7a325381, 0x28958677, 0x3b8f4898, 0x6b4bb9af, 0xc4bfe81b, 0x66282193,
0x61d809cc, 0xfb21a991, 0x487cac60, 0x5dec8032, 0xef845d5d, 0xe98575b1,
0xdc262302, 0xeb651b88, 0x23893e81, 0xd396acc5, 0x0f6d6ff3, 0x83f44239,
0x2e0b4482, 0xa4842004, 0x69c8f04a, 0x9e1f9b5e, 0x21c66842, 0xf6e96c9a,
0x670c9c61, 0xabd388f0, 0x6a51a0d2, 0xd8542f68, 0x960fa728, 0xab5133a3,
0x6eef0b6c, 0x137a3be4, 0xba3bf050, 0x7efb2a98, 0xa1f1651d, 0x39af0176,
0x66ca593e, 0x82430e88, 0x8cee8619, 0x456f9fb4, 0x7d84a5c3, 0x3b8b5ebe,
0xe06f75d8, 0x85c12073, 0x401a449f, 0x56c16aa6, 0x4ed3aa62, 0x363f7706,
0x1bfedf72, 0x429b023d, 0x37d0d724, 0xd00a1248, 0xdb0fead3, 0x49f1c09b,
0x075372c9, 0x80991b7b, 0x25d479d8, 0xf6e8def7, 0xe3fe501a, 0xb6794c3b,
```

```
0x976ce0bd, 0x04c006ba, 0xc1a94fb6, 0x409f60c4, 0x5e5c9ec2, 0x196a2463,
0x68fb6faf, 0x3e6c53b5, 0x1339b2eb, 0x3b52ec6f, 0x6dfc511f, 0x9b30952c,
0xcc814544, 0xaf5ebd09, 0xbee3d004, 0xde334afd, 0x660f2807, 0x192e4bb3,
0xc0cba857, 0x45c8740f, 0xd20b5f39, 0xb9d3fbdb, 0x5579c0bd, 0x1a60320a,
0xd6a100c6, 0x402c7279, 0x679f25fe, 0xfb1fa3cc, 0x8ea5e9f8, 0xdb3222f8,
0x3c7516df, 0xfd616b15, 0x2f501ec8, 0xad0552ab, 0x323db5fa, 0xfd238760,
0x53317b48, 0x3e00df82, 0x9e5c57bb, 0xca6f8ca0, 0x1a87562e, 0xdf1769db,
0xd542a8f6, 0x287effc3, 0xac6732c6, 0x8c4f5573, 0x695b27b0, 0xbbca58c8,
0xe1ffa35d, 0xb8f011a0, 0x10fa3d98, 0xfd2183b8, 0x4afcb56c, 0x2dd1d35b,
0x9a53e479, 0xb6f84565, 0xd28e49bc, 0x4bfb9790, 0xe1ddf2da, 0xa4cb7e33,
0x62fb1341, 0xcee4c6e8, 0xef20cada, 0x36774c01, 0xd07e9efe, 0x2bf11fb4,
0x95dbda4d, 0xae909198, 0xeaad8e71, 0x6b93d5a0, 0xd08ed1d0, 0xafc725e0,
0x8e3c5b2f, 0x8e7594b7, 0x8ff6e2fb, 0xf2122b64, 0x8888b812, 0x900df01c,
0x4fad5ea0, 0x688fc31c, 0xd1cff191, 0xb3a8c1ad, 0x2f2f2218, 0xbe0e1777,
0xea752dfe, 0x8b021fa1, 0xe5a0cc0f, 0xb56f74e8, 0x18acf3d6, 0xce89e299,
0xb4a84fe0, 0xfd13e0b7, 0x7cc43b81, 0xd2ada8d9, 0x165fa266, 0x80957705,
0x93cc7314, 0x211a1477, 0xe6ad2065, 0x77b5fa86, 0xc75442f5, 0xfb9d35cf,
0xebcdaf0c, 0x7b3e89a0, 0xd6411bd3, 0xae1e7e49, 0x00250e2d, 0x2071b35e,
0x226800bb, 0x57b8e0af, 0x2464369b, 0xf009b91e, 0x5563911d, 0x59dfa6aa,
0x78c14389, 0xd95a537f, 0x207d5ba2, 0x02e5b9c5, 0x83260376, 0x6295cfa9,
0x11c81968, 0x4e734a41, 0xb3472dca, 0x7b14a94a, 0x1b510052, 0x9a532915,
0xd60f573f, 0xbc9bc6e4, 0x2b60a476, 0x81e67400, 0x08ba6fb5, 0x571be91f,
0xf296ec6b, 0x2a0dd915, 0xb6636521, 0xe7b9f9b6, 0xff34052e, 0xc5855664,
0x53b02d5d, 0xa99f8fa1, 0x08ba4799, 0x6e85076a};
unsigned long ks1[] = {
0x4b7a70e9, 0xb5b32944, 0xdb75092e, 0xc4192623, 0xad6ea6b0, 0x49a7df7d,
0x9cee60b8, 0x8fedb266, 0xecaa8c71, 0x699a17ff, 0x5664526c, 0xc2b19ee1,
0x193602a5, 0x75094c29, 0xa0591340, 0xe4183a3e, 0x3f54989a, 0x5b429d65,
0x6b8fe4d6, 0x99f73fd6, 0xa1d29c07, 0xefe830f5, 0x4d2d38e6, 0xf0255dc1,
0x4cdd2086, 0x8470eb26, 0x6382e9c6, 0x021ecc5e, 0x09686b3f, 0x3ebaefc9,
0x3c971814, 0x6b6a70a1, 0x687f3584, 0x52a0e286, 0xb79c5305, 0xaa500737,
0x3e07841c, 0x7fdeae5c, 0x8e7d44ec, 0x5716f2b8, 0xb03ada37, 0xf0500c0d,
0xf01c1f04, 0x0200b3ff, 0xae0cf51a, 0x3cb574b2, 0x25837a58, 0xdc0921bd,
0xd19113f9, 0x7ca92ff6, 0x94324773, 0x22f54701, 0x3ae5e581, 0x37c2dadc,
0xc8b57634, 0x9af3dda7, 0xa9446146, 0x0fd0030e, 0xecc8c73e, 0xa4751e41,
0xe238cd99, 0x3bea0e2f, 0x3280bba1, 0x183eb331, 0x4e548b38, 0x4f6db908,
0x6f420d03, 0xf60a04bf, 0x2cb81290, 0x24977c79, 0x5679b072, 0xbcaf89af,
0xde9a771f, 0xd9930810, 0xb38bae12, 0xdccf3f2e, 0x5512721f, 0x2e6b7124,
0x501adde6, 0x9f84cd87, 0x7a584718, 0x7408da17, 0xbc9f9abc, 0xe94b7d8c,
0xec7aec3a, 0xdb851dfa, 0x63094366, 0xc464c3d2, 0xef1c1847, 0x3215d908,
0xdd433b37, 0x24c2ba16, 0x12a14d43, 0x2a65c451, 0x50940002, 0x133ae4dd,
0x71dff89e, 0x10314e55, 0x81ac77d6, 0x5f11199b, 0x043556f1, 0xd7a3c76b,
0x3c11183b, 0x5924a509, 0xf28fe6ed, 0x97f1fbfa, 0x9ebabf2c, 0x1e153c6e,
0x86e34570, 0xeae96fb1, 0x860e5e0a, 0x5a3e2ab3, 0x771fe71c, 0x4e3d06fa,
0x2965dcb9, 0x99e71d0f, 0x803e89d6, 0x5266c825, 0x2e4cc978, 0x9c10b36a,
0xc6150eba, 0x94e2ea78, 0xa5fc3c53, 0x1e0a2df4, 0xf2f74ea7, 0x361d2b3d,
0x1939260f, 0x19c27960, 0x5223a708, 0xf71312b6, 0xebadfe6e, 0xeac31f66,
0xe3bc4595, 0xa67bc883, 0xb17f37d1, 0x018cff28, 0xc332ddef, 0xbe6c5aa5,
0x65582185, 0x68ab9802, 0xeecea50f, 0xdb2f953b, 0x2aef7dad, 0x5b6e2f84,
0x1521b628, 0x29076170, 0xecdd4775, 0x619f1510, 0x13cca830, 0xeb61bd96,
0x0334fe1e, 0xaa0363cf, 0xb5735c90, 0x4c70a239, 0xd59e9e0b, 0xcbaade14,
0xeecc86bc, 0x60622ca7, 0x9cab5cab, 0xb2f3846e, 0x648b1eaf, 0x19bdf0ca,
0xa02369b9, 0x655abb50, 0x40685a32, 0x3c2ab4b3, 0x319ee9d5, 0xc021b8f7,
0x9b540b19, 0x875fa099, 0x95f7997e, 0x623d7da8, 0xf837889a, 0x97e32d77,
```

```
0x11ed935f, 0x16681281, 0x0e358829, 0xc7e61fd6, 0x96dedfa1, 0x7858ba99,
0x57f584a5, 0x1b227263, 0x9b83c3ff, 0x1ac24696, 0xcdb30aeb, 0x532e3054,
0x8fd948e4, 0x6dbc3128, 0x58ebf2ef, 0x34c6ffea, 0xfe28ed61, 0xee7c3c73,
0x5d4a14d9, 0xe864b7e3, 0x42105d14, 0x203e13e0, 0x45eee2b6, 0xa3aaabea,
0xdb6c4f15, 0xfacb4fd0, 0xc742f442, 0xef6abbb5, 0x654f3b1d, 0x41cd2105,
0xd81e799e, 0x86854dc7, 0xe44b476a, 0x3d816250, 0xcf62a1f2, 0x5b8d2646,
0xfc8883a0, 0xc1c7b6a3, 0x7f1524c3, 0x69cb7492, 0x47848a0b, 0x5692b285,
0x095bbf00, 0xad19489d, 0x1462b174, 0x23820e00, 0x58428d2a, 0x0c55f5ea,
0x1dadf43e, 0x233f7061, 0x3372f092, 0x8d937e41, 0xd65fecf1, 0x6c223bdb,
0x7cde3759, 0xcbee7460, 0x4085f2a7, 0xce77326e, 0xa6078084, 0x19f8509e,
0xe8efd855, 0x61d99735, 0xa969a7aa, 0xc50c06c2, 0x5a04abfc, 0x800bcadc,
0x9e447a2e, 0xc3453484, 0xfdd56705, 0x0e1e9ec9, 0xdb73dbd3, 0x105588cd,
0x675fda79, 0xe3674340, 0xc5c43465, 0x713e38d8, 0x3d28f89e, 0xf16dff20,
0x153e21e7, 0x8fb03d4a, 0xe6e39f2b, 0xdb83adf7};
unsigned long ks2[] = {
0xe93d5a68, 0x948140f7, 0xf64c261c, 0x94692934, 0x411520f7, 0x7602d4f7,
0xbcf46b2e, 0xd4a20068, 0xd4082471, 0x3320f46a, 0x43b7d4b7, 0x500061af,
0x1e39f62e, 0x97244546, 0x14214f74, 0xbf8b8840, 0x4d95fc1d, 0x96b591af,
0x70f4ddd3, 0x66a02f45, 0xbfbc09ec, 0x03bd9785, 0x7fac6dd0, 0x31cb8504,
0x96eb27b3, 0x55fd3941, 0xda2547e6, 0xabca0a9a, 0x28507825, 0x530429f4,
0x0a2c86da, 0xe9b66dfb, 0x68dc1462, 0xd7486900, 0x680ec0a4, 0x27a18dee,
0x4f3ffea2, 0xe887ad8c, 0xb58ce006, 0x7af4d6b6, 0xaace1e7c, 0xd3375fec,
0xce78a399, 0x406b2a42, 0x20fe9e35, 0xd9f385b9, 0xee39d7ab, 0x3b124e8b,
0x1dc9faf7, 0x4b6d1856, 0x26a36631, 0xeae397b2, 0x3a6efa74, 0xdd5b4332,
0x6841e7f7, 0xca7820fb, 0xfb0af54e, 0xd8feb397, 0x454056ac, 0xba489527,
0x55533a3a, 0x20838d87, 0xfe6ba9b7, 0xd096954b, 0x55a867bc, 0xa1159a58,
0xcca92963, 0x99e1db33, 0xa62a4a56, 0x3f3125f9, 0x5ef47e1c, 0x9029317c,
0xfdf8e802, 0x04272f70, 0x80bb155c, 0x05282ce3, 0x95c11548, 0xe4c66d22,
0x48c1133f, 0xc70f86dc, 0x07f9c9ee, 0x41041f0f, 0x404779a4, 0x5d886e17,
0x325f51eb, 0xd59bc0d1, 0xf2bcc18f, 0x41113564, 0x257b7834, 0x602a9c60,
0xdff8e8a3, 0x1f636c1b, 0x0e12b4c2, 0x02e1329e, 0xaf664fd1, 0xcad18115,
0x6b2395e0, 0x333e92e1, 0x3b240b62, 0xeebeb922, 0x85b2a20e, 0xe6ba0d99,
0xde720c8c, 0x2da2f728, 0xd0127845, 0x95b794fd, 0x647d0862, 0xe7ccf5f0,
0x5449a36f, 0x877d48fa, 0xc39dfd27, 0xf33e8d1e, 0x0a476341, 0x992eff74,
0x3a6f6eab, 0xf4f8fd37, 0xa812dc60, 0xa1ebddf8, 0x991be14c, 0xdb6e6b0d,
0xc67b5510, 0x6d672c37, 0x2765d43b, 0xdcd0e804, 0xf1290dc7, 0xcc00ffa3,
0xb5390f92, 0x690fed0b, 0x667b9ffb, 0xcedb7d9c, 0xa091cf0b, 0xd9155ea3,
0xbb132f88, 0x515bad24, 0x7b9479bf, 0x763bd6eb, 0x37392eb3, 0xcc115979,
0x8026e297, 0xf42e312d, 0x6842ada7, 0xc66a2b3b, 0x12754ccc, 0x782ef11c,
0x6a124237, 0xb79251e7, 0x06a1bbe6, 0x4bfb6350, 0x1a6b1018, 0x11caedfa,
0x3d25bdd8, 0xe2e1c3c9, 0x44421659, 0x0a121386, 0xd90cec6e, 0xd5abea2a,
0x64af674e, 0xda86a85f, 0xbebfe988, 0x64e4c3fe, 0x9dbc8057, 0xf0f7c086,
0x60787bf8, 0x6003604d, 0xd1fd8346, 0xf6381fb0, 0x7745ae04, 0xd736fccc,
0x83426b33, 0xf01eab71, 0xb0804187, 0x3c005e5f, 0x77a057be, 0xbde8ae24,
0x55464299, 0xbf582e61, 0x4e58f48f, 0xf2ddfda2, 0xf474ef38, 0x8789bdc2,
0x5366f9c3, 0xc8b38e74, 0xb475f255, 0x46fcd9b9, 0x7aeb2661, 0x8b1ddf84,
0x846a0e79, 0x915f95e2, 0x466e598e, 0x20b45770, 0x8cd55591, 0xc902de4c,
0xb90bace1, 0xbb8205d0, 0x11a86248, 0x7574a99e, 0xb77f19b6, 0xe0a9dc09,
0x662d09a1, 0xc4324633, 0xe85a1f02, 0x09f0be8c, 0x4a99a025, 0x1d6efe10,
0x1ab93d1d, 0x0ba5a4df, 0xa186f20f, 0x2868f169, 0xdcb7da83, 0x573906fe,
0xa1e2ce9b, 0x4fcd7f52, 0x50115e01, 0xa70683fa, 0xa002b5c4, 0x0de6d027,
0x9af88c27, 0x773f8641, 0xc3604c06, 0x61a806b5, 0xf0177a28, 0xc0f586e0,
0x006058aa, 0x30dc7d62, 0x11e69ed7, 0x2338ea63, 0x53c2dd94, 0xc2c21634,
0xbbcbee56, 0x90bcb6de, 0xebfc7da1, 0xce591d76, 0x6f05e409, 0x4b7c0188,
```

```
0x39720a3d, 0x7c927c24, 0x86e3725f, 0x724d9db9, 0x1ac15bb4, 0xd39eb8fc,
0xed545578, 0x08fca5b5, 0xd83d7cd3, 0x4dad0fc4, 0x1e50ef5e, 0xb161e6f8,
0xa28514d9, 0x6c51133c, 0x6fd5c7e7, 0x56e14ec4, 0x362abfce, 0xddc6c837,
0xd79a3234, 0x92638212, 0x670efa8e, 0x406000e0};
unsigned long ks3[] = {
0x3a39ce37, 0xd3faf5cf, 0xabc27737, 0x5ac52d1b, 0x5cb0679e, 0x4fa33742,
0xd3822740, 0x99bc9bbe, 0xd5118e9d, 0xbf0f7315, 0xd62d1c7e, 0xc700c47b,
0xb78c1b6b, 0x21a19045, 0xb26eb1be, 0x6a366eb4, 0x5748ab2f, 0xbc946e79,
0xc6a376d2, 0x6549c2c8, 0x530ff8ee, 0x468dde7d, 0xd5730a1d, 0x4cd04dc6,
0x2939bbdb, 0xa9ba4650, 0xac9526e8, 0xbe5ee304, 0xa1fad5f0, 0x6a2d519a,
0x63ef8ce2, 0x9a86ee22, 0xc089c2b8, 0x43242ef6, 0xa51e03aa, 0x9cf2d0a4,
0x83c061ba, 0x9be96a4d, 0x8fe51550, 0xba645bd6, 0x2826a2f9, 0xa73a3ae1,
0x4ba99586, 0xef5562e9, 0xc72fefd3, 0xf752f7da, 0x3f046f69, 0x77fa0a59,
0x80e4a915, 0x87b08601, 0x9b09e6ad, 0x3b3ee593, 0xe990fd5a, 0x9e34d797,
0x2cf0b7d9, 0x022b8b51, 0x96d5ac3a, 0x017da67d, 0xd1cf3ed6, 0x7c7d2d28,
0x1f9f25cf, 0xadf2b89b, 0x5ad6b472, 0x5a88f54c, 0xe029ac71, 0xe019a5e6,
0x47b0acfd, 0xed93fa9b, 0xe8d3c48d, 0x283b57cc, 0xf8d56629, 0x79132e28,
0x785f0191, 0xed756055, 0xf7960e44, 0xe3d35e8c, 0x15056dd4, 0x88f46dba,
0x03a16125, 0x0564f0bd, 0xc3eb9e15, 0x3c9057a2, 0x97271aec, 0xa93a072a,
0x1b3f6d9b, 0x1e6321f5, 0xf59c66fb, 0x26dcf319, 0x7533d928, 0xb155fdf5,
0x03563482, 0x8aba3cbb, 0x28517711, 0xc20ad9f8, 0xabcc5167, 0xccad925f,
0x4de81751, 0x3830dc8e, 0x379d5862, 0x9320f991, 0xea7a90c2, 0xfb3e7bce,
0x5121ce64, 0x774fbe32, 0xa8b6e37e, 0xc3293d46, 0x48de5369, 0x6413e680,
0xa2ae0810, 0xdd6db224, 0x69852dfd, 0x09072166, 0xb39a460a, 0x6445c0dd,
0x586cdecf, 0x1c20c8ae, 0x5bbef7dd, 0x1b588d40, 0xccd2017f, 0x6bb4e3bb,
0xdda26a7e, 0x3a59ff45, 0x3e350a44, 0xbcb4cdd5, 0x72eacea8, 0xfa6484bb,
0x8d6612ae, 0xbf3c6f47, 0xd29be463, 0x542f5d9e, 0xaec2771b, 0xf64e6370,
0x740e0d8d, 0xe75b1357, 0xf8721671, 0xaf537d5d, 0x4040cb08, 0x4eb4e2cc,
0x34d2466a, 0x0115af84, 0xe1b00428, 0x95983a1d, 0x06b89fb4, 0xce6ea048,
0x6f3f3b82, 0x3520ab82, 0x011a1d4b, 0x277227f8, 0x611560b1, 0xe7933fdc,
0xbb3a792b, 0x344525bd, 0xa08839e1, 0x51ce794b, 0x2f32c9b7, 0xa01fbac9,
0xe01cc87e, 0xbcc7d1f6, 0xcf0111c3, 0xa1e8aac7, 0x1a908749, 0xd44fbd9a,
0xd0dadecb, 0xd50ada38, 0x0339c32a, 0xc6913667, 0x8df9317c, 0xe0b12b4f,
0xf79e59b7, 0x43f5bb3a, 0xf2d519ff, 0x27d9459c, 0xbf97222c, 0x15e6fc2a,
0x0f91fc71, 0x9b941525, 0xfae59361, 0xceb69ceb, 0xc2a86459, 0x12baa8d1,
0xb6c1075e, 0xe3056a0c, 0x10d25065, 0xcb03a442, 0xe0ec6e0e, 0x1698db3b,
0x4c98a0be, 0x3278e964, 0x9f1f9532, 0xe0d392df, 0xd3a0342b, 0x8971f21e,
0x1b0a7441, 0x4ba3348c, 0xc5be7120, 0xc37632d8, 0xdf359f8d, 0x9b992f2e,
0xe60b6f47, 0x0fe3f11d, 0xe54cda54, 0x1edad891, 0xce6279cf, 0xcd3e7e6f,
0x1618b166, 0xfd2c1d05, 0x848fd2c5, 0xf6fb2299, 0xf523f357, 0xa6327623,
0x93a83531, 0x56cccd02, 0xacf08162, 0x5a75ebb5, 0x6e163697, 0x88d273cc,
0xde966292, 0x81b949d0, 0x4c50901b, 0x71c65614, 0xe6c6c7bd, 0x327a140a,
0x45e1d006, 0xc3f27b9a, 0xc9aa53fd, 0x62a80f00, 0xbb25bfe2, 0x35bdd2f6,
0x71126905, 0xb2040222, 0xb6cbcf7c, 0xcd769c2b, 0x53113ec0, 0x1640e3d3,
0x38abbd60, 0x2547adf0, 0xba38209c, 0xf746ce76, 0x77afa1c5, 0x20756060,
0x85cbfe4e, 0x8ae88dd8, 0x7aaaf9b0, 0x4cf9aa7e, 0x1948c25c, 0x02fb8a8c,
0x01c36ae4, 0xd6ebe1f9, 0x90d4f869, 0xa65cdea0, 0x3f09252d, 0xc208e69f,
0xb74e6132, 0xce77e25b, 0x578fdfe3, 0x3ac372e6};

/* Initialize s-boxes without file read. */
        for(i=0;i<256;i++){
                c->S[0][i] = ks0[i];
                c->S[1][i] = ks1[i];
                c->S[2][i] = ks2[i];
```

```
                c->S[3][i] = ks3[i];
        }

        j = 0;
        for (i = 0; i < N + 2; ++i) {
                data = 0x00000000;
                for (k = 0; k < 4; ++k) {
                        data = (data << 8) | key[j];
                        j = j + 1;
                        if (j >= keybytes) {
                                j = 0;
                        }
                }
        c->P[i] = c->P[i] ^ data;
        }

     datal = 0x00000000;
        datar = 0x00000000;

        for (i = 0; i < N + 2; i += 2) {
                Blowfish_encipher(c,&datal, &datar);

                c->P[i] = datal;
                c->P[i + 1] = datar;
        }

        for (i = 0; i < 4; ++i) {
                for (j = 0; j < 256; j += 2) {

                        Blowfish_encipher(c,&datal, &datar);

                        c->S[i][j] = datal;
                        c->S[i][j + 1] = datar;
                }
        }
}

void blf_key(blf_ctx *c, char *k, int len){
        InitializeBlowfish(c,k,len);
}

void blf_enc(blf_ctx *c, unsigned long *data, int blocks){
        unsigned long *d;
        int i;

        d = data;
        for(i=0;i<blocks;i++){
                Blowfish_encipher(c,d,d+1);
                d += 2;
        }
}

void blf_dec(blf_ctx *c, unsigned long *data, int blocks){
        unsigned long *d;
        int i;
```

```
        d = data;
        for(i=0;i<blocks;i++){
                Blowfish_decipher(c,d,d+1);
                d += 2;
        }
}

void main(void){
        blf_ctx c;
        char key[]="AAAAA";
        unsigned long data[10];
        int i;

        for(i=0;i<10;i++) data[i] = i;

        blf_key(&c,key,5);
        blf_enc(&c,data,5);
        blf_dec(&c,data,1);
        blf_dec(&c,data+2,4);
        for(i=0;i<10;i+=2) printf("Block %01d decrypts to: %08lx %08lx.\n",
                                  i/2,data[i],data[i+1]);
}
```

3-Way

```
#define   STRT_E   0x0b0b /* round constant of first encryption round */
#define   STRT_D   0xb1b1 /* round constant of first decryption round */
#define     NMBR       11 /* number of rounds is 11                    */

typedef   unsigned long int  word32 ;
                /* the program only works correctly if long = 32bits */
typedef unsigned long u4;
typedef unsigned char u1;

typedef struct {
        u4 k[3],ki[3], ercon[NMBR+1],drcon[NMBR+1];
} twy_ctx;

/* Note:  encrypt and decrypt expect full blocks--padding blocks is
          caller's responsibility.  All bulk encryption is done in
          ECB mode by these calls.  Other modes may be added easily
          enough.                                                   */

/* destroy:  Context. */
/* Scrub context of all sensitive data. */
void twy_destroy(twy_ctx *);

/* encrypt:  Context, ptr to data block, # of blocks. */
void twy_enc(twy_ctx *, u4 *, int);

/* decrypt:  Context, ptr to data block, # of blocks. */
void twy_dec(twy_ctx *, u4 *, int);
```

```
/* key:  Context, ptr to key data. */
void twy_key(twy_ctx *, u4 *);

/* ACCODE--------------------------------------------------------------- */
/* End of AC code prototypes and structures.                            */
/* -------------------------------------------------------------------- */

void mu(word32 *a)       /* inverts the order of the bits of a */
{
int i ;
word32 b[3] ;

b[0] = b[1] = b[2] = 0 ;
for( i=0 ; i<32 ; i++ )
   {
   b[0] <<= 1 ; b[1] <<= 1 ; b[2] <<= 1 ;
   if(a[0]&1) b[2] |= 1 ;
   if(a[1]&1) b[1] |= 1 ;
   if(a[2]&1) b[0] |= 1 ;
   a[0] >>= 1 ; a[1] >>= 1 ; a[2] >>= 1 ;
   }

a[0] = b[0] ;      a[1] = b[1] ;      a[2] = b[2] ;
}

void gamma(word32 *a)   /* the nonlinear step */
{
word32 b[3] ;

b[0] = a[0] ^ (a[1]|(~a[2])) ;
b[1] = a[1] ^ (a[2]|(~a[0])) ;
b[2] = a[2] ^ (a[0]|(~a[1])) ;

a[0] = b[0] ;      a[1] = b[1] ;      a[2] = b[2] ;
}

void theta(word32 *a)    /* the linear step */
{
word32 b[3];

b[0] = a[0] ^  (a[0]>>16) ^ (a[1]<<16) ^     (a[1]>>16) ^ (a[2]<<16) ^
               (a[1]>>24) ^ (a[2]<<8)  ^     (a[2]>>8)  ^ (a[0]<<24) ^
               (a[2]>>16) ^ (a[0]<<16) ^     (a[2]>>24) ^ (a[0]<<8)  ;
b[1] = a[1] ^  (a[1]>>16) ^ (a[2]<<16) ^     (a[2]>>16) ^ (a[0]<<16) ^
               (a[2]>>24) ^ (a[0]<<8)  ^     (a[0]>>8)  ^ (a[1]<<24) ^
               (a[0]>>16) ^ (a[1]<<16) ^     (a[0]>>24) ^ (a[1]<<8)  ;
b[2] = a[2] ^  (a[2]>>16) ^ (a[0]<<16) ^     (a[0]>>16) ^ (a[1]<<16) ^
               (a[0]>>24) ^ (a[1]<<8)  ^     (a[1]>>8)  ^ (a[2]<<24) ^
               (a[1]>>16) ^ (a[2]<<16) ^     (a[1]>>24) ^ (a[2]<<8)  ;

a[0] = b[0] ;      a[1] = b[1] ;      a[2] = b[2] ;
}

void pi_1(word32 *a)
```

```
{
a[0] = (a[0]>>10) ^ (a[0]<<22);
a[2] = (a[2]<<1)  ^ (a[2]>>31);
}

void pi_2(word32 *a)
{
a[0] = (a[0]<<1)  ^ (a[0]>>31);
a[2] = (a[2]>>10) ^ (a[2]<<22);
}

void rho(word32 *a)    /* the round function       */
{
theta(a) ;
pi_1(a) ;
gamma(a) ;
pi_2(a) ;
}

void rndcon_gen(word32 strt,word32 *rtab)
{                              /* generates the round constants */
int i ;

for(i=0 ; i<=NMBR ; i++ )
   {
   rtab[i] = strt ;
   strt <<= 1 ;
   if( strt&0x10000 ) strt ^= 0x11011 ;
   }
}

/* Modified slightly to fit the caller's needs. */
void encrypt(twy_ctx *c, word32 *a)
{
char i ;
for( i=0 ; i<NMBR ; i++ )
   {
   a[0] ^= c->k[0] ^ (c->ercon[i]<<16) ;
   a[1] ^= c->k[1] ;
   a[2] ^= c->k[2] ^ c->ercon[i] ;
   rho(a) ;
   }
a[0] ^= c->k[0] ^ (c->ercon[NMBR]<<16) ;
a[1] ^= c->k[1] ;
a[2] ^= c->k[2] ^ c->ercon[NMBR] ;
theta(a) ;
}

/* Modified slightly to meet caller's needs. */
void decrypt(twy_ctx *c, word32 *a)
{
char i ;

mu(a) ;
```

```
for( i=0 ; i<NMBR ; i++ )
   {
   a[0] ^= c->ki[0] ^ (c->drcon[i]<<16) ;
   a[1] ^= c->ki[1] ;
   a[2] ^= c->ki[2] ^ c->drcon[i] ;
   rho(a) ;
   }
a[0] ^= c->ki[0] ^ (c->drcon[NMBR]<<16) ;
a[1] ^= c->ki[1] ;
a[2] ^= c->ki[2] ^ c->drcon[NMBR] ;
theta(a) ;
mu(a) ;
}

void twy_key(twy_ctx *c, u4 *key){
        c->ki[0] = c->k[0] = key[0];
        c->ki[1] = c->k[1] = key[1];
        c->ki[2] = c->k[2] = key[2];
        theta(c->ki);
        mu(c->ki);
        rndcon_gen(STRT_E,c->ercon);
        rndcon_gen(STRT_D,c->drcon);

}

/* Encrypt in ECB mode. */
void twy_enc(twy_ctx *c, u4 *data, int blkcnt){
        u4 *d;
        int i;

        d = data;
        for(i=0;i<blkcnt;i++) {
                encrypt(c,d);
                d +=3;
        }
}

/* Decrypt in ECB mode. */
void twy_dec(twy_ctx *c, u4 *data, int blkcnt){
        u4 *d;
        int i;

        d = data;
        for(i=0;i<blkcnt;i++){
                decrypt(c,d);
                d+=3;
        }
}

/* Scrub sensitive values from memory before deallocating. */
void twy_destroy(twy_ctx *c){
        int i;

        for(i=0;i<3;i++) c->k[i] = c->ki[i] = 0;
```

```
}

void printvec(char *chrs, word32 *d){
        printf("%20s : %08lx %08lx %08lx \n",chrs,d[2],d[1],d[0]);
}

main()
{
twy_ctx gc;
word32 a[9],k[3];
int i;

/* Test vector 1. */

k[0]=k[1]=k[2]=0;
a[0]=a[1]=a[2]=1;
twy_key(&gc,k);

printf("**********\n");
printvec("KEY = ",k);
printvec("PLAIN = ",a);
encrypt(&gc,a);
printvec("CIPHER = ",a);

/* Test vector 2. */

k[0]=6;k[1]=5;k[2]=4;
a[0]=3;a[1]=2;a[2]=1;
twy_key(&gc,k);

printf("**********\n");
printvec("KEY = ",k);
printvec("PLAIN = ",a);
encrypt(&gc,a);
printvec("CIPHER = ",a);

/* Test vector 3. */

k[2]=0xbcdef012;k[1]=0x456789ab;k[0]=0xdef01234;
a[2]=0x01234567;a[1]=0x9abcdef0;a[0]=0x23456789;
twy_key(&gc,k);

printf("**********\n");
printvec("KEY = ",k);
printvec("PLAIN = ",a);
encrypt(&gc,a);
printvec("CIPHER = ",a);

/* Test vector 4. */

k[2]=0xcab920cd;k[1]=0xd6144138;k[0]=0xd2f05b5e;
a[2]=0xad21ecf7;a[1]=0x83ae9dc4;a[0]=0x4059c76e;
twy_key(&gc,k);

printf("**********\n");
```

```
printvec("KEY = ",k);
printvec("PLAIN = ",a);
encrypt(&gc,a);
printvec("CIPHER = ",a);

/*  TEST VALUES

key        : 00000000 00000000 00000000
plaintext  : 00000001 00000001 00000001
ciphertext : ad21ecf7 83ae9dc4 4059c76e

key        : 00000004 00000005 00000006
plaintext  : 00000001 00000002 00000003
ciphertext : cab920cd d6144138 d2f05b5e

key        : bcdef012 456789ab def01234
plaintext  : 01234567 9abcdef0 23456789
ciphertext : 7cdb76b2 9cdddb6d 0aa55dbb

key        : cab920cd d6144138 d2f05b5e
plaintext  : ad21ecf7 83ae9dc4 4059c76e
ciphertext : 15b155ed 6b13f17c 478ea871

*/

/* Enc/dec test: */
for(i=0;i<9;i++) a[i]=i;
twy_enc(&gc,a,3);
for(i=0;i<9;i+=3) printf("Block %01d encrypts to %08lx %08lx %08lx\n",
                         i/3,a[i],a[i+1],a[i+2]);

twy_dec(&gc,a,2);
twy_dec(&gc,a+6,1);

 for(i=0;i<9;i+=3) printf("Block %01d decrypts to %08lx %08lx %08lx\n",
                         i/3,a[i],a[i+1],a[i+2]);
}
```

RC5

```
#include <stdio.h>

/* An RC5 context needs to know how many rounds it has, and its subkeys. */
typedef struct {
        u4 *xk;
        int nr;
} rc5_ctx;

/* Where possible, these should be replaced with actual rotate instructions.
   For Turbo C++, this is done with _lrotl and _lrotr. */

#define ROTL32(X,C) (((X)<<(C))|((X)>>(32-(C))))
#define ROTR32(X,C) (((X)>>(C))|((X)<<(32-(C))))
```

```
/* Function prototypes for dealing with RC5 basic operations. */
void rc5_init(rc5_ctx *, int);
void rc5_destroy(rc5_ctx *);
void rc5_key(rc5_ctx *, u1 *, int);
void rc5_encrypt(rc5_ctx *, u4 *, int);
void rc5_decrypt(rc5_ctx *, u4 *, int);

/* Function implementations for RC5. */

/* Scrub out all sensitive values. */
void rc5_destroy(rc5_ctx *c){
        int i;
     for(i=0;i<(c->nr)*2+2;i++) c->xk[i]=0;
     free(c->xk);
}

/* Allocate memory for rc5 context's xk and such. */
void rc5_init(rc5_ctx *c, int rounds){
     c->nr = rounds;
     c->xk = (u4 *) malloc(4*(rounds*2+2));
}

void rc5_encrypt(rc5_ctx *c, u4 *data, int blocks){
        u4 *d,*sk;
        int h,i,rc;

     d = data;
        sk = (c->xk)+2;
        for(h=0;h<blocks;h++){
                d[0] += c->xk[0];
                d[1] += c->xk[1];
                for(i=0;i<c->nr*2;i+=2){
                        d[0] ^= d[1];
                        rc = d[1] & 31;
                        d[0] = ROTL32(d[0],rc);
                        d[0] += sk[i];
               d[1] ^= d[0];
                        rc = d[0] & 31;
                        d[1] = ROTL32(d[1],rc);
                        d[1] += sk[i+1];
/*printf("Round %03d : %08lx %08lx  sk= %08lx %08lx\n",i/2,
                                d[0],d[1],sk[i],sk[i+1]);*/
                }
          d+=2;
        }
}

void rc5_decrypt(rc5_ctx *c, u4 *data, int blocks){
     u4 *d,*sk;
        int h,i,rc;

     d = data;
        sk = (c->xk)+2;
     for(h=0;h<blocks;h++){
                for(i=c->nr*2-2;i>=0;i-=2){
```

```
/*printf("Round %03d: %08lx %08lx  sk: %08lx %08lx\n",
        i/2,d[0],d[1],sk[i],sk[i+1]); */
                        d[1] -= sk[i+1];
                        rc = d[0] & 31;
                        d[1] = ROTR32(d[1],rc);
                        d[1] ^= d[0];

                        d[0] -= sk[i];
                        rc = d[1] & 31;
                        d[0] = ROTR32(d[0],rc);
                d[0] ^= d[1];
                 }
                 d[0] -= c->xk[0];
                 d[1] -= c->xk[1];
        d+=2;
     }
}

void rc5_key(rc5_ctx *c, u1 *key, int keylen){
     u4 *pk,A,B; /* padded key */
     int xk_len, pk_len, i, num_steps,rc;
     u1 *cp;

     xk_len = c->nr*2 + 2;
     pk_len = keylen/4;
     if((keylen%4)!=0) pk_len += 1;

     pk = (u4 *) malloc(pk_len * 4);
     if(pk==NULL) {
          printf("An error occurred!\n");
          exit(-1);
     }

     /* Initialize pk -- this should work on Intel machines, anyway.... */
     for(i=0;i<pk_len;i++) pk[i]=0;
     cp = (u1 *)pk;
     for(i=0;i<keylen;i++) cp[i]=key[i];

     /* Initialize xk. */
     c->xk[0] = 0xb7e15163; /* P32 */
     for(i=1;i<xk_len;i++) c->xk[i] = c->xk[i-1] + 0x9e3779b9; /* Q32 */

     /* TESTING */
     A = B = 0;
     for(i=0;i<xk_len;i++) {
          A = A + c->xk[i];
          B = B ^ c->xk[i];
     }

     /* Expand key into xk. */
     if(pk_len>xk_len) num_steps = 3*pk_len;else num_steps = 3*xk_len;

     A = B = 0;
     for(i=0;i<num_steps;i++){
          A = c->xk[i%xk_len] = ROTL32(c->xk[i%xk_len] + A + B,3);
          rc = (A+B) & 31;
```

```
            B = pk[i%pk_len] = ROTL32(pk[i%pk_len] + A + B,rc);

        }

        /* Clobber sensitive data before deallocating memory. */
        for(i=0;i<pk_len;i++) pk[i] =0;

        free(pk);
}

void main(void){
        rc5_ctx c;
        u4 data[8];
        char key[] = "ABCDE";
        int i;

        printf("-------------------------------------------------\n");

           for(i=0;i<8;i++) data[i] = i;
        rc5_init(&c,10); /* 10 rounds */
        rc5_key(&c,key,5);

           rc5_encrypt(&c,data,4);
           printf("Encryptions:\n");
           for(i=0;i<8;i+=2) printf("Block %01d = %08lx %08lx\n",
                                    i/2,data[i],data[i+1]);
           rc5_decrypt(&c,data,2);
        rc5_decrypt(&c,data+4,2);
           printf("Decryptions:\n");
           for(i=0;i<8;i+=2) printf("Block %01d = %08lx %08lx\n",
                                    i/2,data[i],data[i+1]);

}
```

A5

```
typedef struct {
        unsigned long r1,r2,r3;
} a5_ctx;

static int threshold(r1, r2, r3)
unsigned int r1;
unsigned int r2;
unsigned int r3;
{
int total;

  total = (((r1 >>  9) & 0x1) == 1) +
          (((r2 >> 11) & 0x1) == 1) +
          (((r3 >> 11) & 0x1) == 1);

  if (total > 1)
    return (0);
```

```
  else
    return (1);
}

unsigned long clock_r1(ctl, r1)
int ctl;
unsigned long r1;
{
unsigned long feedback;

  ctl ^= ((r1 >> 9) & 0x1);
  if (ctl)
  {
    feedback = (r1 >> 18) ^ (r1 >> 17) ^ (r1 >> 16) ^ (r1 >> 13);
    r1 = (r1 << 1) & 0x7ffff;
    if (feedback & 0x01)
      r1 ^= 0x01;
  }
  return (r1);
}

unsigned long clock_r2(ctl, r2)
int ctl;
unsigned long r2;
{
unsigned long feedback;

  ctl ^= ((r2 >> 11) & 0x1);
  if (ctl)
  {
    feedback = (r2 >> 21) ^ (r2 >> 20) ^ (r2 >> 16) ^ (r2 >> 12);
    r2 = (r2 << 1) & 0x3fffff;
    if (feedback & 0x01)
      r2 ^= 0x01;
  }
  return (r2);
}

unsigned long clock_r3(ctl, r3)
int ctl;
unsigned long r3;
{
unsigned long feedback;

  ctl ^= ((r3 >> 11) & 0x1);
  if (ctl)
  {
    feedback = (r3 >> 22) ^ (r3 >> 21) ^ (r3 >> 18) ^ (r3 >> 17);
    r3 = (r3 << 1) & 0x7fffff;
    if (feedback & 0x01)
      r3 ^= 0x01;
  }
  return (r3);
}
```

```
int keystream(key, frame, alice, bob)
unsigned char *key;   /* 64 bit session key              */
unsigned long frame;  /* 22 bit frame sequence number    */
unsigned char *alice; /* 114 bit Alice to Bob key stream */
unsigned char *bob;   /* 114 bit Bob to Alice key stream */
{
unsigned long r1;   /* 19 bit shift register */
unsigned long r2;   /* 22 bit shift register */
unsigned long r3;   /* 23 bit shift register */
int i;              /* counter for loops     */
int clock_ctl;      /* xored with clock enable on each shift register */
unsigned char *ptr; /* current position in keystream */
unsigned char byte; /* byte of keystream being assembled */
unsigned int bits;  /* number of bits of keystream in byte */
unsigned int bit;   /* bit output from keystream generator */

  /* Initialise shift registers from session key */

  r1 = (key[0] | (key[1] << 8) | (key[2] << 16) ) & 0x7ffff;
  r2 = ((key[2] >> 3) | (key[3] << 5) | (key[4] << 13) | (key[5] << 21)) &
0x3fffff;
  r3 = ((key[5] >> 1) | (key[6] << 7) | (key[7] << 15) ) & 0x7fffff;

  /* Merge frame sequence number into shift register state, by xor'ing it
   * into the feedback path
   */

  for (i=0;i<22;i++)
  {
    clock_ctl = threshold(r1, r2, r2);
    r1 = clock_r1(clock_ctl, r1);
    r2 = clock_r2(clock_ctl, r2);
    r3 = clock_r3(clock_ctl, r3);
    if (frame & 1)
    {
      r1 ^= 1;
      r2 ^= 1;
      r3 ^= 1;
    }
    frame = frame >> 1;
  }

  /* Run shift registers for 100 clock ticks to allow frame number to
   * be diffused into all the bits of the shift registers
   */

  for (i=0;i<100;i++)
  {
    clock_ctl = threshold(r1, r2, r2);
    r1 = clock_r1(clock_ctl, r1);
    r2 = clock_r2(clock_ctl, r2);
    r3 = clock_r3(clock_ctl, r3);
  }

  /* Produce 114 bits of Alice->Bob key stream */
```

```
ptr = alice;
bits = 0;
byte = 0;
for (i=0;i<114;i++)
{
  clock_ctl = threshold(r1, r2, r2);
  r1 = clock_r1(clock_ctl, r1);
  r2 = clock_r2(clock_ctl, r2);
  r3 = clock_r3(clock_ctl, r3);

  bit = ((r1 >> 18) ^ (r2 >> 21) ^ (r3 >> 22)) & 0x01;
  byte = (byte << 1) | bit;
  bits++;
  if (bits == 8)
  {
    *ptr = byte;
    ptr++;
    bits = 0;
    byte = 0;
  }
}
if (bits)
  *ptr = byte;

/* Run shift registers for another 100 bits to hide relationship between
 * Alice->Bob key stream and Bob->Alice key stream.
 */

for (i=0;i<100;i++)
{
  clock_ctl = threshold(r1, r2, r2);
  r1 = clock_r1(clock_ctl, r1);
  r2 = clock_r2(clock_ctl, r2);
  r3 = clock_r3(clock_ctl, r3);
}

/* Produce 114 bits of Bob->Alice key stream */

ptr = bob;
bits = 0;
byte = 0;
for (i=0;i<114;i++)
{
  clock_ctl = threshold(r1, r2, r2);
  r1 = clock_r1(clock_ctl, r1);
  r2 = clock_r2(clock_ctl, r2);
  r3 = clock_r3(clock_ctl, r3);

  bit = ((r1 >> 18) ^ (r2 >> 21) ^ (r3 >> 22)) & 0x01;
  byte = (byte << 1) | bit;
  bits++;
  if (bits == 8)
  {
    *ptr = byte;
```

```
      ptr++;
      bits = 0;
      byte = 0;
    }
  }
  if (bits)
    *ptr = byte;

  return (0);

}

void a5_key(a5_ctx *c, char *k){
        c->r1 = k[0]<<11|k[1]<<3 | k[2]>>5          ; /* 19 */
        c->r2 = k[2]<<17|k[3]<<9 | k[4]<<1 | k[5]>>7; /* 22 */
        c->r3 = k[5]<<15|k[6]<<8 | k[7]             ; /* 23 */
}

/* Step one bit in A5, return 0 or 1 as output bit. */
int a5_step(a5_ctx *c){
        int control;
        control = threshold(c->r1,c->r2,c->r3);
        c->r1 = clock_r1(control,c->r1);
        c->r2 = clock_r2(control,c->r2);
        c->r3 = clock_r3(control,c->r3);
        return( (c->r1^c->r2^c->r3)&1);
}

/* Encrypts a buffer of len bytes. */
void a5_encrypt(a5_ctx *c, char *data, int len){
        int i,j;
        char t;

        for(i=0;i<len;i++){
                for(j=0;j<8;j++) t = t<<1 | a5_step(c);
                data[i]^=t;
        }
}

void a5_decrypt(a5_ctx *c, char *data, int len){
        a5_encrypt(c,data,len);
}

void main(void){
        a5_ctx c;
        char data[100];
        char key[] = {1,2,3,4,5,6,7,8};
        int i,flag;

        for(i=0;i<100;i++) data[i] = i;

        a5_key(&c,key);
        a5_encrypt(&c,data,100);

        a5_key(&c,key);
```

```
        a5_decrypt(&c,data,1);
        a5_decrypt(&c,data+1,99);

        flag = 0;
        for(i=0;i<100;i++) if(data[i]!=i)flag = 1;
        if(flag)printf("Decrypt failed\n"); else printf("Decrypt succeeded\n");
}
```

SEAL

```
#undef SEAL_DEBUG

#define ALG_OK 0
#define ALG_NOTOK 1
#define WORDS_PER_SEAL_CALL 1024

typedef struct {
     unsigned long t[520]; /* 512 rounded up to a multiple of 5 + 5*/
     unsigned long s[265]; /* 256 rounded up to a multiple of 5 + 5*/
     unsigned long r[20];  /* 16 rounded up to multiple of 5 */
        unsigned long counter; /* 32-bit synch value. */
        unsigned long ks_buf[WORDS_PER_SEAL_CALL];
        int ks_pos;
} seal_ctx;

#define ROT2(x) (((x) >> 2) | ((x) << 30))
#define ROT9(x) (((x) >> 9) | ((x) << 23))
#define ROT8(x) (((x) >> 8) | ((x) << 24))
#define ROT16(x) (((x) >> 16) | ((x) << 16))
#define ROT24(x) (((x) >> 24) | ((x) << 8))
#define ROT27(x) (((x) >> 27) | ((x) << 5))

#define WORD(cp)  ((cp[0] << 24)|(cp[1] << 16)|(cp[2] << 8)|(cp[3]))

#define F1(x, y, z) (((x) & (y)) | ((~(x)) & (z)))
#define F2(x, y, z) ((x)^(y)^(z))
#define F3(x, y, z) (((x) & (y)) | ((x) & (z)) | ((y) & (z)))
#define F4(x, y, z) ((x)^(y)^(z))

int g(in, i, h)
unsigned char *in;
int i;
unsigned long *h;
{
unsigned long h0;
unsigned long h1;
unsigned long h2;
unsigned long h3;
unsigned long h4;
unsigned long a;
unsigned long b;
unsigned long c;
unsigned long d;
unsigned long e;
```

```
unsigned char *kp;
unsigned long w[80];
unsigned long temp;

     kp = in;
     h0 = WORD(kp); kp += 4;
     h1 = WORD(kp); kp += 4;
     h2 = WORD(kp); kp += 4;
     h3 = WORD(kp); kp += 4;
     h4 = WORD(kp); kp += 4;

     w[0] = i;
     for (i=1;i<16;i++)
          w[i] = 0;
     for (i=16;i<80;i++)
          w[i] = w[i-3]^w[i-8]^w[i-14]^w[i-16];

     a = h0;
     b = h1;
     c = h2;
     d = h3;
     e = h4;

     for (i=0;i<20;i++)
     {
          temp = ROT27(a) + F1(b, c, d) + e + w[i] + 0x5a827999;
          e = d;
          d = c;
          c = ROT2(b);
          b = a;
          a = temp;
     }
     for (i=20;i<40;i++)
     {
          temp = ROT27(a) + F2(b, c, d) + e + w[i] + 0x6ed9eba1;
          e = d;
          d = c;
          c = ROT2(b);
          b = a;
          a = temp;
     }
     for (i=40;i<60;i++)
     {
          temp = ROT27(a) + F3(b, c, d) + e + w[i] + 0x8f1bbcdc;
          e = d;
          d = c;
          c = ROT2(b);
          b = a;
          a = temp;
     }
     for (i=60;i<80;i++)
     {
          temp = ROT27(a) + F4(b, c, d) + e + w[i] + 0xca62c1d6;
          e = d;
          d = c;
```

```
            c = ROT2(b);
            b = a;
            a = temp;
        }
        h[0] = h0+a;
        h[1] = h1+b;
        h[2] = h2+c;
        h[3] = h3+d;
        h[4] = h4+e;

        return (ALG_OK);
}

unsigned long gamma(a, i)
unsigned char *a;
int i;
{
unsigned long h[5];

        (void) g(a, i/5, h);
        return h[i % 5];
}

int  seal_init(seal_ctx *result, unsigned char *key)
{
int i;
unsigned long h[5];

        for (i=0;i<510;i+=5)
            g(key, i/5, &(result->t[i]));
        /* horrible special case for the end */
        g(key, 510/5, h);
        for (i=510;i<512;i++)
            result->t[i] = h[i-510];
        /* 0x1000 mod 5 is +1, so have horrible special case for the start */
        g(key, (-1+0x1000)/5, h);
        for (i=0;i<4;i++)
            result->s[i] = h[i+1];
        for (i=4;i<254;i+=5)
            g(key, (i+0x1000)/5, &(result->s[i]));
        /* horrible special case for the end */
        g(key, (254+0x1000)/5, h);
        for (i=254;i<256;i++)
            result->s[i] = h[i-254];
        /* 0x2000 mod 5 is +2, so have horrible special case at the start */
        g(key, (-2+0x2000)/5, h);
        for (i=0;i<3;i++)
            result->r[i] = h[i+2];
        for (i=3;i<13;i+=5)
            g(key, (i+0x2000)/5, &(result->r[i]));
        /* horrible special case for the end */
        g(key, (13+0x2000)/5, h);
        for (i=13;i<16;i++)
            result->r[i] = h[i-13];
        return (ALG_OK);
```

```
}

int seal(seal_ctx *key, unsigned long in, unsigned long *out)
{
int i;
int j;
int l;
unsigned long a;
unsigned long b;
unsigned long c;
unsigned long d;
unsigned short p;
unsigned short q;
unsigned long n1;
unsigned long n2;
unsigned long n3;
unsigned long n4;
unsigned long *wp;

     wp = out;

     for (l=0;l<4;l++)
     {
          a = in ^ key->r[4*l];
          b = ROT8(in) ^ key->r[4*l+1];
          c = ROT16(in) ^ key->r[4*l+2];
          d = ROT24(in) ^ key->r[4*l+3];

          for (j=0;j<2;j++)
          {
               p = a & 0x7fc;
               b += key->t[p/4];
               a = ROT9(a);

               p = b & 0x7fc;
               c += key->t[p/4];
               b = ROT9(b);

               p = c & 0x7fc;
               d += key->t[p/4];
               c = ROT9(c);

               p = d & 0x7fc;
               a += key->t[p/4];
               d = ROT9(d);

          }
          n1 = d;
          n2 = b;
          n3 = a;
          n4 = c;

          p = a & 0x7fc;
          b += key->t[p/4];
```

```
  a = ROT9(a);

  p = b & 0x7fc;
  c += key->t[p/4];
  b = ROT9(b);

  p = c & 0x7fc;
  d += key->t[p/4];
  c = ROT9(c);

  p = d & 0x7fc;
  a += key->t[p/4];
  d = ROT9(d);

/* This generates 64 32-bit words, or 256 bytes of keystream. */
  for (i=0;i<64;i++)
  {
       p = a & 0x7fc;
       b += key->t[p/4];
       a = ROT9(a);
       b ^= a;

       q = b & 0x7fc;
       c ^= key->t[q/4];
       b = ROT9(b);
       c += b;

       p = (p+c) & 0x7fc;
       d += key->t[p/4];
       c = ROT9(c);
       d ^= c;

       q = (q+d) & 0x7fc;
       a ^= key->t[q/4];
       d = ROT9(d);
       a += d;

       p = (p+a) & 0x7fc;
       b ^= key->t[p/4];
       a = ROT9(a);

       q = (q+b) & 0x7fc;
       c += key->t[q/4];
       b = ROT9(b);

       p = (p+c) & 0x7fc;
       d ^= key->t[p/4];
       c = ROT9(c);

       q = (q+d) & 0x7fc;
       a += key->t[q/4];
       d = ROT9(d);

       *wp = b + key->s[4*i];
```

```
                wp++;
                *wp = c ^ key->s[4*i+1];
                wp++;
                *wp = d + key->s[4*i+2];
                wp++;
                *wp = a ^ key->s[4*i+3];
                wp++;

                if (i & 1)
                {
                     a += n3;
                     c += n4;
                }
                else
                {
                     a += n1;
                     c += n2;
                }

          }
     }
     return (ALG_OK);
}

/* Added call to refill ks_buf and reset counter and ks_pos. */
void seal_refill_buffer(seal_ctx *c){
        seal(c,c->counter,c->ks_buf);
        c->counter++;
        c->ks_pos = 0;
}

void seal_key(seal_ctx *c, unsigned char *key){
        seal_init(c,key);
        c->counter = 0;  /* By default, init to zero. */
        c->ks_pos = WORDS_PER_SEAL_CALL;
                /* Refill keystream buffer on next call. */
}

/* This encrypts the next w words with SEAL. */
void seal_encrypt(seal_ctx *c, unsigned long *data_ptr, int w){
        int i;

        for(i=0;i<w;i++){
                if(c->ks_pos>=WORDS_PER_SEAL_CALL) seal_refill_buffer(c);
                data_ptr[i]^=c->ks_buf[c->ks_pos];
                c->ks_pos++;
        }
}

void seal_decrypt(seal_ctx *c, unsigned long *data_ptr, int w) {
        seal_encrypt(c,data_ptr,w);
}

void seal_resynch(seal_ctx *c, unsigned long synch_word){
        c->counter = synch_word;
```

```
        c->ks_pos = WORDS_PER_SEAL_CALL;
}

void main(void){
        seal_ctx sc;
        unsigned long buf[1000],t;
        int i,flag;
        unsigned char key[] =
                {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19};

        printf("1\n");
        seal_key(&sc,key);

        printf("2\n");
        for(i=0;i<1000;i++) buf[i]=0;
        printf("3\n");
        seal_encrypt(&sc,buf,1000);
        printf("4\n");
        t = 0;
        for(i=0;i<1000;i++) t = t ^ buf[i];
                printf("XOR of buf is %08lx.\n",t);

        seal_key(&sc,key);
        seal_decrypt(&sc,buf,1);
        seal_decrypt(&sc,buf+1,999);
        flag = 0;
        for(i=0;i<1000;i++) if(buf[i]!=0)flag=1;
        if(flag) printf("Decrypt failed.\n");
        else printf("Decrypt succeeded.\n");

}
```

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