

Internet-Draft
Obsoletes: [4009](#)(if approved)
Expires: November 2005

H.J. Lee
S.J. Lee
J.H. Yoon
D.H. Cheon
J.I. Lee
KISA
May 2005

The SEED Encryption Algorithm
[**<draft-lee-rfc4009bis-02.txt>**](#)

Status of this Memo

By submitting this Internet-Draft, each author represents that any applicable patent or other IPR claims of which he or she is aware have been or will be disclosed, and any of which he or she becomes aware will be disclosed, in accordance with [Section 6 of BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress".

The list of current Internet-Drafts can be accessed at
<http://www.ietf.org/ietf/1id-abstracts.txt>

The list of Internet-Draft Shadow Directories can be accessed at
<http://www.ietf.org/shadow.html>

This Internet-Draft will expire on November 30, 2005.

Copyright Notice

Copyright (C) The Internet Society (2005).

Abstract

This document describes the SEED encryption algorithm, which has been adopted by most of the security systems in the Republic of Korea. Included are a description of the encryption and the key scheduling algorithm ([Section 2](#)), the S-boxes (Appendix A), and a set of test vectors (Appendix B).

1. Introduction

1.1. Changes from RFC 4009

This specification obsoletes [RFC 4009](#), because the [RFC 4009](#) had ambiguous function and SS-boxes definitions cryptographically. Thus, some definitions have been changed and for better understanding, the SEED pseudo codes have been modified. This update is to provide clarity and facilitate the development of interoperable implementations. The SEED algorithm itself has not been changed.

This specification updates the [RFC 4009](#) in the following areas:

- Pseudo code changes. The Pseudo code in section2 in [RFC4009](#) is insufficient for the explanation of the structure of SEED. Thus detailed pseudo code is introduced.
- Some corrections of errata which are the definition of R1', Z, X and SS-boxes.

1.1. SEED Overview

SEED is a 128-bit symmetric key block cipher that has been developed by KISA (Korea Information Security Agency) since 1998. SEED is a national standard encryption algorithm in the Republic of Korea [[TTASSEED](#)] and is designed to use the S-boxes and permutations that balance with the current computing technology. It has the Feistel structure with 16-round and is strong against DC(Differential Cryptanalysis), LC(Linear Cryptanalysis), and related key attacks, balanced with security/efficiency trade-off.

The features of SEED are outlined as follows:

- The Feistel structure with 16-round
- 128-bit input/output data block size
- 128-bit key length
- A round function strong against known attacks
- Two 8x8 S-boxes
- Mixed operations of XOR and modular addition

SEED has been widely used in the Republic of Korea for confidential services such as electronic commerce; e.g., financial services provided in wired and wireless communication.

1.2. Notation

The following notation is used in the description of the SEED encryption algorithm:

Lee, et. al.

Expires - November 2005

[Page 2]

&	bitwise AND
^	bitwise exclusive OR
+	addition in modular 2^{32}
-	subtraction in modular 2^{32}
	concatenation
<< n	left circular rotation by n bits
>> n	right circular rotation by n bits
0x	hexadecimal representation

2. The Structure of SEED

The input/output block size of SEED is 128-bit, and the key length is also 128-bit. SEED has the 16-round Feistel structure. A 128-bit input is divided into two 64-bit blocks (L , R), and the right 64-bit block is an input to the round function F , with a 64-bit subkey K_i generated from the key schedule. L is the most significant 64 bits of 128-bit input, and R is the least significant 64 bits.

A pseudo code for the structure of SEED is as follows:

```

Input : (L, R)

for i = 1 to 15

    T = R;
    R = L ^ F(Ki, R);
    L = T;

    L = L ^ F(K16, R), R=R

Output : (L, R)

```

Where, T is a temporary.

2.1. The Round Function F

SEED uses two 8x8 S-boxes, permutations, rotations, and basic modular operations such as exclusive OR (XOR) and additions to provide strong security, high speed, and simplicity in its implementation.

A 64-bit input block of the round function F is divided into two 32-bit blocks (R_0 , R_1) and wrapped with 4 phases:

- A mixing phase of two 32-bit subkey blocks (K_{i0} , K_{i1})
- 3 layers of function G (See [Section 2.2](#)), with additions for mixing two 32-bit blocks

Where R_0 is the most significant 32bits of R , and R_1 is the least

Lee, et. al.

Expires - November 2005

[Page 3]

significant 32bits.

The outputs ($R0'$, $R1'$) of function F are as follows:

$$R0' = G[G[G[(R0 \wedge Ki0) \wedge (R1 \wedge Ki1)] + (R0 \wedge Ki0)] + G[(R0 \wedge Ki0) \wedge (R1 \wedge Ki1)]] + G[G[(R0 \wedge Ki0) \wedge (R1 \wedge Ki1)] + (R0 \wedge Ki0)]$$

$$R1' = G[G[G[(R0 \wedge Ki0) \wedge (R1 \wedge Ki1)] + (R0 \wedge Ki0)] + G[(R0 \wedge Ki0) \wedge (R1 \wedge Ki1)]]$$

2.2. The Function G

The function G has two layers. A layer of two 8x8 S-boxes and a layer of block permutation of sixteen 8-bit sub-blocks. The outputs Z ($= Z3 || Z2 || Z1 || Z0$) of the function G with four 8-bit inputs X ($= X3 || X2 || X1 || X0$) are as follows:

$$\begin{aligned} Z0 &= \{S0(X0) \& m0\} \wedge \{S1(X1) \& m1\} \wedge \{S0(X2) \& m2\} \wedge \{S1(X3) \& m3\} \\ Z1 &= \{S0(X0) \& m1\} \wedge \{S1(X1) \& m2\} \wedge \{S0(X2) \& m3\} \wedge \{S1(X3) \& m0\} \\ Z2 &= \{S0(X0) \& m2\} \wedge \{S1(X1) \& m3\} \wedge \{S0(X2) \& m0\} \wedge \{S1(X3) \& m1\} \\ Z3 &= \{S0(X0) \& m3\} \wedge \{S1(X1) \& m0\} \wedge \{S0(X2) \& m1\} \wedge \{S1(X3) \& m2\} \end{aligned}$$

where $m0 = 0xFC$, $m1 = 0xF3$, $m2 = 0xCF$, and $m3 = 0x3F$.

To increase the efficiency of G function, four extended S-boxes "SS-box" (See [Appendix A.2](#)) are defined as follows:

$$\begin{aligned} SS0(X0) &= \{S0(X0) \& m3\} \mid\mid \{S0(X0) \& m2\} \mid\mid \{S0(X0) \& m1\} \mid\mid \{S0(X0) \& m0\} \\ SS1(X1) &= \{S1(X1) \& m0\} \mid\mid \{S1(X1) \& m3\} \mid\mid \{S1(X1) \& m2\} \mid\mid \{S1(X1) \& m1\} \\ SS2(X2) &= \{S0(X2) \& m1\} \mid\mid \{S0(X2) \& m0\} \mid\mid \{S0(X2) \& m3\} \mid\mid \{S0(X2) \& m2\} \\ SS3(X3) &= \{S1(X3) \& m2\} \mid\mid \{S1(X3) \& m1\} \mid\mid \{S1(X3) \& m0\} \mid\mid \{S1(X3) \& m3\} \end{aligned}$$

New G function, Z , can be defined as follows:

$$Z = SS0(X0) \wedge SS1(X1) \wedge SS2(X2) \wedge SS3(X3)$$

This new G function is faster than the original G function but takes more memory to store four SS-boxes.

2.3. Key Schedule

The key schedule generates each round subkeys. It uses the function G, addition in modular 2^{32} , subtraction in modular 2^{32} , and (left/right) circular rotation. A 128-bit input key is divided into four 32-bit blocks ($Key0$, $Key1$, $Key2$, $Key3$). The two 32-bit subkeys of the i th round, $Ki0$ and $Ki1$, are generated as follows:

- Type 1 : Odd round

Lee, et. al.

Expires - November 2005

[Page 4]

```

Ki0 = G(Key0 + Key2 - KCi)
Ki1 = G(Key1 - Key3 + KCi)
Key0 || Key1 = (Key0 || Key1) >> 8

```

- Type 2 : Even round

```

Ki0 = G(Key0 + Key2 - KCi)
Ki1 = G(Key1 - Key3 + KCi)
Key2 || Key3 = (Key2 || Key3) << 8

```

Where $Ki0$ is the most significant 32bits of Ki , and $Ki1$ is the least significant 32bits of Ki . (where, $i=0, \dots, 3$)

The following table shows constants used in KCi :

i		Value	i		Value
KC1		0x9E3779B9	KC2		0x3C6EF373
KC3		0x78DDE6E6	KC4		0xF1BBCDCC
KC5		0xE3779B99	KC6		0xC6EF3733
KC7		0x8DDE6E67	KC8		0x1BBCDCCF
KC9		0x3779B99E	KC10		0x6EF3733C
KC11		0xDDE6E678	KC12		0xBBBCDCCF1
KC13		0x779B99E3	KC14		0xEF3733C6
KC15		0xDE6E678D	KC16		0xBCDCCF1B

A pseudo code for the key schedule is as follows:

```

Input : (Key0, Key1, Key2, Key3)

for i = 1 to 16
    Ki0 = G(Key0 + Key2 - KCi)
    Ki1 = G(Key1 - Key3 + KCi)
    if i is odd
        Key0 || Key1 = (Key0 || Key1) >> 8
    else
        Key2 || Key3 = (Key2 || Key3) << 8

```

Output : (Keyi0, Keyi1), i=1 to 16

2.4. Decryption Procedure

Decryption procedure is the reverse step of the encryption procedure. It can be implemented by using the encryption algorithm with reverse order of the round subkeys.

Lee, et. al.

Expires - November 2005

[Page 5]

2.5. SEED Object Identifiers

For those who may be using SEED in algorithm negotiation within a protocol, or in any other context that may require the use of OIDs, the following three OIDs have been defined.

```
algorithm OBJECT IDENTIFIER ::=  
{ iso(1) member-body(2) korea(410) kisa(200004) algorithm(1) }  
  
id-seedCBC OBJECT IDENTIFIER ::= { algorithm seedCBC(4) }  
  
seedCBCParameter ::= OCTET STRING (SIZE(16))  
-- 128-bit Initialization Vector
```

The id-seedCBC OID is used when the CBC mode of operation based on the SEED block cipher is provided.

```
id-seedMAC OBJECT IDENTIFIER ::= { algorithm seedMAC(7) }  
  
seedMACParameter ::= INTEGER -- MAC length, in bits
```

The id-seedMAC OID is used when the message authentication code (MAC) algorithm based on the SEED block cipher is provided.

```
pbeWithSHA1AndSEED-CBC OBJECT IDENTIFIER ::=  
{ algorithm seedCBCwithSHA1(15) }  
  
PBEPParameters ::= SEQUENCE {  
salt OCTET STRING,  
iteration INTEGER } -- Total number of hash iterations
```

This OID is used when a password-based encryption in CBC mode based on SHA-1 and the SEED block cipher is provided. The details of the PBE computation are well described in [Section 6.1 of \[RFC2898\]](#).

3. Security Considerations

No security problem has been found on SEED. See [[ISOSEED](#)] and [[CRYPTREC](#)].

4. Reference

4.1. Normative References

[TTASSEED] Telecommunications Technology Association(TTA), "128-bit Symmetric Block Cipher (SEED)", TTAS.KO-12.0004, September, 1998 (In Korean)
<http://www.tta.or.kr/English/new/main/index.htm>

Lee, et. al.

Expires - November 2005

[Page 6]

[RFC2898] Kaliski, B., "PKCS #5: Password-Based Cryptography Specification Version 2.0", [RFC 2898](#), September 2000.

4.2. Informative References

[ISOSEED] ISO/IEC, ISO/IEC JTC1/SC 27 N 256r1, "National Body contributions on NP 18033 Encryption algorithms in response to document SC 27 N 2563", October, 2000

[CRYPTREC] Information-technology Promotion Agency (IPA), Japan, CRYPTREC. "SEED Evaluation Report", February, 2002
[http://www.kisa.or.kr/seed/data/Document_pdf/
SEED_Evaluation_Report_by_CRYPTREC.pdf](http://www.kisa.or.kr/seed/data/Document_pdf/SEED_Evaluation_Report_by_CRYPTREC.pdf)

5. Acknowledgments

Alfred Hoenes(ah@tr-sys.de) has contributed significantly to work on the definition of R1', Z, X and SS-boxes. Thanks for his contribution for this document.

6. Authors' Addresses

Hyangjin Lee
Korea Information Security Agency
78, Garak-Dong, Songpa-Gu, Seoul, 138-803
REPUBLIC OF KOREA
Phone: +82-2-405-5446
FAX : +82-2-405-5319
EMail: jiinii@kisa.or.kr

Sungjae Lee
Korea Information Security Agency
Phone: +82-2-405-5243
FAX : +82-2-405-5499
EMail: sjlee@kisa.or.kr

Jaeho Yoon
Korea Information Security Agency
Phone: +82-2-405-5434
FAX : +82-2-405-5219
EMail: jhyoon@kisa.or.kr

Donghyeon Cheon
Korea Information Security Agency
Phone: +82-2-405-5251
FAX : +82-2-405-5319
EMail: dhcheon@kisa.or.kr

Lee, et. al.

Expires - November 2005

[Page 7]

Jaeil Lee
Korea Information Security Agency
Phone: +82-2-405-5300
FAX : +82-2-405-5219
EMail: jilee@kisa.or.kr

Appendix A. S-Boxes

In this part, all data are hexadecimal numbers(not prefixed by "0x").

A.1. S-Boxes(two original S-boxes)

- S-Box S0

```
A9, 85, D6, D3, 54, 1D, AC, 25, 5D, 43, 18, 1E, 51, FC, CA, 63,
28, 44, 20, 9D, E0, E2, C8, 17, A5, 8F, 03, 7B, BB, 13, D2, EE,
70, 8C, 3F, A8, 32, DD, F6, 74, EC, 95, 0B, 57, 5C, 5B, BD, 01,
24, 1C, 73, 98, 10, CC, F2, D9, 2C, E7, 72, 83, 9B, D1, 86, C9,
60, 50, A3, EB, 0D, B6, 9E, 4F, B7, 5A, C6, 78, A6, 12, AF, D5,
61, C3, B4, 41, 52, 7D, 8D, 08, 1F, 99, 00, 19, 04, 53, F7, E1,
FD, 76, 2F, 27, B0, 8B, 0E, AB, A2, 6E, 93, 4D, 69, 7C, 09, 0A,
BF, EF, F3, C5, 87, 14, FE, 64, DE, 2E, 4B, 1A, 06, 21, 6B, 66,
02, F5, 92, 8A, 0C, B3, 7E, D0, 7A, 47, 96, E5, 26, 80, AD, DF,
A1, 30, 37, AE, 36, 15, 22, 38, F4, A7, 45, 4C, 81, E9, 84, 97,
35, CB, CE, 3C, 71, 11, C7, 89, 75, FB, DA, F8, 94, 59, 82, C4,
FF, 49, 39, 67, C0, CF, D7, B8, 0F, 8E, 42, 23, 91, 6C, DB, A4,
34, F1, 48, C2, 6F, 3D, 2D, 40, BE, 3E, BC, C1, AA, BA, 4E, 55,
3B, DC, 68, 7F, 9C, D8, 4A, 56, 77, A0, ED, 46, B5, 2B, 65, FA,
E3, B9, B1, 9F, 5E, F9, E6, B2, 31, EA, 6D, 5F, E4, F0, CD, 88,
16, 3A, 58, D4, 62, 29, 07, 33, E8, 1B, 05, 79, 90, 6A, 2A, 9A
```

- S-Box S1

```
38, E8, 2D, A6, CF, DE, B3, B8, AF, 60, 55, C7, 44, 6F, 6B, 5B,
C3, 62, 33, B5, 29, A0, E2, A7, D3, 91, 11, 06, 1C, BC, 36, 4B,
EF, 88, 6C, A8, 17, C4, 16, F4, C2, 45, E1, D6, 3F, 3D, 8E, 98,
28, 4E, F6, 3E, A5, F9, 0D, DF, D8, 2B, 66, 7A, 27, 2F, F1, 72,
42, D4, 41, C0, 73, 67, AC, 8B, F7, AD, 80, 1F, CA, 2C, AA, 34,
D2, 0B, EE, E9, 5D, 94, 18, F8, 57, AE, 08, C5, 13, CD, 86, B9,
FF, 7D, C1, 31, F5, 8A, 6A, B1, D1, 20, D7, 02, 22, 04, 68, 71,
07, DB, 9D, 99, 61, BE, E6, 59, DD, 51, 90, DC, 9A, A3, AB, D0,
81, 0F, 47, 1A, E3, EC, 8D, BF, 96, 7B, 5C, A2, A1, 63, 23, 4D,
C8, 9E, 9C, 3A, 0C, 2E, BA, 6E, 9F, 5A, F2, 92, F3, 49, 78, CC,
15, FB, 70, 75, 7F, 35, 10, 03, 64, 6D, C6, 74, D5, B4, EA, 09,
76, 19, FE, 40, 12, E0, BD, 05, FA, 01, F0, 2A, 5E, A9, 56, 43,
85, 14, 89, 9B, B0, E5, 48, 79, 97, FC, 1E, 82, 21, 8C, 1B, 5F,
77, 54, B2, 1D, 25, 4F, 00, 46, ED, 58, 52, EB, 7E, DA, C9, FD,
30, 95, 65, 3C, B6, E4, BB, 7C, 0E, 50, 39, 26, 32, 84, 69, 93,
37, E7, 24, A4, CB, 53, 0A, 87, D9, 4C, 83, 8F, CE, 3B, 4A, B7
```

A.2. S-Boxes (four extended S-boxes)

Lee, et. al.

Expires - November 2005

[Page 9]

- S-Box SS0

2989A1A8, 05858184, 16C6D2D4, 13C3D3D0, 14445054, 1D0D111C, 2C8CA0AC, 25052124,
1D4D515C, 03434340, 18081018, 1E0E121C, 11415150, 3CCCF0FC, 0ACAC2C8, 23436360,
28082028, 04444044, 20002020, 1D8D919C, 20C0E0E0, 22C2E2E0, 08C8C0C8, 17071314,
2585A1A4, 0F8F838C, 03030300, 3B4B7378, 3B8BB3B8, 13031310, 12C2D2D0, 2ECEE2EC,
30407070, 0C8C808C, 3F0F333C, 2888A0A8, 32023230, 1DCDD1DC, 36C6F2F4, 34447074,
2CCCE0EC, 15859194, 0B0B0308, 17475354, 1C4C505C, 1B4B5358, 3D8DB1BC, 01010100,
24042024, 1C0C101C, 33437370, 18889098, 10001010, 0CCCC0CC, 32C2F2F0, 19C9D1D8,
2C0C202C, 27C7E3E4, 32427270, 03838380, 1B8B9398, 11C1D1D0, 06868284, 09C9C1C8,
20406060, 10405050, 2383A3A0, 2BCBE3E8, 0D0D010C, 3686B2B4, 1E8E929C, 0F4F434C,
3787B3B4, 1A4A5258, 06C6C2C4, 38487078, 2686A2A4, 12021210, 2F8FA3AC, 15C5D1D4,
21416160, 03C3C3C0, 3484B0B4, 01414140, 12425250, 3D4D717C, 0D8D818C, 08080008,
1F0F131C, 19899198, 00000000, 19091118, 04040004, 13435350, 37C7F3F4, 21C1E1E0,
3DCDF1FC, 36467274, 2F0F232C, 27072324, 3080B0B0, 0B8B8388, 0E0E020C, 2B8BA3A8,
2282A2A0, 2E4E626C, 13839390, 0D4D414C, 29496168, 3C4C707C, 09090108, 0A0A0208,
3F8FB3BC, 2FCFE3EC, 33C3F3F0, 05C5C1C4, 07878384, 14041014, 3ECEF2FC, 24446064,
1ECED2DC, 2E0E222C, 0B4B4348, 1A0A1218, 06060204, 21012120, 2B4B6368, 26466264,
02020200, 35C5F1F4, 12829290, 0A8A8288, 0C0C000C, 3383B3B0, 3E4E727C, 10C0D0D0,
3A4A7278, 07474344, 16869294, 25C5E1E4, 26062224, 00808080, 2D8DA1AC, 1FCFD3DC,
2181A1A0, 30003030, 37073334, 2E8EA2AC, 36063234, 15051114, 22022220, 38083038,
34C4F0F4, 2787A3A4, 05454144, 0C4C404C, 01818180, 29C9E1E8, 04848084, 17879394,
35053134, 0BCBC3C8, 0ECEC2CC, 3C0C303C, 31417170, 11011110, 07C7C3C4, 09898188,
35457174, 3BCBF3F8, 1ACAD2D8, 38C8F0F8, 14849094, 19495158, 02828280, 04C4C0C4,
3FCFF3FC, 09494148, 39093138, 27476364, 00C0C0C0, 0FCFC3CC, 17C7D3D4, 3888B0B8,
0F0F030C, 0E8E828C, 02424240, 23032320, 11819190, 2C4C606C, 1BCBD3D8, 2484A0A4,
34043034, 31C1F1F0, 08484048, 02C2C2C0, 2F4F636C, 3D0D313C, 2D0D212C, 00404040,
3E8EB2BC, 3E0E323C, 3C8CB0BC, 01C1C1C0, 2A8AA2A8, 3A8AB2B8, 0E4E424C, 15455154,
3B0B3338, 1CCCD0DC, 28486068, 3F4F737C, 1C8C909C, 18C8D0D8, 0A4A4248, 16465254,
37477374, 2080A0A0, 2DCDE1EC, 06464244, 3585B1B4, 2B0B2328, 25456164, 3ACAF2F8,
23C3E3E0, 3989B1B8, 3181B1B0, 1F8F939C, 1E4E525C, 39C9F1F8, 26C6E2E4, 3282B2B0,
31013130, 2ACAE2E8, 2D4D616C, 1F4F535C, 24C4E0E4, 30C0F0F0, 0DCDC1CC, 08888088,
16061214, 3A0A3238, 18485058, 14C4D0D4, 22426260, 29092128, 07070304, 33033330,
28C8E0E8, 1B0B1318, 05050104, 39497178, 10809090, 2A4A6268, 2A0A2228, 1A8A9298

- S-Box SS1

38380830, E828C8E0, 2C2D0D21, A42686A2, CC0FCFC3, DC1ECED2, B03383B3, B83888B0,
AC2F8FA3, 60204060, 54154551, C407C7C3, 44044440, 6C2F4F63, 682B4B63, 581B4B53,
C003C3C3, 60224262, 30330333, B43585B1, 28290921, A02080A0, E022C2E2, A42787A3,
D013C3D3, 90118191, 10110111, 04060602, 1C1C0C10, BC3C8CB0, 34360632, 480B4B43,
EC2FCFE3, 88088880, 6C2C4C60, A82888A0, 14170713, C404C4C0, 14160612, F434C4F0,
C002C2C2, 44054541, E021C1E1, D416C6D2, 3C3F0F33, 3C3D0D31, 8C0E8E82, 98188890,
28280820, 4C0E4E42, F436C6F2, 3C3E0E32, A42585A1, F839C9F1, 0C0D0D01, DC1FCFD3,
D818C8D0, 282B0B23, 64264662, 783A4A72, 24270723, 2C2F0F23, F031C1F1, 70324272,
40024242, D414C4D0, 40014141, C000C0C0, 70334373, 64274763, AC2C8CA0, 880B8B83,
F437C7F3, AC2D8DA1, 80008080, 1C1F0F13, C80ACAC2, 2C2C0C20, A82A8AA2, 34340430,

Lee, et. al.

Expires - November 2005

[Page 10]

D012C2D2, 080B0B03, EC2ECEE2, E829C9E1, 5C1D4D51, 94148490, 18180810, F838C8F0,
54174753, AC2E8EA2, 08080800, C405C5C1, 10130313, CC0DCDC1, 84068682, B83989B1,
FC3FCFF3, 7C3D4D71, C001C1C1, 30310131, F435C5F1, 880A8A82, 682A4A62, B03181B1,
D011C1D1, 20200020, D417C7D3, 00020202, 20220222, 04040400, 68284860, 70314171,
04070703, D81BCBD3, 9C1D8D91, 98198991, 60214161, BC3E8EB2, E426C6E2, 58194951,
DC1DCDD1, 50114151, 90108090, DC1CCCD0, 981A8A92, A02383A3, A82B8BA3, D010C0D0,
80018181, 0C0F0F03, 44074743, 181A0A12, E023C3E3, EC2CCCE0, 8C0D8D81, BC3F8FB3,
94168692, 783B4B73, 5C1C4C50, A02282A2, A02181A1, 60234363, 20230323, 4C0D4D41,
C808C8C0, 9C1E8E92, 9C1C8C90, 383A0A32, 0C0C0C00, 2C2E0E22, B83A8AB2, 6C2E4E62,
9C1F8F93, 581A4A52, F032C2F2, 90128292, F033C3F3, 48094941, 78384870, CC0CCCC0,
14150511, F83BCBF3, 70304070, 74354571, 7C3F4F73, 34350531, 10100010, 00030303,
64244460, 6C2D4D61, C406C6C2, 74344470, D415C5D1, B43484B0, E82ACAE2, 08090901,
74364672, 18190911, FC3ECEF2, 40004040, 10120212, E020C0E0, BC3D8DB1, 04050501,
F83ACAF2, 00010101, F030C0F0, 282A0A22, 5C1E4E52, A82989A1, 54164652, 40034343,
84058581, 14140410, 88098981, 981B8B93, B03080B0, E425C5E1, 48084840, 78394971,
94178793, FC3CCCF0, 1C1E0E12, 80028282, 20210121, 8C0C8C80, 181B0B13, 5C1F4F53,
74374773, 54144450, B03282B2, 1C1D0D11, 24250521, 4C0F4F43, 00000000, 44064642,
EC2DCDE1, 58184850, 50124252, E82BCBE3, 7C3E4E72, D81ACAD2, C809C9C1, FC3DCDF1,
30300030, 94158591, 64254561, 3C3C0C30, B43686B2, E424C4E0, B83B8BB3, 7C3C4C70,
0C0E0E02, 50104050, 38390931, 24260622, 30320232, 84048480, 68294961, 90138393,
34370733, E427C7E3, 24240420, A42484A0, C80BCBC3, 50134353, 080A0A02, 84078783,
D819C9D1, 4C0C4C40, 80038383, 8C0F8F83, CC0ECEC2, 383B0B33, 480A4A42, B43787B3

- S-Box SS2

A1A82989, 81840585, D2D416C6, D3D013C3, 50541444, 111C1D0D, A0AC2C8C, 21242505,
515C1D4D, 43400343, 10181808, 121C1E0E, 51501141, F0FC3CCC, C2C80ACA, 63602343,
20282808, 40440444, 20202000, 919C1D8D, E0E020C0, E2E022C2, C0C808C8, 13141707,
A1A42585, 838C0F8F, 03000303, 73783B4B, B3B83B8B, 13101303, D2D012C2, E2EC2ECE,
70703040, 808C0C8C, 333C3F0F, A0A82888, 32303202, D1DC1DCD, F2F436C6, 70743444,
E0EC2CCC, 91941585, 03080B0B, 53541747, 505C1C4C, 53581B4B, B1BC3D8D, 01000101,
20242404, 101C1C0C, 73703343, 90981888, 10101000, C0CC0CCC, F2F032C2, D1D819C9,
202C2C0C, E3E427C7, 72703242, 83800383, 93981B8B, D1D011C1, 82840686, C1C809C9,
60602040, 50501040, A3A02383, E3E82BCB, 010C0D0D, B2B43686, 929C1E8E, 434C0F4F,
B3B43787, 52581A4A, C2C406C6, 70783848, A2A42686, 12101202, A3AC2F8F, D1D415C5,
61602141, C3C003C3, B0B43484, 41400141, 52501242, 717C3D4D, 818C0D8D, 00080808,
131C1F0F, 91981989, 00000000, 11181909, 00040404, 53501343, F3F437C7, E1E021C1,
F1FC3DCD, 72743646, 232C2F0F, 23242707, B0B03080, 83880B8B, 020C0E0E, A3A82B8B,
A2A02282, 626C2E4E, 93901383, 414C0D4D, 61682949, 707C3C4C, 01080909, 02080A0A,
B3BC3F8F, E3EC2FCF, F3F033C3, C1C405C5, 83840787, 10141404, F2FC3ECE, 60642444,
D2DC1ECE, 222C2E0E, 43480B4B, 12181A0A, 02040606, 21202101, 63682B4B, 62642646,
02000202, F1F435C5, 92901282, 82880A8A, 000C0C0C, B3B03383, 727C3E4E, D0D010C0,
72783A4A, 43440747, 92941686, E1E425C5, 22242606, 80800080, A1AC2D8D, D3DC1FCF,
A1A02181, 30303000, 33343707, A2AC2E8E, 32343606, 11141505, 22202202, 30383808,
F0F434C4, A3A42787, 41440545, 404C0C4C, 81800181, E1E829C9, 80840484, 93941787,
31343505, C3C80BCB, C2CC0ECE, 303C3C0C, 71703141, 11101101, C3C407C7, 81880989,
71743545, F3F83BCB, D2D81ACA, F0F838C8, 90941484, 51581949, 82800282, C0C404C4,

Lee, et. al.

Expires - November 2005

[Page 11]

F3FC3FCF, 41480949, 31383909, 63642747, C0C000C0, C3CC0FCF, D3D417C7, B0B83888,
030C0F0F, 828C0E8E, 42400242, 23202303, 91901181, 606C2C4C, D3D81BCB, A0A42484,
30343404, F1F031C1, 40480848, C2C002C2, 636C2F4F, 313C3D0D, 212C2D0D, 40400040,
B2BC3E8E, 323C3E0E, B0BC3C8C, C1C001C1, A2A82A8A, B2B83A8A, 424C0E4E, 51541545,
33383B0B, D0DC1CCC, 60682848, 737C3F4F, 909C1C8C, D0D818C8, 42480A4A, 52541646,
73743747, A0A02080, E1EC2DCD, 42440646, B1B43585, 23282B0B, 61642545, F2F83ACA,
E3E023C3, B1B83989, B1B03181, 939C1F8F, 525C1E4E, F1F839C9, E2E426C6, B2B03282,
31303101, E2E82ACA, 616C2D4D, 535C1F4F, E0E424C4, F0F030C0, C1CC0DCD, 80880888,
12141606, 32383A0A, 50581848, D0D414C4, 62602242, 21282909, 03040707, 33303303,
E0E828C8, 13181B0B, 01040505, 71783949, 90901080, 62682A4A, 22282A0A, 92981A8A

- S-Box SS3

08303838, C8E0E828, 0D212C2D, 86A2A426, CFC3CC0F, CED2DC1E, 83B3B033, 88B0B838,
8FA3AC2F, 40606020, 45515415, C7C3C407, 44404404, 4F636C2F, 4B63682B, 4B53581B,
C3C3C003, 42626022, 03333033, 85B1B435, 09212829, 80A0A020, C2E2E022, 87A3A427,
C3D3D013, 81919011, 01111011, 06020406, 0C101C1C, 8CB0BC3C, 06323436, 4B43480B,
CFE3EC2F, 88808808, 4C606C2C, 88A0A828, 07131417, C4C0C404, 06121416, C4F0F434,
C2C2C002, 45414405, C1E1E021, C6D2D416, 0F333C3F, 0D313C3D, 8E828C0E, 88909818,
08202828, 4E424C0E, C6F2F436, 0E323C3E, 85A1A425, C9F1F839, 0D010C0D, CFD3DC1F,
C8D0D818, 0B23282B, 46626426, 4A72783A, 07232427, 0F232C2F, C1F1F031, 42727032,
42424002, C4D0D414, 41414001, C0C0C000, 43737033, 47636427, 8CA0AC2C, 8B83880B,
C7F3F437, 8DA1AC2D, 80808000, 0F131C1F, CAC2C80A, 0C202C2C, 8AA2A82A, 04303434,
C2D2D012, 0B03080B, CEE2EC2E, C9E1E829, 4D515C1D, 84909414, 08101818, C8F0F838,
47535417, 8EA2AC2E, 08000808, C5C1C405, 03131013, CDC1CC0D, 86828406, 89B1B839,
CFF3FC3F, 4D717C3D, C1C1C001, 01313031, C5F1F435, 8A82880A, 4A62682A, 81B1B031,
C1D1D011, 00202020, C7D3D417, 02020002, 02222022, 04000404, 48606828, 41717031,
07030407, CBD3D81B, 8D919C1D, 89919819, 41616021, 8EB2BC3E, C6E2E426, 49515819,
CDD1DC1D, 41515011, 80909010, CCD0DC1C, 8A92981A, 83A3A023, 8BA3A82B, C0D0D010,
81818001, 0F030C0F, 47434407, 0A12181A, C3E3E023, CCE0EC2C, 8D818C0D, 8FB3BC3F,
86929416, 4B73783B, 4C505C1C, 82A2A022, 81A1A021, 43636023, 03232023, 4D414C0D,
C8C0C808, 8E929C1E, 8C909C1C, 0A32383A, 0C000C0C, 0E222C2E, 8AB2B83A, 4E626C2E,
8F939C1F, 4A52581A, C2F2F032, 82929012, C3F3F033, 49414809, 48707838, CCC0CC0C,
05111415, CBF3F83B, 40707030, 45717435, 4F737C3F, 05313435, 00101010, 03030003,
44606424, 4D616C2D, C6C2C406, 44707434, C5D1D415, 84B0B434, CAE2E82A, 09010809,
46727436, 09111819, CEF2FC3E, 40404000, 02121012, C0E0E020, 8DB1BC3D, 05010405,
CAF2F83A, 01010001, C0F0F030, 0A22282A, 4E525C1E, 89A1A829, 46525416, 43434003,
85818405, 04101414, 89818809, 8B93981B, 80B0B030, C5E1E425, 48404808, 49717839,
87939417, CCF0FC3C, 0E121C1E, 82828002, 01212021, 8C808C0C, 0B13181B, 4F535C1F,
47737437, 44505414, 82B2B032, 0D111C1D, 05212425, 4F434C0F, 00000000, 46424406,
CDE1EC2D, 48505818, 42525012, CBE3E82B, 4E727C3E, CAD2D81A, C9C1C809, CDF1FC3D,
00303030, 85919415, 45616425, 0C303C3C, 86B2B436, C4E0E424, 8BB3B83B, 4C707C3C,
0E020C0E, 40505010, 09313839, 06222426, 02323032, 84808404, 49616829, 83939013,
07333437, C7E3E427, 04202424, 84A0A424, CBC3C80B, 43535013, 0A02080A, 87838407,
C9D1D819, 4C404C0C, 83838003, 8F838C0F, CEC2CC0E, 0B33383B, 4A42480A, 87B3B437

Lee, et. al.

Expires - November 2005

[Page 12]

Appendix B. Test Vectors

This appendix provides test vectors for the SEED cipher described in this document.

All data are hexadecimal numbers(not prefixed by "0x").

B.1.

```
Key      : 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Plaintext : 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
Ciphertext : 5E BA C6 E0 05 4E 16 68 19 AF F1 CC 6D 34 6C DB
```

Intermediate Value

	Ki0	Ki1	L0	L1	R0	R1
<hr/>						
Round 1 :	7C8F8C7E	C737A22C	00010203	04050607	08090A0B	0C0D0E0F
Round 2 :	FF276CDB	A7CA684A	08090A0B	0C0D0E0F	8081BC57	C4EA8A1F
Round 3 :	2F9D01A1	70049E41	8081BC57	C4EA8A1F	117A8B07	D7358C24
Round 4 :	AE59B3C4	4245E90C	117A8B07	D7358C24	D1738C94	7326CAB0
Round 5 :	A1D6400F	DBC1394E	D1738C94	7326CAB0	577ECE6D	1F8433EC
Round 6 :	85963508	0C5F1FCB	577ECE6D	1F8433EC	910F62AB	DDA096C1
Round 7 :	B684BDA7	61A4AEAE	910F62AB	DDA096C1	EA4D39B4	B17B1938
Round 8 :	D17E0741	FEE90AA1	EA4D39B4	B17B1938	B04E251F	97D7442C
Round 9 :	76CC05D5	E97A7394	B04E251F	97D7442C	B86D31BF	A5988C06
Round 10 :	50AC6F92	1B2666E5	B86D31BF	A5988C06	9008EABF	38DF7430
Round 11 :	65B7904A	8EC3A7B3	9008EABF	38DF7430	33E47DE0	54EFF76C
Round 12 :	2F7E2E22	A2B121B9	33E47DE0	54EFF76C	6BE9C434	BF3F378A
Round 13 :	4D0BFDE4	4E888D9B	6BE9C434	BF3F378A	B8DC3842	03A02D33
Round 14 :	631C8DDC	4378A6C4	B8DC3842	03A02D33	6679FCF7	9791DFCB
Round 15 :	216AF65F	7878C031	6679FCF7	9791DFCB	1A415792	A02B8C54
Round 16 :	71891150	98B255B0	1A415792	A02B8C54	19AFF1CC	6D346CDB

B.2.

```
Key      : 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
Plaintext : 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Ciphertext : C1 1F 22 F2 01 40 50 50 84 48 35 97 E4 37 0F 43
```

Intermediate Value

	Ki0	Ki1	L0	L1	R0	R1
<hr/>						
Round 1 :	C119F584	5AE033A0	00000000	00000000	00000000	00000000
Round 2 :	62947390	A600AD14	00000000	00000000	9D8DB62C	911F0C19
Round 3 :	F6F6544E	596C4B49	9D8DB62C	911F0C19	21229A97	4AB4B7B8

Lee, et. al.

Expires - November 2005

[Page 13]

Round 4 :	C1A3DE02 CE483C49	21229A97 4AB4B7B8 5A27B404 899D7315
Round 5 :	5E742E6D 7E25163D	5A27B404 899D7315 B8489E76 BA0EF3EA
Round 6 :	8299D2B4 790A46CE	B8489E76 BA0EF3EA 04A3DF29 31A27FB4
Round 7 :	EA67D836 55F354F2	04A3DF29 31A27FB4 EC9C17BF 81AA2AA0
Round 8 :	C47329FB F50DB634	EC9C17BF 81AA2AA0 4FA74E8D CDB21BB8
Round 9 :	2BD30235 51679CE6	4FA74E8D CDB21BB8 D93492FE 4F71A4DA
Round 10 :	FA8D6B76 A9F37E02	D93492FE 4F71A4DA B14053D9 A911379B
Round 11 :	8B99CC60 0F6092D4	B14053D9 A911379B 5A7024D6 3905668B
Round 12 :	BDAEFCFA 489C2242	5A7024D6 3905668B 605C8C3A 73DFBB75
Round 13 :	F6357C14 CFCCB126	605C8C3A 73DFBB75 40282F39 31CB8987
Round 14 :	A0AA6D85 F8C10774	40282F39 31CB8987 E9F834A8 3B9586D4
Round 15 :	47F4FEC5 353AE1BA	E9F834A8 3B9586D4 4B60324B 761C9958
Round 16 :	FECCEA48 A4EF9F9B	4B60324B 761C9958 84483597 E4370F43

B.3.

```

Key      : 47 06 48 08 51 E6 1B E8 5D 74 BF B3 FD 95 61 85
Plaintext : 83 A2 F8 A2 88 64 1F B9 A4 E9 A5 CC 2F 13 1C 7D
Ciphertext : EE 54 D1 3E BC AE 70 6D 22 6B C3 14 2C D4 0D 4A

```

Intermediate Value

	Ki0	Ki1	L0	L1	R0	R1
Round 1 :	56BE4A0F E9F62877	83A2F8A2 88641FB9 A4E9A5CC 2F131C7D				
Round 2 :	68BCB66C 078911DD	A4E9A5CC 2F131C7D 7CE5F012 47F8C1E6				
Round 3 :	5B82740B FD24D09B	7CE5F012 47F8C1E6 AAC99520 609F4CB7				
Round 4 :	8D608015 A120E0BE	AAC99520 609F4CB7 3E126D1F 44FA99F0				
Round 5 :	810A75AE 1BF223E5	3E126D1F 44FA99F0 11716365 9BA775AC				
Round 6 :	F9C0D2D0 0F676C02	11716365 9BA775AC 32C9838F BA5757CB				
Round 7 :	8F9B5C84 8A7C8DDD	32C9838F BA5757CB 77E00C64 CF9F6B32				
Round 8 :	D4AB4896 18E93447	77E00C64 CF9F6B32 3F09B1F7 DE7D6D58				
Round 9 :	CF090F51 5A4C8202	3F09B1F7 DE7D6D58 300E5CAA D0BF2345				
Round 10 :	4EC3196F 61B1A0DC	300E5CAA D0BF2345 9574FDD7 4DF050D1				
Round 11 :	244E07C1 D0D10B12	9574FDD7 4DF050D1 A15EDA6F 624265FD				
Round 12 :	69917C6C 7FF94FB3	A15EDA6F 624265FD 9F39B682 D841C76F				
Round 13 :	9A7EB482 723B5738	9F39B682 D841C76F EEEBAD8B C1F488EF				
Round 14 :	B97522C5 39CC6349	EEEBAD8B C1F488EF 45CF5D4E BEEA4AA2				
Round 15 :	FFC2AFD5 1412E731	45CF5D4E BEEA4AA2 43B7FE1B BCF87781				
Round 16 :	A9AF7241 A3E67359	43B7FE1B BCF87781 226BC314 2CD40D4A				

B.4.

```

Key      : 28 DB C3 BC 49 FF D8 7D CF A5 09 B1 1D 42 2B E7
Plaintext : B4 1E 6B E2 EB A8 4A 14 8E 2E ED 84 59 3C 5E C7
Ciphertext : 9B 9B 7B FC D1 81 3C B9 5D 0B 36 18 F4 0F 51 22

```

Lee, et. al.

Expires - November 2005

[Page 14]

Intermediate Value

	Ki0	Ki1	L0	L1	R0	R1
<hr/>						
Round 1 :	B2B11B63	2EE9E2D1	B41E6BE2	EBA84A14	8E2EED84	593C5EC7
Round 2 :	11967260	71A62F24	8E2EED84	593C5EC7	1B31F2F7	3DDE00BA
Round 3 :	2E017A5A	35DAD7A7	1B31F2F7	3DDE00BA	35CC49C0	2AFB59EA
Round 4 :	1B2AB5FF	A3ADA69F	35CC49C0	2AFB59EA	D7AB53AA	AE82F1C7
Round 5 :	519C9903	DA90AAEE	D7AB53AA	AE82F1C7	24139958	B840E56F
Round 6 :	29FD95AD	B94C3F13	24139958	B840E56F	24AB5291	544C9DBA
Round 7 :	6F629D19	8ACE692F	24AB5291	544C9DBA	E8152994	75D0B424
Round 8 :	30A26E73	2F22338E	E8152994	75D0B424	A2CD1153	F32BB23A
Round 9 :	9721073A	98EE8DAE	A2CD1153	F32BB23A	C386008B	E3257731
Round 10 :	C597A8A9	27DCDC97	C386008B	E3257731	98396BFD	814F8972
Round 11 :	F5163A00	5FFD0003	98396BFD	814F8972	E74D2D0D	11D889D1
Round 12 :	5CBE65DA	A73403E4	E74D2D0D	11D889D1	29D8C7B3	D1B71C0C
Round 13 :	7D5CF070	1D3B8092	29D8C7B3	D1B71C0C	C4E692C2	D2F57F18
Round 14 :	388C702B	1BAA4945	C4E692C2	D2F57F18	2FAFB300	5F0C4BFF
Round 15 :	87D1AB5A	FA13FB5C	2FAFB300	5F0C4BFF	60E5F17C	5626BB68
Round 16 :	C97D7EED	90724A6E	60E5F17C	5626BB68	5D0B3618	F40F5122

Lee, et. al.

Expires - November 2005

[Page 15]

Intellectual Property Statement

The IETF takes no position regarding the validity or scope of any Intellectual Property Rights or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; nor does it represent that it has made any independent effort to identify any such rights. Information on the procedures with respect to rights in RFC documents can be found in [BCP 78](#) and [BCP 79](#).

Copies of IPR disclosures made to the IETF Secretariat and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementers or users of this specification can be obtained from the IETF on-line IPR repository at <http://www.ietf.org/ipr>.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights that may cover technology that may be required to implement this standard. Please address the information to the IETF at ietf-ipr@ietf.org.

Disclaimer of Validity

This document and the information contained herein are provided on an "AS IS" basis and THE CONTRIBUTOR, THE ORGANIZATION HE/SHE REPRESENTS OR IS SPONSORED BY (IF ANY), THE INTERNET SOCIETY AND THE INTERNET ENGINEERING TASK FORCE DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Copyright Statement

Copyright (C) The Internet Society (2005). This document is subject to the rights, licenses and restrictions contained in [BCP 78](#), and except as set forth therein, the authors retain all their rights.

Acknowledgment

Funding for the RFC Editor function is currently provided by the Internet Society.

Lee, et. al.

Expires - November 2005

[Page 16]