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GOST R 34.12-2015: Block Cipher "Magma"
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Abstract

This document is intended to be a source of information about updated version of the block cipher with block length of $n=64$ bits and key length $k=256$ bits ([RFC5830](#)), which is also referred as "Magma" and is described in the Russian Federal standard GOST R 34.12-2015, containing also the description of block cipher "Kuznechik" ([RFC7801](#)). These algorithms are from the set of Russian cryptographic standard algorithms (called GOST algorithms).

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Table of Contents

| | | |
|-----------------------------|-------------------------------------------|--------------------|
| 1. | Introduction | 2 |
| 2. | General Information | 3 |
| 3. | Definitions and Notations | 3 |
| 3.1. | Definitions | 3 |
| 3.2. | Notations | 4 |
| 4. | Description of Kuznechik cipher | 5 |
| 5. | Parameter Values | 5 |
| 5.1. | Nonlinear Bijection | 5 |
| 5.2. | Transformations | 6 |
| 5.3. | Key schedule | 6 |
| 6. | Basic encryption algorithm | 7 |
| 6.1. | Encryption | 7 |
| 6.2. | Decryption | 7 |
| 7. | IANA Considerations | 7 |
| 8. | Security Considerations | 7 |
| 9. | References | 7 |
| 9.1. | Normative References | 7 |
| 9.2. | Informative References | 8 |
| Appendix A. | Test Examples | 8 |
| A.1. | Transformation t | 8 |
| A.2. | Transformation g | 8 |
| A.3. | Key schedule | 9 |
| A.4. | Test Encryption | 10 |
| A.5. | Test Decryption | 11 |
| Appendix B. | Background | 12 |
| | Authors' Addresses | 12 |

[1.](#) Introduction

The Russian Federal standard [[GOSTR3412-2015](#)] specifies basic block ciphers used as cryptographic techniques for information processing and information protection including the provision of confidentiality, authenticity, and integrity of information during information transmission, processing and storage in computer-aided systems.

The cryptographic algorithms specified in this Standard are designed both for hardware and software implementation. They comply with modern cryptographic requirements, and put no restrictions on the confidentiality level of the protected information.

2. General Information

The Russian Federal standard [[GOSTR3412-2015](#)] was developed by the Center for Information Protection and Special Communications of the Federal Security Service of the Russian Federation with participation of the Open Joint-Stock company "Information Technologies and Communication Systems" (InfoTeCS JSC). GOST R 34.12-2015 was approved and introduced by Decree #749 of the Federal Agency on Technical Regulating and Metrology on 19.06.2015.

Terms and concepts in the standard comply with the following international standards:

- o ISO/IEC 10116 [[ISO-IEC10116](#)],
- o series of standards ISO/IEC 18033 [[ISO-IEC18033-1](#)], [[ISO-IEC18033-3](#)].

3. Definitions and Notations

The following terms and their corresponding definitions are used in the standard.

3.1. Definitions

Definitions

encryption algorithm: process which transforms plaintext into ciphertext (Clause 2.19 of [[ISO-IEC18033-1](#)]),

decryption algorithm: process which transforms ciphertext into plaintext (Clause 2.14 of [[ISO-IEC18033-1](#)]),

basic block cipher: block cipher which for a given key provides a single invertible mapping of the set of fixed-length plaintext blocks into ciphertext blocks of the same length,

block: string of bits of a defined length (Clause 2.6 of [[ISO-IEC18033-1](#)]),

block cipher: symmetric encipherment system with the property that the encryption algorithm operates on a block of plaintext, i.e. a string of bits of a defined length, to yield a block of ciphertext (Clause 2.7 of [[ISO-IEC18033-1](#)]),

Note: In GOST R 34.12-2015, it is established that the terms "block cipher" and "block encryption algorithm" are synonyms.

encryption: reversible transformation of data by a cryptographic algorithm to produce ciphertext, i.e., to hide the information content of the data (Clause 2.18 of [[ISO-IEC18033-1](#)]),

round key: sequence of symbols which is calculated from the key and controls a transformation for one round of a block cipher,

key: sequence of symbols that controls the operation of a cryptographic transformation (e.g., encipherment, decipherment) (Clause 2.21 of [[ISO-IEC18033-1](#)]),

Note: In GOST R 34.12-2015, the key must be a binary sequence.

plaintext: unencrypted information (Clause 3.11 of [[ISO-IEC10116](#)]),

key schedule: calculation of round keys from the key,

decryption: reversal of a corresponding encipherment (Clause 2.13 of [[ISO-IEC18033-1](#)]),

symmetric cryptographic technique: cryptographic technique that uses the same secret key for both the originator's and the recipient's transformation (Clause 2.32 of [[ISO-IEC18033-1](#)]),

cipher: alternative term for encipherment system (Clause 2.20 of [[ISO-IEC18033-1](#)]),

ciphertext: data which has been transformed to hide its information content (Clause 3.3 of [[ISO-IEC10116](#)]).

3.2. Notations

The following notations are used in the standard:

V^* the set of all binary vector-strings of a finite length (hereinafter referred to as the strings) including the empty string,

V_s the set of all binary strings of length s , where s is a non-negative integer; substrings and string components are enumerated from right to left starting from zero,

$U[*]W$ direct (Cartesian) product of two set U and W ,

$|A|$ the number of components (the length) of a string A belonging to V^* (if A is an empty string, then $|A| = 0$),

$A||B$ concatenation of strings A and B both belonging to V^* , i.e., a string from $V_{(|A|+|B|)}$, where the left substring from $V_{|A|}$ is equal to A and the right substring from $V_{|B|}$ is equal to B ,

$A \lll_{11}$ cyclic rotation of string A belonging to V_{32} by 11 components in the direction of components having greater indices

$Z_{(2^n)}$ ring of residues modulo 2^n ,

(xor) exclusive-or of the two binary strings of the same length,

$[+]$ addition in the ring $Z_{(2^{32})}$

$Vec_s: Z_{(2^s)} \rightarrow V_s$ bijective mapping which maps an element from ring $Z_{(2^s)}$ into its binary representation, i.e., for an element z of the ring $Z_{(2^s)}$, represented by the residue $z_0 + (2 \cdot z_1) + \dots + (2^{s-1} \cdot z_{s-1})$, where $z_i \in \{0, 1\}$, $i = 0, \dots, s-1$, the equality $Vec_s(z) = z_{s-1}||\dots||z_1||z_0$ holds,

$Int_s: V_s \rightarrow Z_{(2^s)}$ the mapping inverse to the mapping Vec_s , i.e., $Int_s = Vec_s^{-1}$,

PS composition of mappings, where the mapping S applies first,

P^s composition of mappings P^{s-1} and P , where $P^1=P$,

4. Description of Kuznechik cipher

This section corresponds to "Kuznechik" cipher and is described in [\[RFC7801\]](#)

5. Parameter Values

5.1. Nonlinear Bijection

The bijective nonlinear mapping is a set of substitutions:

$Pi_i = Vec_4 Pi'_i Int_4: V_4 \rightarrow V_4$,

where

$Pi'_i: Z_{(2^4)} \rightarrow Z_{(2^4)}$, $i = 0, 1, \dots, 7$.

The values of the substitution Pi' are specified below as arrays

$Pi'_i = (Pi'_i(0), Pi'_i(1), \dots, Pi'_i(15)), i = 0, 1, \dots, 7:$

```
Pi'_0 = (12, 4, 6, 2, 10, 5, 11, 9, 14, 8, 13, 7, 0, 3, 15, 1);
Pi'_1 = (6, 8, 2, 3, 9, 10, 5, 12, 1, 14, 4, 7, 11, 13, 0, 15);
Pi'_2 = (11, 3, 5, 8, 2, 15, 10, 13, 14, 1, 7, 4, 12, 9, 6, 0);
Pi'_3 = (12, 8, 2, 1, 13, 4, 15, 6, 7, 0, 10, 5, 3, 14, 9, 11);
Pi'_4 = (7, 15, 5, 10, 8, 1, 6, 13, 0, 9, 3, 14, 11, 4, 2, 12);
Pi'_5 = (5, 13, 15, 6, 9, 2, 12, 10, 11, 7, 8, 1, 4, 3, 14, 0);
Pi'_6 = (8, 14, 2, 5, 6, 9, 1, 12, 15, 4, 11, 0, 13, 10, 3, 7);
Pi'_7 = (1, 7, 14, 13, 0, 5, 8, 3, 4, 15, 10, 6, 9, 12, 11, 2);
```

5.2. Transformations

The following transformations are applicable for encryption and decryption algorithms:

$t: V_{32} \rightarrow V_{32}$ $t(a) = t(a_7 || \dots || a_0) = Pi_7(a_7) || \dots || Pi_0(a_0)$,
where $a = a_7 || \dots || a_0$ belongs to V_{32} , a_i belongs to V_4 , $i=0, 1, \dots, 7$;

$g[k]: V_{32} \rightarrow V_{32}$ $g[k](a) = (t(Vec_{32}(Int_{32}(a) [+ Int_{32}(k)]))$
 $<<<_{11}$, where k, a belong to V_{32} ;

$G[k]: V_{32}[*]V_{32} \rightarrow V_{32}[*]V_{32}$ $G[k](a_1, a_0) = (a_0, g[k](a_0)$
 $(xor) a_1)$, where k, a_0, a_1 belong to V_{32} ;

$G^*[k]: V_{32}[*]V_{32} \rightarrow V_{64}$ $G^*[k](a_1, a_0) = (g[k](a_0) (xor)$
 $a_1) || a_0$, where k, a_0, a_1 belong to V_{32} .

5.3. Key schedule

Round keys K_i belonging to V_{32} , $i=1, 2, \dots, 32$ are derived from key $K=k_{255} || \dots || k_0$ belonging to V_{256} , k_i belongs to V_1 , $i=0, 1, \dots, 255$, as follows:

```
K_1=k_255 || ... || k_224;
K_2=k_223 || ... || k_192;
K_3=k_191 || ... || k_160;
K_4=k_159 || ... || k_128;
K_5=k_127 || ... || k_96;
K_6=k_95 || ... || k_64;
K_7=k_63 || ... || k_32;
K_8=k_31 || ... || k_0;
K_(i+8)=K_i, i = 1, 2, ..., 8;
K_(i+16)=K_i, i = 1, 2, ..., 8;
K_(i+24)=K_(9-i), i = 1, 2, ..., 8.
```


6. Basic encryption algorithm

6.1. Encryption

Depending on the values of round keys K_1, \dots, K_{32} , the encryption algorithm is a substitution $E(K_1, \dots, K_{32})$ defined as follows:

$$E(K_1, \dots, K_{32})(a) = G^{*[K_{32}]}G[K_{31}] \dots G[K_2]G[K_1](a_1, a_0),$$

where $a = (a_1, a_0)$ belongs to V_{64} , and a_0, a_1 belong to V_{32} .

6.2. Decryption

Depending on the values of round keys K_1, \dots, K_{32} , the decryption algorithm is a substitution $D(K_1, \dots, K_{32})$ defined as follows:

$$D(K_1, \dots, K_{32})(a) = G^{*[K_1]}G[K_2] \dots G[K_{31}]G[K_{32}](a_1, a_0),$$

where $a = (a_1, a_0)$ belongs to V_{64} , and a_0, a_1 belong to V_{32} .

7. IANA Considerations

This memo includes no request to IANA.

8. Security Considerations

This entire document is about security considerations.

9. References

9.1. Normative References

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[9.2.](#) Informative References

[GOST28147-89]
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[ISO-IEC10116]
ISO-IEC, "Information technology - Security techniques -
Modes of operation for an n-bit block cipher, ISO-IEC
10116", 2006.

[ISO-IEC18033-1]
ISO-IEC, "Information technology - Security techniques -
Encryption algorithms - Part 1: General, ISO-IEC 18033-1",
2013.

[ISO-IEC18033-3]
ISO-IEC, "Information technology - Security techniques -
Encryption algorithms - Part 3: Block ciphers, ISO-IEC
18033-3", 2010.

[Appendix A.](#) Test Examples

This section is for information only and is not a normative part of the standard.

[A.1.](#) Transformation t

t(fdb97531) = 2a196f34,
t(2a196f34) = ebd9f03a,
t(ebd9f03a) = b039bb3d,
t(b039bb3d) = 68695433.

[A.2.](#) Transformation g

g[87654321](fedcba98) = fdcbc20c,
g[fdcbc20c](87654321) = 7e791a4b,
g[7e791a4b](fdcbc20c) = c76549ec,
g[c76549ec](7e791a4b) = 9791c849.

A.3. Key schedule

With key set to

K = ffeeddccbbaa99887766554433221100f0f1f2f3f4f5f6f7f8f9fafbfcfdfeff,

following round keys are generated:

K_1 = ffeeddcc,
K_2 = bbaa9988,
K_3 = 77665544,
K_4 = 33221100,
K_5 = f0f1f2f3,
K_6 = f4f5f6f7,
K_7 = f8f9fafb,
K_8 = fcfdfeff,

K_9 = ffeeddcc,
K_10 = bbaa9988,
K_11 = 77665544,
K_12 = 33221100,
K_13 = f0f1f2f3,
K_14 = f4f5f6f7,
K_15 = f8f9fafb,
K_16 = fcfdfeff,

K_17 = ffeeddcc,
K_18 = bbaa9988,
K_19 = 77665544,
K_20 = 33221100,
K_21 = f0f1f2f3,
K_22 = f4f5f6f7,
K_23 = f8f9fafb,
K_24 = fcfdfeff,

K_25 = fcfdfeff,
K_26 = f8f9fafb,
K_27 = f4f5f6f7,
K_28 = f0f1f2f3,
K_29 = 33221100,
K_30 = 77665544,
K_31 = bbaa9988,
K_32 = ffeeddcc.

[A.4.](#) Test Encryption

In this test example, encryption is performed on the round keys specified in clause A.3. Let the plaintext be

$a = \text{fedcba9876543210}$,

then

```
(a_1, a_0) = (fedcba98, 76543210),
G[K_1](a_1, a_0) = (76543210, 28da3b14),
G[K_2]G[K_1](a_1, a_0) = (28da3b14, b14337a5),
G[K_3]...G[K_1](a_1, a_0) = (b14337a5, 633a7c68),
G[K_4]...G[K_1](a_1, a_0) = (633a7c68, ea89c02c),
G[K_5]...G[K_1](a_1, a_0) = (ea89c02c, 11fe726d),
G[K_6]...G[K_1](a_1, a_0) = (11fe726d, ad0310a4),
G[K_7]...G[K_1](a_1, a_0) = (ad0310a4, 37d97f25),
G[K_8]...G[K_1](a_1, a_0) = (37d97f25, 46324615),
G[K_9]...G[K_1](a_1, a_0) = (46324615, ce995f2a),
G[K_10]...G[K_1](a_1, a_0) = (ce995f2a, 93c1f449),
G[K_11]...G[K_1](a_1, a_0) = (93c1f449, 4811c7ad),
G[K_12]...G[K_1](a_1, a_0) = (4811c7ad, c4b3edca),
G[K_13]...G[K_1](a_1, a_0) = (c4b3edca, 44ca5ce1),
G[K_14]...G[K_1](a_1, a_0) = (44ca5ce1, fef51b68),
G[K_15]...G[K_1](a_1, a_0) = (fef51b68, 2098cd86),
G[K_16]...G[K_1](a_1, a_0) = (2098cd86, 4f15b0bb),
G[K_17]...G[K_1](a_1, a_0) = (4f15b0bb, e32805bc),
G[K_18]...G[K_1](a_1, a_0) = (e32805bc, e7116722),
G[K_19]...G[K_1](a_1, a_0) = (e7116722, 89cadf21),
G[K_20]...G[K_1](a_1, a_0) = (89cadf21, bac8444d),
G[K_21]...G[K_1](a_1, a_0) = (bac8444d, 11263a21),
G[K_22]...G[K_1](a_1, a_0) = (11263a21, 625434c3),
G[K_23]...G[K_1](a_1, a_0) = (625434c3, 8025c0a5),
G[K_24]...G[K_1](a_1, a_0) = (8025c0a5, b0d66514),
G[K_25]...G[K_1](a_1, a_0) = (b0d66514, 47b1d5f4),
G[K_26]...G[K_1](a_1, a_0) = (47b1d5f4, c78e6d50),
G[K_27]...G[K_1](a_1, a_0) = (c78e6d50, 80251e99),
G[K_28]...G[K_1](a_1, a_0) = (80251e99, 2b96eca6),
G[K_29]...G[K_1](a_1, a_0) = (2b96eca6, 05ef4401),
G[K_30]...G[K_1](a_1, a_0) = (05ef4401, 239a4577),
G[K_31]...G[K_1](a_1, a_0) = (239a4577, c2d8ca3d).
```

Then the ciphertext is

$b = G^{*}[K_{32}]G[K_{31}]...G[K_1](a_1, a_0) = 4ee901e5c2d8ca3d$.

A.5. Test Decryption

In this test example, decryption is performed on the round keys specified in clause A.3. Let the ciphertext be

$b = 4ee901e5c2d8ca3d$,

then

```
(b_1, b_0) = (4ee901e5, c2d8ca3d),
G[K_32](b_1, b_0) = (c2d8ca3d, 239a4577),
G[K_31]G[K_32](b_1, b_0) = (239a4577, 05ef4401),
G[K_30]...G[K_32](b_1, b_0) = (05ef4401, 2b96eca6),
G[K_29]...G[K_32](b_1, b_0) = (2b96eca6, 80251e99),
G[K_28]...G[K_32](b_1, b_0) = (80251e99, c78e6d50),
G[K_27]...G[K_32](b_1, b_0) = (c78e6d50, 47b1d5f4),
G[K_26]...G[K_32](b_1, b_0) = (47b1d5f4, b0d66514),
G[K_25]...G[K_32](b_1, b_0) = (b0d66514, 8025c0a5),
G[K_24]...G[K_32](b_1, b_0) = (8025c0a5, 625434c3),
G[K_23]...G[K_32](b_1, b_0) = (625434c3, 11263a21),
G[K_22]...G[K_32](b_1, b_0) = (11263a21, bac8444d),
G[K_21]...G[K_32](b_1, b_0) = (bac8444d, 89cadf21),
G[K_20]...G[K_32](b_1, b_0) = (89cadf21, e7116722),
G[K_19]...G[K_32](b_1, b_0) = (e7116722, e32805bc),
G[K_18]...G[K_32](b_1, b_0) = (e32805bc, 4f15b0bb),
G[K_17]...G[K_32](b_1, b_0) = (4f15b0bb, 2098cd86),
G[K_16]...G[K_32](b_1, b_0) = (2098cd86, fef51b68),
G[K_15]...G[K_32](b_1, b_0) = (fef51b68, 44ca5ce1),
G[K_14]...G[K_32](b_1, b_0) = (44ca5ce1, c4b3edca),
G[K_13]...G[K_32](b_1, b_0) = (c4b3edca, 4811c7ad),
G[K_12]...G[K_32](b_1, b_0) = (4811c7ad, 93c1f449),
G[K_11]...G[K_32](b_1, b_0) = (93c1f449, ce995f2a),
G[K_10]...G[K_32](b_1, b_0) = (ce995f2a, 46324615),
G[K_9]...G[K_32](b_1, b_0) = (46324615, 37d97f25),
G[K_8]...G[K_32](b_1, b_0) = (37d97f25, ad0310a4),
G[K_7]...G[K_32](b_1, b_0) = (ad0310a4, 11fe726d),
G[K_6]...G[K_32](b_1, b_0) = (11fe726d, ea89c02c),
G[K_5]...G[K_32](b_1, b_0) = (ea89c02c, 633a7c68),
G[K_4]...G[K_32](b_1, b_0) = (633a7c68, b14337a5),
G[K_3]...G[K_32](b_1, b_0) = (b14337a5, 28da3b14),
G[K_2]...G[K_32](b_1, b_0) = (28da3b14, 76543210).
```

Then the plaintext is

$a = G^{*}[K_1]G[K_2]...G[K_{32}](b_1, b_0) = fedcba9876543210$.

Appendix B. Background

Algorithmically Magma is a variation of block cipher defined in [RFC5830] ([GOST28147-89]) with the following clarifications and minor modifications:

1. S-BOX set is fixed at id-tc26-gost-28147-param-Z (See [Appendix C of \[RFC7836\]](#));
2. key is parsed as a single big-endian integer (compared to little-endian approach used in [GOST28147-89]), which results in different subkey values being used;
3. data are also parsed as single big-endian integer (instead of being parsed as little-endian integer).

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