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The SEED Encryption Algorithm
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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).

INTERNET-DRAFT

The SEED Encryption Algorithm

May 2005

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]

INTERNET-DRAFT

The SEED Encryption Algorithm

May 2005

&	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( $K_i$ , R);
    L = T;

L = L ^ F( $K_{16}$ , 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 (R0, R1) and wrapped with 4 phases:

- A mixing phase of two 32-bit subkey blocks (Ki0 , Ki1)
- 3 layers of function G (See [Section 2.2](#)), with additions for mixing two 32-bit blocks

Where R0 is the most significant 32bits of R, and R1 is the least

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:

$$\begin{aligned} SS0(X0) &= \{S0(X0) \& m3\} \parallel \{S0(X0) \& m2\} \parallel \{S0(X0) \& m1\} \parallel \{S0(X0) \& m0\} \\ SS1(X1) &= \{S1(X1) \& m0\} \parallel \{S1(X1) \& m3\} \parallel \{S1(X1) \& m2\} \parallel \{S1(X1) \& m1\} \end{aligned}$$

$$SS2(X2) = \{S0(X2) \& m1\} \parallel \{S0(X2) \& m0\} \parallel \{S0(X2) \& m3\} \parallel \{S0(X2) \& m2\}$$

$$SS3(X3) = \{S1(X3) \& m2\} \parallel \{S1(X3) \& m1\} \parallel \{S1(X3) \& m0\} \parallel \{S1(X3) \& m3\}$$

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 ith round, Ki0 and Ki1, are generated as follows:

- Type 1 : Odd round

Lee, et. al.

Expires - November 2005

[Page 4]

INTERNET-DRAFT

The SEED Encryption Algorithm

May 2005

$$Ki0 = G(Key0 + Key2 - KCi)$$

$$Ki1 = G(Key1 - Key3 + KCi)$$

$$Key0 \parallel Key1 = (Key0 \parallel Key1) \gg 8$$

- Type 2 : Even round

$$Ki0 = G(Key0 + Key2 - KCi)$$

$$Ki1 = G(Key1 - Key3 + KCi)$$

$$Key2 \parallel Key3 = (Key2 \parallel Key3) \ll 8$$

Where Ki0 is the most significant 32bits of Ki, and Ki1 is the least significant 32bits of Ki.(where, i=0,...,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	0xBBDCDCF1

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
  esle
    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.

[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.K0-12.0004, September, 1998 (In Korean)
<http://www.tta.or.kr/English/new/main/index.htm>

[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

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[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)

- 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,03030300,3B4B7378,3B8BB3B8,13031310,12C2D2D0,2ECEEE2EC,
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,33C3F3F0,05C5C1C4,07878384,14041014,3ECEFE2FC,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,
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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,

D012C2D2,080B0B03,EC2ECEE2,E829C9E1,5C1D4D51,94148490,18180810,F838C8F0,
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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,
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- S-Box SS2

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- S-Box SS3

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[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
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
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
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]

INTERNET-DRAFT

The SEED Encryption Algorithm

May 2005

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 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

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