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The Security Evaluated Standardized Password Authenticated Key Exchange
(SESPAKE) Protocol
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Abstract

This document specifies the Security Evaluated Standardized Password Authenticated Key Exchange (SESPAKE) protocol. The SESPAKE protocol provides password authenticated key exchange for usage in the systems for protection of sensitive information. The security proofs of the protocol was made for the case of an active adversary in the channel, including MitM attacks and attacks with trials of impersonation as one of subjects.

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[1.](#) Introduction

The current document contains the description of the password authenticated key exchange protocol SESPAKE (security evaluated standardized password authenticated key exchange) for usage in the systems for protection of sensitive information. The protocol is intended to use for establishment of keys that are then used for organization of secure channel for protection of sensitive information. The security proofs of the protocol was made for the case of an active adversary in the channel, including MitM attacks and attacks with trials of impersonation as one of subjects.

The protocol is based on the Russian national standards GOST R 34.10-2012 [[GOST3410-2012](#)] and GOST R 34.11-2012 [[GOST3411-2012](#)]. The English versions of these standards can be found in [[RFC7091](#)] and [[RFC6986](#)];

[2.](#) Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [[RFC2119](#)].

3. notations

This document uses the following parameters of elliptic curves in accordance with the GOST R 34.10-2012 [[GOST3410-2012](#)] standard:

- E an elliptic curve defined over a finite prime field $GF(p)$, where $p > 3$;
- p the characteristic of the underlying prime field;
- a, b the coefficients of the equation of the elliptic curve in the canonical form;
- m the elliptic curve group order;
- q the elliptic curve subgroup order;
- P generator of the subgroup of order q;
- X, Y the coordinates of the elliptic curve point in the canonical form;
- O zero point of the elliptic curve.

This memo uses the following functions:

H₂₅₆(T) the value of the GOST R 34.11-2012 hash function (see [[RFC6986](#)]) with 256-bit output for a message T;

H₅₁₂(T) the value of the GOST R 34.11-2012 hash function (see [[RFC6986](#)]) with 512-bit output for a message T;

HMAC(K,T) the 256-bit value of the function for calculating a message authentication code, based on a hash function in accordance with [[RFC2104](#)];

F(PW, salt, n) the value of the function PBKDF2(PW,salt,n,len), where PBKDF2(PW,salt,n,len) is calculated according to [[RFC2898](#)] using HMAC_GOSTR3411_2012_512 defined in [[I-D.smyshlyaev-gost-usage](#)] as PRF function. The parameter len is considered equal to 256, if the order of the subgroup q is such that $2^{254} < q < 2^{256}$, and equal to 512, if $2^{508} < q < 2^{512}$.

This document uses the following terms and definitions for the sets and operations on the elements of these sets

B_n the set of byte strings of size n , $n \geq 0$, for $n = 0$ the B_n set consists of a single empty string of size 0; if b is an element of B_n , then $b = (b_1, \dots, b_n)$, where b_1, \dots, b_n are elements of $\{0, \dots, 255\}$;

$\text{int}(w')$ if the byte string $w' = (w_1, \dots, w_l)$ is in B_l , then $\text{int}(w')$ is an integer $w = 256^{(l-1)}w_1 + \dots + 256^{(0)}w_l$;

$\text{INT}(w')$ if the byte string $w' = (w_1, \dots, w_l)$ is in B_l , then $\text{INT}(w')$ is an integer $W = 256^{(l-1)}w_1 + \dots + 256^{(0)}w_l$;

$F(\text{PW}, \text{salt}, n)$ the value of the function $\text{PBKDF2}(\text{PW}, \text{salt}, n, \text{len})$, where $\text{PBKDF2}(\text{PW}, \text{salt}, n, \text{len})$ is calculated according to [\[RFC2898\]](#) using $\text{HMAC_GOSTR3411_2012_512}$ defined in [\[I-D.smyshlyaev-gost-usage\]](#) as PRF function. The parameter len is considered equal to 256, if the order of the subgroup q is such that $2^{254} < q < 2^{256}$, and equal to 512, if $2^{508} < q < 2^{512}$.

$||$ concatenation of byte strings A and C , i.e., if A in B_{n1} , C in B_{n2} , $A = (a_1, a_2, \dots, a_{n1})$ and $C = (c_1, c_2, \dots, c_{n2})$, then $A||C = (a_1, a_2, \dots, a_{n1}, c_1, c_2, \dots, c_{n2})$ is an element of $B_{(n1+n2)}$;

Byte representation of a point $\{X, Y\}$ If $\{X, Y\}$ is an elliptic curve point then the byte representation of $\{X, Y\}$ is a concatenation of the coordinates of this point $X||Y$; the length of the bit representations of the coordinates X and Y is equal to the minimum possible length of the byte representation of the subgroup generator p .

4. Protocol description

The protocol is used by subjects A and B that are commencing key establishment with password-based authentication.

4.1. Protocol parameters

Various elliptic curves can be used in the protocol. For each elliptic curve the following values must be defined:

- o the curve identifier ID_ALG , that is a byte string of arbitrary length;
- o the point P , that is a generator point of the q -order group of the curve (the point MUST be generated with a "proven random generation" technique - similar to the technique described in [Section 5](#));

- o the set of distinct curve points $\{Q_1, Q_2, \dots, Q_N\}$, where the total number of points N is defined for protocol instance. The method of generation of the points $\{Q_1, Q_2, \dots, Q_N\}$ is described in [Section 5](#)).

The protocol parameters that are used by subject A are the following:

1. The secret password value PW , which is a byte string that is uniformly randomly chosen from a subset of cardinality 10^{10} or greater of the set B_k , where $k \geq 6$ is password length.
2. The list of curve identifiers supported by A.
3. Sets of points $\{Q_1, Q_2, \dots, Q_N\}$, corresponding to curves supported by A.
4. The C_1^A counter, that tracks the total number of unsuccessful authentication trials in a row, and a value of $CLim_1$ that stores the maximum possible number of such events.
5. The C_2^A counter, that tracks the total number of unsuccessful authentication events during the period of usage of the specific PW , and a value of $CLim_2$ that stores the maximum possible number of such events.
6. The C_3^A counter, that tracks the total number of authentication events (successful and unsuccessful) during the period of usage of the specific PW , and a value of $CLim_3$ that stores the maximum possible number of such events. The identifier ID_A of subject A (optional), a byte string of an arbitrary length.

The protocol parameters that are used by subject B are the following:

1. The values ind and $salt$, where ind is in $\{1, \dots, N\}$, $salt$ is in $\{1, \dots, 2^{128}-1\}$.
2. The point Q_{PW} , satisfying the following equation:

$$Q_{PW} = \text{int} (F (PW, salt, 2000)) * Q_{ind}.$$

It is possible that the point Q_{PW} is not stored and is calculated using PW in the beginning of the protocol. In that case B has to store PW and points Q_1, Q_2, \dots, Q_N .

3. The ID_ALG identifier of the elliptic curve used in the protocol.

4. The C_{1^A} counter, that tracks the total number of unsuccessful authentication trials in a row, and a value of $CLim_1$ that stores the maximum possible number of such events.
5. The C_{2^A} counter, that tracks the total number of unsuccessful authentication events during the period of usage of the specific PW, and a value of $CLim_2$ that stores the maximum possible number of such events.
6. The C_{3^A} counter, that tracks the total number of authentication events (successful and unsuccessful) during the period of usage of the specific PW, and a value of $CLim_3$ that stores the maximum possible number of such events. The identifier ID_B of subject B (optional), a byte string of an arbitrary length.

4.2. Initial values of the protocol counters

After the setup of a new password value PW the values of the counters must be assigned as follows:

- o $C_{1^A} = C_{1^B} = CLim_1$, where $CLim_1$ is in $\{3, \dots, 5\}$;
- o $C_{2^A} = C_{2^B} = CLim_2$, where $CLim_2$ is in $\{7, \dots, 20\}$;
- o $C_{3^A} = C_{3^B} = CLim_3$, where $CLim_3$ is in $\{10^3, \dots, 10^5\}$.

4.3. Protocol actions

The described protocol consists of the following actions:

1. The values ind and $salt$, where ind is in $\{1, \dots, N\}$, $salt$ is in $\{1, \dots, 2^{128}-1\}$.
2. If any of the counters C_{1^A} , C_{2^A} , C_{3^A} is equal to 0, A finishes the protocol with an error that informs of exceeding the number of trials that is controlled by the corresponding counter.
3. A decrements each of the counters C_{1^A} , C_{2^A} , C_{3^A} by 1, requests open authentication information from B and sends the ID_A identifier.
4. If any of the counters C_{1^B} , C_{2^B} , C_{3^B} is equal to 0, B finishes the protocol with an error that informs of exceeding the number of trials that is controlled by the corresponding counter.
5. B decrements each of the counters C_{1^B} , C_{2^B} , C_{3^B} by 1.

6. B sends the values of `ind`, `salt` and the `ID_ALG` identifier to A. All following calculations are done by B in the elliptic curve group defined by the `ID_ALG` identifier.
7. A sets the curve defined by the received `ID_ALG` identifier as the used elliptic curve. All following calculations are done by A in this elliptic curve group.
8. A calculates the point $Q_{PW^A} = \text{int}(F(PW, \text{salt}, 2000)) * Q_{ind}$.
9. A chooses randomly (according to the uniform distribution) the value `alpha`, `alpha` is in $\{1, \dots, q-1\}$, and assigns $z_A=0$.
10. A sends the value $u_1 = \text{alpha} * P - Q_{PW^A}$ to B.
11. After receiving `u_1` B checks that `u_1` is in E. If it is not, B finishes with an error, considering the authentication process unsuccessful.
12. B calculates $Q_B = u_1 + Q_{PW}$, assigns $z_B = 0$ and chooses randomly (according to the uniform distribution) the value `beta`, `beta` is in $\{1, \dots, q-1\}$.
13. If $m/q * Q_B = 0$, B assigns $Q_B = P$ and $z_B = 1$.
14. B calculates $K_B = H_{256}((m/q * \text{beta} * (\text{mod } q)) * Q_B)$, where the input of a hash function is a little-endian representation of the obtained point (x-coordinate first, then y-coordinate).
15. B sends the value $u_2 = \text{beta} * P + Q_{PW}$ to A.
16. After receiving `u_2`, A checks that `u_2` is in E. If it is not, A finishes with an error, considering the authentication process unsuccessful.
17. A calculates $Q_A = u_2 - Q_{PW^A}$.
18. If $m/q * Q_A = 0$, then A assigns $Q_A = P$ and $z_A = 1$.
19. A calculates $K_A = H_{256}((m/q * \text{alpha} * (\text{mod } q)) * Q_A)$, where the input of a hash function is a little-endian representation of the obtained point (x-coordinate first, then y-coordinate).
20. A calculates $MAC_A = \text{HMAC}(K_A, 0x01 || ID_A || ind || salt || u_1 || u_2 || DATA_A)$ and sends $DATA_A || MAC_A$ to B, where `DATA_A` is an optional string that is authenticated with `MAC_A` (if it is not used, then `DATA_A` is considered to be of zero length).

21. B checks that the values MAC_A and HMAC (K_B, 0x01 || ID_A || ind || salt || u_1 || u_2 || DATA_A) are equal. If they are not, it finishes with an error, considering the authentication process unsuccessful.
22. If z_B = 1, B finishes, considering the authentication process unsuccessful.
23. B sets the value of C_1^B to CLim_1 and increases C_2^B by 1.
24. B calculates MAC_B = HMAC(K_B, 0x02 || ID_B || ind || salt || u_1 || u_2 || DATA_A || DATA_B) and sends MAC_B || DATA_B to A, where DATA_B is an optional string that is authenticated with MAC_B (if it is not used, then DATA_B is considered to be of zero length).
25. A checks that the values MAC_B and HMAC (K_A, 0x02 || ID_B || ind || salt || u_1 || u_2 || DATA_A || DATA_B) are equal. If they are not, it finishes with an error, considering the authentication process unsuccessful.
26. If z_A = 1, A finishes, considering the authentication process unsuccessful.
27. A sets the value of C_1^A to CLim_1 and increases C_2^A by 1.

After the successful finish of the procedure the subjects A and B are mutually authenticated and each subject has an explicitly authenticated value of $K = K_A = K_B$.

N o t e:

1. Keys K_A, K_B in actions 13 and 18 are produced according to VKO_GOSTR3410_2012_256, algorithm defined in [\[I-D.smyshlyaev-gost-usage\]](#).
2. If an optional parameter ID_A (or ID_B) is not defined, it SHOULD be considered equal to a fixed byte string (zero-length string is allowed) defined by a specific implementation.
3. The ID_ALG parameter can be fixed or agreed in advance.
4. The ind, ID_A, ID_B and salt parameters can be agreed in advance. If some parameter is agreed in advance, it is possible not to send it during a corresponding action. Nevertheless, all parameters MUST be used as corresponding inputs to HMAC function HMAC during stages 19, 20, 23 and 24.

5. Continuation of protocol interaction in case of any of the counters C_{1^A} , C_{1^B} being equal to zero MAY be done without changing password. In this case these counters can be used for protection against denial-of-service attacks. For example, continuation of interaction can be allowed after a certain delay.
6. Continuation of protocol interaction in case of any of the counters C_{2^A} , C_{3^A} , C_{2^B} , C_{3^B} being equal to zero MUST be done only after changing password.

5. Construction of points Q_1, \dots, Q_N

For a given elliptic curve E the algorithm of construction of each point Q_i in the set $\{Q_1, \dots, Q_N\}$ that corresponds to this curve is based on choosing points with coordinates with known preimages of a cryptographic hash function: H_{256} , if the subgroup order q is such that $2^{254} < q < 2^{256}$, and H_{512} , if $2^{508} < q < 2^{512}$. The algorithm consists of the following steps:

1. Choose an arbitrary SEED value with length of 32 bytes or more.
2. Calculate $X = \text{INT}(H_{\text{len}}(\text{SEED})) \bmod p$.
3. Check that the value of $X^3 + aX + b$ is a quadratic residue in the field F_p . If it is not, return to Step 1.
4. Choose the value of Y arbitrarily from the set $\{+\sqrt{A}, -\sqrt{A}\}$, where $A = X^3 + aX + b$. Here \sqrt{A} is an element of F_p , for which $(\sqrt{A})^2 = A \bmod p$.
5. Check that for point $Q = (X, Y)$ the following relations hold: $Q \neq 0$ and $q \cdot Q = 0$. If they do not, return to Step 1.

With the defined algorithm for any elliptic curve E point sets $\{Q_1, \dots, Q_N\}$ are constructed. Constructed points in one set MUST have distinct x-coordinates.

N o t e: The knowledge of hash function preimage prevents knowledge of the multiplicity of any point related to generator point P . It is of primary importance, because such a knowledge could be used to implement an attack against protocol with exhaustive search of password.

6. Acknowledgments

We thank Lolita Sonina, Georgy Borodin, Sergei Agafin and Ekaterina Smyshlyaeva for their careful readings and useful comments.

7. Security Considerations

This entire document is about security considerations.

8. Normative References

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[Appendix A](#). Examples of points

There are three points (Q_1 , Q_2 , Q_3) for each of the elliptic curves below. This points were constructed using the method described in [Section 5](#). The same method should be used for constructing, if necessary, additional points. Each of the points is represented by a pair of $\{X, Y\}$ coordinates in the canonical form and by a pair of $\{U, V\}$ coordinates in the twisted Edward form in accordance with the document [[I-D.smyshlyaev-gost-usage](#)] for the curves that have the equivalent representation in this form. There is a SEED value for each point, by which it was generated.

[A.1](#) Curve `id-GostR3410-2001-CryptoPro-A-ParamSet`

Point Q_1

X= 0xa33ce065b0c23e1d3d026a206f8a1f8747ed1cd92a665bf85198cdb10ac90a5c

Y= 0xb00d0dc0733883f05de9f55fd711f55998f5508cc40bead80c913b4d5b533667

SEED:

```
f8 18 95 b4 13 69 d9 08 9e 3d 3c 56 e8 70 ba 5e
9d 55 5e 20 eb d9 c7 22 66 10 6d 79 c2 83 48 b8
ce 63 70 52 9a 82 9f 18 a4 d3 e3 fd 7b f2 dd 73
b1 1b bc d4 10 9d 27 c9 a3 d4 bd 3a 42 cc 26 ae
43 5b 52 f5 89 a4 c3 b7 61 c0 1b a2 88 b7 e0 8d
f9 4e 22 40 29 f3 aa 96 11 5c 43 f5 eb 87 99 70
```

Point Q_2

X= 0x4ce9c2bcf17212b9efcab65c3c815c0ff96d7461c957634dbfd1fe7c9a324d27

Y= 0xf7500d7adea2c2b4a16d838a8faa02b46639eb881f124d0f2506efca0e24289d

SEED:

```
fd 99 6d bc c7 2e 49 a4 37 e7 49 a8 85 ad de 28
4b 58 64 bd 3b 7e 60 fc b5 2f c8 36 0e 0a bf 98
fd 35 7a 3f 98 c5 f6 20 c8 68 3d b2 ca b9 27 b6
13 f2 91 a1 52 45 c0 65 71 dc 62 b0 4f 2e e5 76
56 a9 fa 51 12 23 5d 0b 80 67 59 af e2 33 b1 09
6a 94 84 91 45 f2 18 50 65 b7 9b 86 ab 68 8a 39
```

Point Q_3

X= 0x31fb8e5070b1e0f52f047f40477c38c6020fd8da9f685791f9237cc47bd89324

Y= 0x8ba1184a4e296dc5c5873639747339ecc71b7fa44d31cc8e35b6615a4f797dd7

SEED:

```
29 0c 12 66 47 91 2e de 11 cc 43 78 0c f8 87 d4
7d a1 63 bc fb 91 1d 92 86 2a ae 4f 53 a6 80 70
08 c1 ec 0c 8f e7 2e 0a a0 81 df a3 32 7c 86 ad
5f 24 da 28 a7 1d 07 f5 fd b7 61 31 a1 fb 04 d5
b2 31 c7 7f ca 26 d3 a6 42 99 9e 3b 10 74 b5 a7
b3 54 2f 03 b0 39 63 2a 6b 44 56 36 fb 52 8d 58
```

[A.2](#) Curve `id-GostR3410-2001-CryptoPro-B-ParamSet`

Point Q_1

X= 0x0ad754474a915d9d706c6b8dc879858a1cb85cc8f6c148fc3120825393ecd394

Y= 0x68c33b6d0343cf72cb19666ffd487fa94294dc677b28c8e27ec36068fff85ed83

SEED:


```

78 1d 7d 85 ff 04 12 b9 92 a7 6e 65 37 dd 83 81
9b 81 2f fa bf e8 92 3c d0 12 fe dc 00 c4 96 69
f6 52 44 4d 38 9a f2 b2 6f 57 b5 3e 2d 0f 81 2e
db 2c f3 d6 a7 18 42 52 32 da 47 18 75 1e ec ef
8f 2b c5 03 17 fb 49 6f 02 05 d7 99 bc 3c 34 87
12 f5 1b d3 ef aa 7f f5 ba c2 52 07 80 46 34 77

```

Point Q_2

```

X= 0x1cd96e72fdf1ce6b544dec12d0d7bcb9f6ba65bba3d9f7af732bcb133c1b6437
Y= 0x34ab5b63c286a2b885ca443ac875a8f9ec0c2f148f1622bc64c83b80e6e3d31f
SEED:

```

```

62 93 40 15 63 0c 9a 09 ce 76 32 6c fd 1c 04 36
ee 08 bc 92 b9 c0 3a d9 63 c6 db 00 18 12 12 fa
e0 1a 46 38 8b b6 81 df ae 4f 64 3e cc 0c 93 8c
e4 10 36 2f d9 6d 5c fd 99 f3 9c 13 fd 30 52 a1
3e 8b 35 8b ed 1c 31 b0 39 9c 03 dc 5a 94 2b 41
f8 ff 9d 62 41 bd eb 9d bf cf 54 b6 c8 cc d1 06

```

Point Q_3

```

X= 0x18dda7154e5abef001dc9943554439cb44b9e26256def176849da5f09b5f690d
Y= 0x3ef584be59673d1751b2fd6e3fdc619e3d756c0d355595b3a62196de048ece44
SEED:

```

```

33 17 39 c1 38 82 98 88 14 68 83 c6 97 14 86 8c
d0 d2 1a 28 41 51 99 a9 33 40 15 0b 30 88 35 01
4a 41 42 f8 d8 9a a6 bd e1 a6 81 23 94 19 e8 a0
ef 3d 36 02 ef ff 38 e6 10 4b 11 2f 7b b5 50 42
5a 7b 39 a6 00 53 1a 92 fc cc 2b 0d 95 dd ea 95
42 d4 27 6f a8 0f ae 45 b2 d6 f4 38 c1 52 17 5d

```

[A.3 Curve id-GostR3410-2001-CryptoPro-C-ParamSet](#)

Point Q_1

```

X= 0x339f791f62938871f241c1c89643619aa8b2c7d7706ce69be01fddff3f840003
Y= 0x31d6d9264cc6f8fe09bf7aa48910b4ad5ddfd74a2ef4699b76de09ffed295f11
SEED:

```

```

0e 29 35 9d 45 dd a3 b4 57 9b 17 e8 87 d9 9e 63
b9 d6 04 e3 ac 74 83 11 91 2a 5b d4 86 7b 5d 9c
5d 07 70 64 cd f1 2d 93 f7 f0 2e f0 0a e1 7b 8b
c1 87 50 b3 8f 39 bb 95 68 21 5c 42 e2 4e 8c fe
59 e9 0f a6 05 0b 76 68 a2 94 da 5f 2c 9a 27 28
1f 3a 7e 4e 14 54 10 21 01 6f 2c a2 97 77 94 12

```

Point Q_2

```

X= 0x80f4d03b00b1b9b53f6bb4ffa52be65a6d316de846e27f44ccd795bc62d89e23
Y= 0x38dd712518ddec19b46afcccba97338d89d1292427dc12985d4e848066cd1ab
SEED:

```

```

f5 61 4e 92 8f e5 5c 77 26 37 ab ac 1b 1e 3c dd
2a 37 77 be 25 23 cc 58 9a 79 5a 60 28 db 9e 64
f8 62 73 01 98 3e dd 23 0b eb 07 3e 81 9b cb d9
94 bc bf 7f 9e 5f e1 8f a5 8a ce 9e f2 99 0e 9d
fb ee 1c 64 38 22 33 c3 1b e7 05 9e c2 e9 bb 46
b9 dc 15 19 9d e0 9f cb 65 d5 6d 46 2f 01 21 65

```

Point Q_3

X= 0x0c8b64c3f0ec7ece81b6232db2e8054666d051ee28254d4b9a4bcb1460ca546b
 Y= 0x88c98b48b22b90d0d3a018da55ca0d05cedd82b6c838bd62aba2b823ce82b28f
 SEED:

8a 1b 29 62 38 f5 c2 e2 9b 4a c0 5b 6d 57 99 88
 86 69 a4 1b b9 f6 60 f3 a3 15 26 e5 f4 33 1e ae
 80 9a 38 52 f5 44 86 91 71 76 1c ab 77 0a b6 2e
 c3 6f d6 4d 3c 31 a3 67 2a 82 25 bf d6 ae c9 95
 66 95 b8 87 39 6a 3e bf ef 28 65 16 b9 51 29 1d
 65 df 12 7a eb 4c ec f1 6f 08 f5 98 36 0a b9 a0

A.4 Curve id-tc26-gost-3410-2012-512-paramSetA

Point Q_1

X= 0x301aac1a3b3e9c8a65bc095b541ce1d23728b93818e8b61f963e5d5b13eec0fe
 e6b06f8cd481a07bb647b649232e5179b019eef7296a3d9cfa2b66ee8bf0cbf2
 Y= 0x191177dd41ce19cc849c3938abf3adaab366e5eb2d22a972b2dcc69283523e89
 c9907f1d89ab9d96f473f96815da6e0a47297fcdd8b3adac37d4886f7ad055e0

SEED:

64 1c 90 19 c5 d7 68 91 de d1 9a 31 28 4e 7c d3
 c6 8b 74 e5 e6 a7 20 b5 2c fb 45 17 9f 91 b3 f6
 3a 0c b2 5e 3f 91 e3 eb 80 3d 80 4f 79 98 a3 57
 f2 e5 dc 5d 84 ab d6 7d 33 a3 2b 89 66 db c6 94
 96 8f 96 2d 37 9e 33 c0 fd 14 32 dd 02 70 fb 61
 1a 88 4c 6d ae 1b 58 20 24 6e 80 80 5d cd a8 66

Point Q_2

X= 0x7edc38f17f88e3105bafb67c419d58fe6a9094dd4dc1a83bcaccc61f020ac447
 92eba888457c658ee2d82557b7c6ab6efd61ba0c3327741d09a561a8b860a085
 Y= 0x3af1400a7a469058d9ba75e65ea5d3f4d0bdb357fa57eb73fa4900e2dca4da78
 b8e5ff35ca70e522610bb1fc76b102c81cc4729f94b12822584f6b6229a57ea1

SEED:

3d ad a1 b4 fb 87 3e 13 1e 51 62 60 1f ee f1 54
 b0 77 e0 71 1b cf da 74 a2 20 7e a3 20 01 c3 f5
 79 00 5f 10 9f c1 83 83 4e 29 46 b3 29 8a 4c 10
 0c 69 f4 c6 40 92 3f ed af b2 68 08 0b 6b 1c 07
 48 a1 18 29 6e 64 9b f6 1d eb 26 27 b4 77 9e e8
 e0 ff c1 db 48 5d 8b c1 10 8c 58 b1 af 07 5f 7b

Point Q_3

X= 0x387acfba7bbc5815407474a7c1132a1bded12497243d73ef8133d9810eb21716
 95dde2ff15597e159464a1db207b4d1fff98fbb989f80c2db13bc8ff5fea16d59
 Y= 0x4c816d1ca3e145ac448478fb79a77e1ad2dfc69576685e2f6867ec93fbad8aa4
 4111acd104036317095bce467e98f295436199c8ead57f243860d1bde8d88b68

SEED:

7c 8d a6 91 96 0d 9d 06 65 92 23 08 df cf 51 71
 bd 7c 4b f8 50 1b 3f fd 3c b1 58 3a 30 e1 a7 17
 4e 09 e2 5f 1d 19 35 6e b0 51 66 1c d0 2a c1 9e
 48 22 38 49 76 0d 43 4e 20 ea d1 80 73 84 1c e8
 36 a6 8e f3 24 bb 2d 57 45 32 a5 d4 e6 08 73 fa
 d3 8c 32 e8 af a1 c5 25 8c ff 3d 52 ca ac 98 d1

A.5 Curve id-tc26-gost-3410-2012-512-paramSetB

Point Q_1

X= 0x488cf12b403e539fde9ee32fc36b6ed52aad9ec34ff478c259159a85e99d3dda
 dfd5d73606ecee351e0f780a14c3e9f14e985d9d7ddec93b064fc89b0c843650
 Y= 0x7bc73c032edc5f2c74dd7d9da12e1856a061ce344a77253f620592752b1f3a3d
 cbbc87eb27ec4ed5e236dfcb03f3972404747e277671e53a9e412e82aaf6c3f7

SEED:

40 57 8b 1a c0 bd 53 8d 75 97 2d 49 9b 1c c6 73
 94 c8 f7 d4 76 cd fe 15 59 02 fa 0f 28 b8 06 e1
 81 4c fb d0 4d 62 86 0c 4a ce c1 0e 88 13 da 2a
 d4 fd 7a 13 4d ba 75 0d 2c 80 f2 68 ba c1 b4 34
 98 ea fe 10 51 86 60 b7 70 30 f8 64 6f 21 d9 40
 aa da 62 3e ad 44 3f 93 73 a5 6b c3 15 55 3c bd

Point Q_2

X= 0x175166b97248bda12ec035df2e312a2771d0b16977c9cbc79461ff05e01f719c
 92ae8b53f3b7e3edcacffcc5063b5e9c8de18d0cb87da358350992132173df69
 Y= 0x10e2943dc1a18a841ab76ac756fa974948d5a18d071d458a4769c2494fe2a6c5
 966e3c8931e624d87259156aea9317157502698e4a4a489c327b89277cf59b4c

SEED:

26 01 07 1b 3d 3e 6d e7 0e d0 22 ae be 81 be 47
 51 77 49 b6 5d 29 d1 07 5c df cb f4 56 a8 77 54
 2b e9 91 50 34 06 b3 aa 71 c5 ce 16 b6 5f e9 93
 e7 48 99 58 b1 26 81 10 9f 9b e4 30 38 73 77 13
 f0 6a 4f 30 05 b2 66 76 9f b8 1b 5f 39 55 52 97
 ab 46 6b 5d 2e 19 2d 12 f3 2a b3 18 72 71 52 62

Point Q_3

X= 0x01f4583db894cdebd7c591af848783ee011a20567751ca1561f398a6118ace08
 a4efe1501bda67f39d060270ba660526dc53063c6b40fa5548c9a9e7688f2239
 Y= 0x7bc640641d70c8296bd9257c9eebb5b1bd3196a169bac04f7579bf27b5847d4e
 7b4f63748ad81b5469070ed35ad93e5a5258652306f84094eae04a91954536ee

SEED:

bb 9a 63 a5 67 7d 40 7c f3 4d 06 df 96 7d d9 e9
 ca 4d 42 eb d6 7d a5 69 a4 9b d8 b1 04 64 2e 20
 fb a9 9d 84 2f cb 54 76 61 dc 7a a4 de 72 6f 67
 4a 09 85 46 20 04 7c c1 75 2c ab 67 99 8b 5c 8e
 6a 88 6d 0a 06 e6 a3 fa e8 19 34 21 1a ec 81 8d
 89 03 9e 45 dc a1 85 03 7e c3 49 37 33 ee 3c 2e

A.6 Curve id-tc26-gost-3410-2012-256-paramSetA

Point Q_1

X= 0x5161b08a973d521bdde0cbd45b68aa0470e1058dd936e5bd618fd3373770eed9
 Y= 0xc1633db551677c62b9c2b69d47e503c0f8ca83b6b3109dece0a5f985d77a83a7
 U= 0x9c5ad63ddc3314ac009d879780d6219720bf4573f4fe6b4bf7a0a88860677f9d
 V= 0x8ee071a767f3d6f0435eb6100d1a936f984e43d9af0bc91c864a9e65cee025fb

SEED:

c4 7e 5e 42 31 4e dd 8e e9 ac 39 fb c8 da ea c8
 e6 5b fd 26 58 27 4e 1f 99 e9 33 e1 1e 5d f2 62
 4a e3 97 f1 7e db f9 83 60 f3 ec 2e 8f 6f 2e ff
 d4 aa 80 5c 71 d6 ed 5b a1 5b c9 d0 ad d6 38 23
 84 c1 55 20 a5 b8 bb bd 7b 23 1f c8 fb 8c 77 71

57 b9 77 25 91 55 3f 17 46 8c 4b b3 64 6f 9f 53

Point Q_2

X= 0xd47abd59dcccad35849dec9dc721ffa1e44419ca8686406a9f441e61294b210ed
Y= 0xa78b64220bf3375d08de0ea5e2920cfd8f204da6757bf1878ac870fb7e5ca0e8
U= 0xf0195efb6b249eb8018c19376907c787511bf30516a5c27d045fc7ba2af58ed0
V= 0xacae88466127df000b663863bc7bd394eafa6996fcedad11d7834f502a6a2686

SEED:

30 5f d0 bb ce c7 16 49 ac e4 1b 4d ca 07 6c a6
96 a8 8c c6 fd 06 91 a8 79 13 5d e1 90 96 e3 c8
03 c5 b4 ad 41 68 36 9b e7 b9 ed 81 d6 e2 bd 0c
a2 8e b0 e9 6f 74 2d 50 e2 df b6 a1 86 ae 15 60
96 a3 5a 97 a2 20 fa 6d 0f cf 88 db 6d 86 cd db
19 7c 3a 21 5f 10 cc ea 42 95 ef aa b2 63 95 d5

Point Q_3

X= 0xe0d610ff42ce21eb308980964ca368963f5eb5cb08c277187d22d0c94f4bf0762
Y= 0x82619b88da25b666e07b617ff487be8afd5af8b092568b493ecef44ee0c04b5f
U= 0x723df0719311d095b814ee05ca086e18c410c375a48789dc03c3fe844ed3b7c9
V= 0x160e1b5338337ee0620745206dbe5556a7ff5d19735418a3cc03bf7f2735ce25

SEED:

22 16 91 c7 21 8d 93 d4 a8 ad 15 e4 72 33 84 90
ca 5c 5e 3b 84 84 57 4e bc df 83 26 68 84 5e f4
09 53 71 79 7a f8 e2 a6 e3 99 93 de 2a 7c 65 f0
37 26 2e cc fa 95 58 9a c6 e8 b1 2d e6 09 af be
f9 2f 12 d0 a3 08 56 9a b3 c0 fa d8 ec 5d 7b 9c
f4 27 1f aa 54 bc bb da 31 61 b7 cd f5 40 d6 b8

A.7 Curve id-tc26-gost-3410-2012-512-paramSetC

Point Q_1

X= 0x5b065ead2e94de0ee2e462de204c93c6b2bf3498ad920393cb60259e1a8ffc7c
7e7d4defa20ff4282abf70207e4611d532f40db6800e29d2b53f6ac0713e5b38
Y= 0xa39a28c59ff7f796b85223b8834384907c626086415487288ed1182ca4487dc1
ae5f37af90fd267b7c0dc8542ea52cd984af54731bc84271d6186d973c91359b
U= 0x3c80e89805380f52cfe86ff990501801d70e5b4636e8478674d2d5706a56a666
63eb03abdc332584f7ea8c3255b1be3ca75e4685a060e0ea88e569612d9e7227
V= 0xd8f2cf17c484f4bb6a0208b3796a2609971c55d56bfffadf155c0bfb76f7afe99
7d6b6e8fde9e2cef0ab3e31a1862953425a70334e4e2404c9cd9079856c7259

SEED:

03 8a 01 b5 ea a2 28 3b bb 29 7b 81 ad 94 92 01
e4 32 11 df 76 a3 70 ec c0 09 ec 49 1f 9f 8d 33
f2 ee 24 08 c7 88 27 cd 0c 51 17 a7 e3 8d 58 5b
3d 15 50 30 a3 29 1b ad 6a 21 ab 48 38 1d 66 bc
1b d6 b9 ba 6e d8 6a 21 65 c5 99 84 dc 5d 51 81
f3 f1 97 fe 4a 86 81 c2 e5 0a 22 a0 61 2c 55 7e

Point Q_2

X= 0xb3e6c475f173af4494dd02ad7c9df3bd6a5ca82c3d65ad86fbb330dfb1c40e34
c4cd04d93f609cff2daea5907d0e08192a29be3fff2752223b868e8bcc6a7b74
Y= 0x53ffcfc818281bcf383d9b6542b3b1fcee5bd20cd1c805ed1dacb83ba161167a5
eb96df52c1d290496043ea514c465ecb37970fcd7ffbb6ca35a767cd0227fe8c
U= 0x8dd3f6f455ffae85c3935750792b65fa1ba990c7ac8bc449a77bb86aeb87eb6


```
ecb6bf387924885b0ea1e30fc4d742919504cd7baf4926b777ed40b898be41f8
V= 0x2d7edc1ca6078878d2d8ecafabc2abc83fcb269c049baa11951ff2523b69bd1
4ee6c0fa7cbd5a566cb32246d14568eb9fa04e3b53ee6175bb32887796870ba9
```

SEED:

```
63 ce db 44 3d f8 df 68 8d 5d fd d0 ea 54 41 62
f5 6d 78 92 73 0c 86 88 53 e2 24 4d dd 87 1e 4a
0e 3f b7 32 40 c8 7a bc e8 fd b3 16 dd 0e 9b 23
ec 1f c7 40 86 29 8c fc f2 a1 d9 18 31 af a3 cf
1e 98 b8 0d 42 0c f6 73 8d 57 44 77 8e 1a d3 e4
42 d7 26 39 6c 91 b7 f5 e8 84 09 8d be 02 aa 80
```

Point Q_3

```
X= 0xbe963ad90f84ff9ff6ff7ddd39d91cea649e849bf20b8cc1e72040cf689a974f
40f24e10c737bfa558b514c605b7c156e24251b859202b12ef311b0f363171eb
Y= 0x007cfa56f5ae239694e74f7996e1f44fcd4f62205a555fdb627e4212576b4591
7f88667bcd924a3271f40dc4bbd2f2e216b4fcf59c25fdd8154241d40f42e2ad
U= 0xff6697883ce5c6cc165fa78ff158c03b31add23dc01b24902b18c5487f1835ff
eaf4af5ede44f8b254748704e504810597d0e4418daf50e0253f33915de97b7b
V= 0x54e1ba656234479c5845c06af70bbefa741a863d5186ca720ee2f43bdd4d5b74
71594871d532ce263928aa30ae3c25efc6a2f82d4163c45869339426888be3bc
```

SEED:

```
06 ce 08 fa 5d 11 50 45 e2 d2 a8 03 01 d2 9e 2a
39 c3 ea e7 f1 61 37 f9 3e 51 d1 46 f3 21 b1 89
fb 5c 17 70 26 5b 30 8b 6d f2 87 7c d9 d3 6f 8a
3c b4 e7 1d f0 99 a4 73 69 1d d5 46 8d 43 50 f9
87 df e5 e5 de ff 3c 7b b8 f4 62 ed 19 9b f3 33
7a 6f f9 0e c5 f0 bc bb 1a 59 1e cd c2 9b 52 64
```

[Appendix B](#). Test examples

The test examples for one of the three points of each curve in [Appendix A](#) of this document are given below.

B.1 Curveid-GostR3410-2001-CryptoPro-A-ParamSet

The input protocol parameters in this example take the following values:

N= 3

ind= 1

ID_A:

```
00 00 00 00
```

ID_B:

```
00 00 00 00
```

PW:

```
31 32 33 34 35 36 ('123456')
```

salt:

```
29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb
```

Q_ind:

```
X= 0xa33ce065b0c23e1d3d026a206f8a1f8747ed1cd92a665bf85198cdb10ac90a5c
Y= 0xb00d0dc0733883f05de9f55fd711f55998f5508cc40bead80c913b4d5b533667
```


The function F (PW , $salt$, 2000) takes the following values:

$F(PW, salt, 2000)$:

```
bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71
d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67
```

The coordinates of the point Q_{PW} are:

$X = 0x9d339b3396ae4a816388a14c79ab3a8dd495fa4c53f0d4076579022ef2aaeb68$

$Y = 0xdad91482e208590fd316bf959480f5ec2c17463ec8fc8f63030649b452cddda8$

During the calculation of the message u_1 on the side A the parameter α , the point $\alpha * P$ and the message u_1 take the following values:

$\alpha = 0xfccbd45d1f2538097d5a031fa68bbb43c84d12b3de47b7061c0d5e24993e0c87$

$\alpha * P$:

$X = 0x24538e096781b9d53316c342ae5bbd49ccfb2db627c3659175bc4fa9d95b4618$

$Y = 0xf6e39a7490ae0ac449f5abe7e2135697c582daf3a038c40a05e6e8be3e466a2b$

u_1 :

$X = 0xcf73b30dd577369fb98e2a93d6d98d7450f9ceef2bada1e3dcb8bb1016dff1e1$

$Y = 0x1cf05014caedb1635120b30e0a445060b8f1cca52965cf83c4838d554ca4e2$

During processing a message u_1 , calculation the K_B key and the message u_2 on the side B the parameters β , src , $K_B = H_{256}(src)$, $\beta * P$ and u_2 take the following values:

$\beta = 0xf2144faddc497d9ef6324912fd367840ee509a2032aedb1c0a890d133b45f596$

src :

```
39 c0 e8 83 59 91 cd 6d 56 88 fc ad 55 29 1f 79
e5 0f 87 9d 94 b5 0a b2 db d6 bd f7 e8 39 b7 1a
10 b5 a7 8d c0 36 b8 73 f7 e4 b1 6b 12 48 6f eb
69 d7 39 d4 01 4d ae e2 cc 5c 2f c7 4a 2c c8 06
```

K_B :

$e0 4e e0 14 7f 9f 19 8d e2 5a af 33 a2 84 99 e0$

$ce 7d 31 6e 47 39 76 2f d5 19 f8 e9 91 d7 fc 00$

$\beta * P$:

$X = 0xb11f1a8fb043bc6d4068667b897e4ff637b8410f5eb19e11b0a7028f34d6936a$

$Y = 0x266d952955e2ab3f3ba75d14a919795d6b8ac04dbcff1cfaac6ba32291c099fd$

u_2 :

$X = 0x6e1bfb24b6131a3ad0b60e477a38715c6f96f21bb0b2f9ebd67680e804a77199$

$Y = 0x873ee3c546c41e8f707298f11b955fe64f7577d52d7dad1becb9925178ca80$

During processing a message u_2 and calculation the key on the side A the the K_A key takes the following value:

K_A :

$e0 4e e0 14 7f 9f 19 8d e2 5a af 33 a2 84 99 e0$

$ce 7d 31 6e 47 39 76 2f d5 19 f8 e9 91 d7 fc 00$

The message $MAC_A = HMAC(K_A, 0x01 || ID_A || ind || salt || u_1 || u_2)$ from the side A takes the following value:

MAC_A :

$bd 35 c5 0e 90 60 e6 4f 04 2e 7b e6 cc 02 99 84$

$0c 8e 27 82 b8 e5 9c 3d d4 47 50 11 16 73 c5 ea$

The message $MAC_B = HMAC(K_B, 0x02 || ID_B || ind || salt || u_1 || u_2)$ from the side B takes the following value:

MAC_B :

$c8 c8 2c 0f ed 8e 4d 1e 41 42 d7 a9 f0 55 b4 5f$

f6 71 2d 2f 41 bf 26 ef 2f bc 37 c5 56 4b 86 d3

B.2 Curveid-GostR3410-2001-CryptoPro-B-ParamSet

The input protocol parameters in this example take the following values:

N= 3

ind= 1

ID_A:

00 00 00 00

ID_B:

00 00 00 00

PW:

31 32 33 34 35 36 ('123456')

salt:

29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb

Q_ind:

X= 0x0ad754474a915d9d706c6b8dc879858a1cb85cc8f6c148fc3120825393ecd394

Y= 0x68c33b6d0343cf72cb19666ffd487fa94294dc677b28c8e27ec36068ff85ed83

The function F (PW, salt, 2000) takes the following values:

F(PW, salt, 2000):

bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71

d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67

The coordinates of the point Q_PW are:

X= 0x7a7211a430fd4e31b815e6d2454eea9574f034c5c442dce1723d69555d3ee4c9

Y= 0x2995e857187808e80d3e40a00fb87128e203f2d91c1f15d8193a5aad95964734

During the calculation of the message u_1 on the side A the parameter alpha, the point alpha*P and the message u_1 take the following values:
alpha=0x499d72b90299cab0da1f8be19d9122f622a13b32b730c46bd0664044f2144fad
alphaP:

X= 0x61d6f916db717222d74877f179f7ebef7cd4d24d8c1f523c048e34a1df30f8dd

Y= 0x3ec48863049cfcfe662904082e78503f4973a4e105e2f1b18c69a5e7fb209000

u_1:

X= 0x35e78fcbcb24998eb3039445a9de7032aadf291e7768196ef618e45bed80edf88

Y= 0x1970a4697295f6d361d2c3edd3885794c1254bac3f4adb4a3346ad01a911d13c

During processing a message u_1, calculation the K_B key and the message u_2 on the side B the parameters betta, src, K_B = H_256 (src), betta*P and u_2 take the following values:

betta=0x0f69ff614957ef83668edc2d7ed614be76f7b253db23c5cc9c52bf7df8f4669d
src:

50 14 0a 5d ed 33 43 ef c8 25 7b 79 e6 46 d9 f0

df 43 82 8c 04 91 9b d4 60 c9 7a d1 4b a3 a8 6b

00 c4 06 b5 74 4d 8e b1 49 dc 8e 7f c8 40 64 d8

53 20 25 3e 57 a9 b6 b1 3d 0d 38 fe a8 ee 5e 0a

K_B:

a6 26 de 01 b1 68 0f f7 51 30 09 12 2b ce e1 89

68 83 39 4f 96 03 01 72 45 5c 9a e0 60 cc e4 4a

betta*P:

X= 0x33bc6f7e9c0ba10cfb2b72546c327171295508ea97f8c8ba9f890f2478ab4d6c

Y= 0x75d57b396c396f492f057e9222ccc686437a2aad464e452ef426fc8eed1a4a6

u_2:

X= 0x20d7a92b238143e3f137be904d52fa35c45a29f02a7226a7ac83a1172c2a55cd

Y= 0x5fc4cd6ffb0e76ea8603ce9e6dab5164285617969ab3bfab09fbeb8595d1f47b

During processing a message u_2 and calculation the key on the side A the K_A key takes the following value:

K_A :

a6 26 de 01 b1 68 0f f7 51 30 09 12 2b ce e1 89

68 83 39 4f 96 03 01 72 45 5c 9a e0 60 cc e4 4a

The message $MAC_A=HMAC(K_A, 0x01 || ID_A || ind || salt || u_1 || u_2)$ from the side A takes the following value:

MAC_A :

55 7a 59 61 42 60 39 a1 52 c8 23 a7 65 04 59 b0

62 be 3d 47 56 53 03 09 95 57 1c e7 53 40 26 47

The message $MAC_B=HMAC(K_B, 0x02 || ID_B || ind || salt || u_1 || u_2)$ from the side B takes the following value:

MAC_B :

3b c5 5e 27 07 84 19 94 c4 b9 ca ba 43 e6 ce 6a

09 2d e9 08 83 76 5f b6 c3 44 c6 1d 76 02 96 e9

B.3 Curveid-GostR3410-2001-CryptoPro-C-ParamSet

The input protocol parameters in this example take the following values:

$N= 3$

$ind= 1$

ID_A :

00 00 00 00

ID_B :

00 00 00 00

PW :

31 32 33 34 35 36 ('123456')

$salt$:

29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb

Q_{ind} :

X= 0x339f791f62938871f241c1c89643619aa8b2c7d7706ce69be01fddff3f840003

Y= 0x31d6d9264cc6f8fe09bf7aa48910b4ad5ddfd74a2ef4699b76de09ffed295f11

The function $F(PW, salt, 2000)$ takes the following values:

$F(PW, salt, 2000)$:

bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71

d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67

The coordinates of the point Q_{PW} are:

X= 0x8b666917d42c455331358c50c3c12c85b898a2e454b50dd773541da02e1c3068

Y= 0x8a9b6c4703934b7f0dc903f52c16275e1d38b568117c7cff3bd322a99a311fe9

During the calculation of the message u_1 on the side A the parameter alpha, the point $\alpha * P$ and the message u_1 take the following values:
 $\alpha=0x3a54ac3f19ad9d0b1eac8acdcea70e581f1dac33d13feafd81e762378639c1a8$
 αP :

X= 0x96b7f09c94d297c257a7da48364c0076e59e48d221cba604ae111ca3933b446a

Y= 0x54e4953d86b77ecceb578500931e822300f7e091f79592ca202a020d762c34a6

u_1 :

X= 0x2124a22e00b1be2114f5ca42d58d55a0a9f2b08f8cb10275eddf8243402abb7a

Y= 0x62497815861d15877b7ad2e86768a2deb0f755a8b1a8897fc5235da783914a59

During processing a message u_1 , calculation the K_B key and the message u_2 on the side B the parameters beta , src , $K_B = H_{256}(\text{src})$, $\text{beta} * P$ and u_2 take the following values:

$\text{beta} = 0x448781782bf7c0e52a1dd9e6758fd3482d90d3cfccf42232cf357e59a4d49fd4$

src :

```
16 a1 2d 88 54 7e 1c 90 06 ba a0 08 e8 cb ec c9
d1 68 91 ed c8 36 cf b7 5f 8e b9 56 fa 76 11 94
d2 8e 25 da d3 81 8d 16 3c 49 4b 05 9a 8c 70 a5
a1 b8 8a 7f 80 a2 ee 35 49 30 18 46 54 2c 47 0b
```

K_B :

```
be 7e 7e 47 b4 11 16 f2 c7 7e 3b 8f ce 40 30 72
ca 82 45 0d 65 de fc 71 a9 56 49 e4 de ea ec ee
```

$\text{beta} * P$:

```
X= 0x4b9c0ab55a938121f282f48a2cc4396eb16e7e0068b495b0c1dd4667786a3eb7
Y= 0x223460aa8e09383e9df9844c5a0f2766484738e5b30128a171b69a77d9509b96
```

u_2 :

```
X= 0x47ad0110d1620fe38832e90b58971d2e0b9183dd52de23422b6fc47bec64541a
Y= 0x8296af496b3c52640e738a195d63ab7bfb457aba7c71b5649cc3e300829cbf0a
```

During processing a message u_2 and calculation the key on the side A the K_A key takes the following value:

K_A :

```
be 7e 7e 47 b4 11 16 f2 c7 7e 3b 8f ce 40 30 72
ca 82 45 0d 65 de fc 71 a9 56 49 e4 de ea ec ee
```

The message $\text{MAC}_A = \text{HMAC}(K_A, 0x01 || ID_A || \text{ind} || \text{salt} || u_1 || u_2)$ from the side A takes the following value:

MAC_A :

```
47 58 fa 64 9f 2e 31 3b f2 70 8b 76 a7 f7 a7 5a
37 ce 9e 7f 55 c3 fc 5a 55 77 e8 77 a7 a2 c1 ea
```

The message $\text{MAC}_B = \text{HMAC}(K_B, 0x02 || ID_B || \text{ind} || \text{salt} || u_1 || u_2)$ from the side B takes the following value:

MAC_B :

```
2f 33 b9 bf f0 7d cd e3 44 67 bd b0 7f 62 fc a8
b3 52 3a 64 39 ef f1 c9 93 ba 0b 4c e6 c2 ed e4
```

[B.4 Curveid-tc26-gost-3410-2012-512-paramSetA](#)

The input protocol parameters in this example take the following values:

$N = 3$

$\text{ind} = 1$

ID_A :

```
00 00 00 00
```

ID_B :

```
00 00 00 00
```

PW :

```
31 32 33 34 35 36 ('123456')
```

salt :

```
29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb
```

Q_{ind} :

```
X= 0x301aac1a3b3e9c8a65bc095b541ce1d23728b93818e8b61f963e5d5b13eec0fe
e6b06f8cd481a07bb647b649232e5179b019eef7296a3d9cfa2b66ee8bf0cbf2
```


Y= 0x191177dd41ce19cc849c3938abf3adaab366e5eb2d22a972b2dcc69283523e89
c9907f1d89ab9d96f473f96815da6e0a47297fcdd8b3adac37d4886f7ad055e0

The function F (PW, salt, 2000) takes the following values:

F(PW, salt, 2000):

bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71
d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67

The coordinates of the point Q_PW are:

X= 0xa8b54a6339b296f5c5227670fb1482010b4b07e3642974b40c58a5f1da33370e
fed546eb17c6a707f3fc69671deba10a6de03a55f859473e9074a89b4a7b5488

Y= 0xfefb437ecf21536328b32f4c8e0430d5c0c096001c08a378ac30b8634412f44c
5ba9b7096642f51cc3a018cd1599c849cd62917a370eca3bbc6bed5eedabdd77

During the calculation of the message u_1 on the side A the parameter alpha, the point alpha*P and the message u_1 take the following values:

alpha=0x3ce54325db52fe798824aead11bb16fa766857d04a4af7d468672f16d90e739e
046a46f815693e85b1ce5464da9270181f82333b0715057bbe8d61d400505f0e

alphaP:

X= 0xb93093eb0fcc463239b7df276e09e592fcfc9b635504ea4531655d76a0a3078e
2b4e51cfe2fa400cc5de9fbc369db204b3e8ed7edd85ee5cca654c1aed70e396

Y= 0x809770b8d910ea30bd2fa89736e91dc31815d2d9b31128077eedc371e9f69466
f497dc64dd5b1fad5c587f860ee256109138c4a9cd96b628e65a8f590520fc882

u_1:

X= 0xe8732d5471901b3eb9a31aaebeac7a6155c2c8fc1c960cb475e14074987dd2c8
4eccafac0835735a5c2df3d1c8dacf4a1d2e38e1e4419f5df4e25b7f8dd90b50

Y= 0xd680a41eaec979d49f4752008e9e92eb0efc1950d74b85e852be47f3958d5500
0442d859e5b459de5dc7acaa0c36383cd1f98f271333c6083dcecaf07ac825b8

During processing a message u_1, calculation the K_B key and the message u_2 on the side B the parameters betta, src, K_B = H_256 (src), betta*P and u_2 take the following values:

betta=0xb5c286a79aa8e97ec0e19bc1959a1d15f12f8c97870ba9d68cc12811a56a3bb1
1440610825796a49d468cdc9c2d02d76598a27973d5960c5f50bce28d8d345f4

src:

84 59 c2 0c b5 c5 32 41 6d b9 28 eb 50 c0 52 0f
b2 1b 9c d3 9a 4e 76 06 b2 21 be 15 ca 1d 02 da
08 15 de c4 49 79 c0 8c 7d 23 07 af 24 7d da 1f
89 ec 81 20 69 f5 d9 cd e3 06 af f0 bc 3f d2 6e
d2 01 b9 53 52 a2 56 06 b6 43 e8 88 30 2e fc 8d
3e 95 1e 3e b4 68 4a db 5c 05 7b 8f 8c 89 b6 cc
0d ee d1 00 06 5b 51 8a 1c 71 7f 76 82 ff 61 2b
bc 79 8e c7 b2 49 0f b7 00 3f 94 33 87 37 1c 1d

K_B:

53 24 de f8 48 b6 63 cc 26 42 2f 5e 45 ee c3 4c
51 d2 43 61 b1 65 60 ca 58 a3 d3 28 45 86 cb 7a

betta*P:

X= 0x238b38644e440452a99fa6b93d9fd7da0cb83c32d3c1e3cfe5df5c3eb0f9db91
e588daedc849ea2fb867ae855a21b4077353c0794716a6480995113d8c20c7af

Y= 0xb2273d5734c1897f8d15a7008b862938c8c74ca7e877423d95243eb7ebd02fd2
c456cf9fc956f078a59aa86f19dd1075e5167e4ed35208718ea93161c530ed14

u_2:


```
X= 0x1830804bf1fb07ebd43f27d03ff71ad9c7c31becaf1d3585dfb9e356c36638dc
   d82aba559dec06d46c862566653dfe0b116eb1a68439b0283f4d79ce48408eee
Y= 0x23b33ae97fba92e06095c41525aedf7b5d96fe9ca8e0244ed6c8a565d542d05e
   d3044cafb1a8ac9a570c5133ba846d61da77f54da2daf13b0def7d90a0796f06
```

During processing a message `u_2` and calculation the key on the side A the `K_A` key takes the following value:

`K_A`:

```
53 24 de f8 48 b6 63 cc 26 42 2f 5e 45 ee c3 4c
51 d2 43 61 b1 65 60 ca 58 a3 d3 28 45 86 cb 7a
```

The message `MAC_A=HMAC (K_A, 0x01 || ID_A || ind || salt || u_1 || u_2)` from the side A takes the following value:

`MAC_A`:

```
37 e6 1a 43 2d 85 75 9b 30 13 a2 9d d6 82 f1 4d
33 ca 86 89 37 db 4b f2 02 91 ed cf 6b e2 4b 4e
```

The message `MAC_B=HMAC (K_B, 0x02 || ID_B || ind || salt || u_1 || u_2)` from the side B takes the following value:

`MAC_B`:

```
72 dc de 19 5f 26 4b b8 a8 1d 2a fe 2f d9 da 2d
60 12 81 9c 15 f7 11 db 2b c4 c5 74 85 9e 05 3e
```

B.5 Curveid-tc26-gost-3410-2012-512-paramSetB

The input protocol parameters in this example take the following values:

`N= 3`

`ind= 1`

`ID_A`:

```
00 00 00 00
```

`ID_B`:

```
00 00 00 00
```

`PW`:

```
31 32 33 34 35 36 ('123456')
```

`salt`:

```
29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb
```

`Q_ind`:

```
X= 0x488cf12b403e539fde9ee32fc36b6ed52aad9ec34ff478c259159a85e99d3dda
   dfd5d73606ecee351e0f780a14c3e9f14e985d9d7ddec93b064fc89b0c843650
Y= 0x7bc73c032edc5f2c74dd7d9da12e1856a061ce344a77253f620592752b1f3a3d
   cbbc87eb27ec4ed5e236dfef03f3972404747e277671e53a9e412e82aaf6c3f7
```

The function `F (PW, salt, 2000)` takes the following values:

`F(PW, salt, 2000)`:

```
bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71
d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67
```

The coordinates of the point `Q_PW` are:

```
X= 0x2383039092052ed0e8ca3f751c11ebb891b8f32f7c66a437dec86345c63efc4b
   a1ecd04dfc11826dd581cbc1d744754e284c00b04eef9cd6eff22c12432c46fd
Y= 0x374202580afbaf2f68da8a5c03ab82e71eb4c1f1fdd881aa2911d0206d470039
   275d298d5477901565ab826ec4492f67eebcf3194442f272fd2cad9a5f04234f
```

During the calculation of the message `u_1` on the side A the parameter `alpha`, the point `alpha*P` and the message `u_1` take the following values:
`alpha=0x715e893fa639bf341296e0623e6d29dadf26b163c278767a7982a989462a3863`

fe12aef8bd403d59c4dc4720570d4163db0805c7c10c4e818f9cb785b04b9997

alphaP:

X= 0x10c479ea1c04d3c2c02b0576a9c42d96226ff033c1191436777f66916030d87d02fb93738ed7669d07619ffce7c1f3c4db5e5df49e2186d6fa1e2eb5767602b9

Y= 0x039f6044191404e707f26d59d979136a831cce43e1c5f0600d1ddf8f39d0ca3d52fbd943bf04ddced1aa2ce8f5ebd7487acdef239c07d015084d796784f35436

u_1:

X= 0x0ab9e56fc0d48e4982ee0a0b09507a63dc530181611d9f00d0464724415757b9de1c647178783a0fb4648dfd8e3da1efeb4db29de4711c8599191054ca7de6c4

Y= 0x4decae941f8d19c44daae9eb132019e116478124e76430b8bee16ce6910a06c8a2fed68f4907e4ba17c4f4e3356dc3b3b8647165b9c1aae54b1c13239bfa8213

During processing a message u_1, calculation the K_B key and the message u_2 on the side B the parameters betta, src, K_B = H_256 (src), betta*P and u_2 take the following values:

betta=0x30fa8c2b4146c2dbbe82bed04d7378877e8c06753bd0a0ff71ebf2befe8da8f3dc0836468e2ce7c5c961281b6505140f8407413f03c2cb1d201ea1286ce30e6d

src:

3f 04 02 e4 0a 9d 59 63 20 5b cd f4 fd 89 77 91
9b ba f4 80 f8 e4 fb d1 25 5a ec e6 ed 57 26 4b
d0 a2 87 98 4f 59 d1 02 04 b5 f4 5e 4d 77 f3 cf
8a 63 b3 1b eb 2d f5 9f 8a f7 3c 20 9c ca 8b 50
b4 18 d8 01 e4 90 ae 13 3f 04 f4 f3 f4 d8 fe 8e
19 64 6a 1b af 44 d2 36 fc c2 1b 7f 4d 8f c6 a1
e2 9d 6b 69 ac ce ed 4e 62 ab b2 0d ad 78 ac f4
fe b0 ed 83 8e d9 1e 92 12 ab a3 89 71 4e 56 0c

K_B:

d5 90 e0 5e f5 ae ce 8b 7c fb fc 71 be 45 5f 29
a5 cc 66 6f 85 cd b1 7e 7c c7 16 c5 9f f1 70 e9

betta*P:

X= 0x34c0149e7bb91ae377b02573fcc48af7bfb7b16deb8f9ce870f384688e3241a3a868588cc0ef4364cca67d17e3260cd82485c202adc76f895d5df673b1788e67

Y= 0x608e944929bd643569ed5189db871453f13333a1eaf82b2fe1be8100e775f13dd9925bd317b63bfaf05024d4a738852332b64501195c1b2ef789e34f23ddafc5

u_2:

X= 0x66defd2a42f0efe38ed3d4a4dfbed6b86d40f4adf156c86fee1605dbf6b057b12fe82a0be4823f7f215b5110673e02e3bf44f0ae26630005fcfd9f01473127eb

Y= 0x36168c6d20c9514556ab442bf63ded0115346916ef45af7e5517f59205d1cc52ae2e72c3036f13cab7de12932e4a3acd0789f5e2474ff722b81334676c8a3371

During processing a message u_2 and calculation the key on the side A the K_A key takes the following value:

K_A:

d5 90 e0 5e f5 ae ce 8b 7c fb fc 71 be 45 5f 29
a5 cc 66 6f 85 cd b1 7e 7c c7 16 c5 9f f1 70 e9

The message MAC_A=HMAC (K_A, 0x01 || ID_A || ind || salt || u_1 || u_2) from the side A takes the following value:

MAC_A:

9e c1 a8 74 93 b2 87 c9 ca c3 da c2 a2 d7 1b 82
8d c5 97 7c b0 03 93 42 c1 5a cd fb 66 c8 cf 89

The message $MAC_B=HMAC(K_B, 0x02 || ID_B || ind || salt || u_1 || u_2)$ from the side B takes the following value:

MAC_B:

```
a9 b2 f1 9b d9 c1 fd 0f 0c ab fd 09 52 94 c6 e6
3c d5 9f 12 cf 8e fd 01 12 46 0d b7 aa 20 bb 6e
```

B.6 Curveid-tc26-gost-3410-2012-256-paramSetA

The input protocol parameters in this example take the following values:

N= 3

ind= 1

ID_A:

```
00 00 00 00
```

ID_B:

```
00 00 00 00
```

PW:

```
31 32 33 34 35 36 ('123456')
```

salt:

```
29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb
```

Q_ind:

```
X= 0x5161b08a973d521bdde0cbd45b68aa0470e1058dd936e5bd618fd3373770eed9
```

```
Y= 0xc1633db551677c62b9c2b69d47e503c0f8ca83b6b3109dece0a5f985d77a83a7
```

The function $F(PW, salt, 2000)$ takes the following values:

$F(PW, salt, 2000)$:

```
bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71
```

```
d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67
```

The coordinates of the point Q_PW are:

X= 0xa0fd0bcfaa07f640c802aa95f42e80b28bb758fbc7ee2aca2cc0a615b567207

Y= 0x52cf0c960f362894bd097d198999e965bd940c7828e0d2ad38a0097f68135047

During the calculation of the message u_1 on the side A the parameter α , the point $\alpha * P$ and the message u_1 take the following values:
 $\alpha=0x147b72f6684fb8fd1b418a899f7dbecaf5fce60b13685baa95328654a7f0707f$
 αP :

```
X= 0x33fbac14eae538275a769417829c431bd9fa622b6f02427ef55bd60ee6bc2888
```

```
Y= 0x22f2ebcf960a82e6cdb4042d3ddda511b2fba925383c2273d952ea2d406eae46
```

u_1 :

```
X= 0x8e8929226c7f679ea8c2dfb833d1f8062d62a9672493df02ad7462014c0edbc6
```

```
Y= 0x20f2382c2425aaa638f61e8b70fcf70dae6bcb2f9f341b33ae577c62395aa816
```

During processing a message u_1 , calculation the K_B key and the message u_2 on the side B the parameters β , src , $K_B = H_{256}(src)$, $\beta * P$ and u_2 take the following values:

$\beta=0x30d5cfadaa0e31b405e6734c03ec4c5df0f02f4ba25c9a3b320ee6453567b4cb$
 src :

```
a3 39 a0 b8 9c ef 1a 6f fd 4c a1 28 04 9e 06 84
```

```
df 4a 97 75 b6 89 a3 37 84 1b f7 d7 91 20 7f 35
```

```
11 86 28 f7 28 8e aa 0f 7e c8 1d a2 0a 24 ff 1e
```

```
69 93 c6 3d 9d d2 6a 90 b7 4d d1 a2 66 28 06 63
```

K_B :

```
7d f7 1a c3 27 ed 51 7d 0d e4 03 e8 17 c6 20 4b
```

```
c1 91 65 b9 d1 00 2b 9f 10 88 a6 cd a6 ea cf 27
```


betta*P:

X= 0x2b2d89fab735433970564f2f28cfa1b57d640cb902bc6334a538f44155022cb2

Y= 0x10ef6a82eef1e70f942aa81d6b4ce5dec0ddb9447512962874870e6f2849a96f

u_2:

X= 0x47182ed8f018fa93a5d837e52724af6051c168ef15e4a40fe926473bc3f1032a

Y= 0x97f3e1e674da53b0ec3ebb1a62a25c7424f4334950daec4d33045f78d9faeeb4

During processing a message u_2 and calculation the key on the side A the K_A key takes the following value:

K_A:

7d f7 1a c3 27 ed 51 7d 0d e4 03 e8 17 c6 20 4b

c1 91 65 b9 d1 00 2b 9f 10 88 a6 cd a6 ea cf 27

The message MAC_A=HMAC (K_A, 0x01 || ID_A || ind || salt || u_1 || u_2) from the side A takes the following value:

MAC_A:

f5 69 f6 e7 68 9e f0 ba 08 46 98 cc 0e bc ac 59

67 8c 93 26 af 21 f5 4d 3e 90 05 29 32 6b 41 ee

The message MAC_B=HMAC (K_B, 0x02 || ID_B || ind || salt || u_1 || u_2) from the side B takes the following value:

MAC_B:

80 d5 f0 3b 48 22 37 76 43 b4 ff 92 05 dd ed b1

9f 22 80 1f b4 de 0b fb e0 74 55 c2 54 32 45 1e

B.7 Curveid-tc26-gost-3410-2012-512-paramSetC

The input protocol parameters in this example take the following values:

N= 3

ind= 1

ID_A:

00 00 00 00

ID_B:

00 00 00 00

PW:

31 32 33 34 35 36 ('123456')

salt:

29 23 be 84 e1 6c d6 ae 52 90 49 f1 f1 bb e9 eb

Q_ind:

X= 0x5b065ead2e94de0ee2e462de204c93c6b2bf3498ad920393cb60259e1a8ffc7c

7e7d4defa20ff4282abf70207e4611d532f40db6800e29d2b53f6ac0713e5b38

Y= 0xa39a28c59ff7f796b85223b8834384907c626086415487288ed1182ca4487dc1

ae5f37af90fd267b7c0dc8542ea52cd984af54731bc84271d6186d973c91359b

The function F (PW, salt, 2000) takes the following values:

F(PW, salt, 2000):

bd 04 67 3f 71 49 b1 8e 98 15 5b d1 e2 72 4e 71

d0 09 9a a2 51 74 f7 92 d3 32 6c 6f 18 12 70 67

The coordinates of the point Q_PW are:

X= 0x463e9d38239ddac18e7cc7f6caa7244ae5c49d58dcd6a56510d7779496744d

75e3e0d5795d4e603f7baea8d24ada989d4179e1db33d1912602fc59470192df

Y= 0x088874b12c160930aa840f046ee75fa86206f19ca5f431d81e2381d6d947b7b0

30577e40f09b1c16f8e6ef84daddba028f8b6e397a27ece0e13197662659af4d

During the calculation of the message u_1 on the side A the parameter

alpha, the point alpha*P and the message u_1 take the following values:
alpha=0x0b3fe942126aefc0287f82c6290505aeb117aa8dcb033cee56222dd1b9f9e1e5
377583ba300211ec2c399546b4f54578ee925c238d52530c159c7034ccfa0ddd

alphaP:

X= 0x61427a12468974b5829de1263d91fdfd8e26ea337c6c223595e05b4da4f8fe93
2b532f33c0f4631729422c04f7018a7bf619c026ef0edc4ba2a96b79397eba92
Y= 0x6833806e26791ef1dd01e60c10cc247173b97d7d8d7fea53de4a8a6a444bacc7
042bf35394aef4cfd0f236788f2e9fca9e10f7d7fee54fff951ae17996808c1

u_1:

X= 0x03664ef83e51beaec1f11711f8742b180001c7734a715e4a693758acd9851b38
c6d7e0a316d809b75694ae1b356951a93c91a9b85aa3e3a561742211fd238852
Y= 0x2b92fa93fab060fa86c3039eb2904bc18cbe45032dc3c93ce1c6ba1542a29e0d
790a5f7b63928ed9e50d1fefdb6bd00ade4eb021bc62a560567a3419e74dfc08a

During processing a message u_1, calculation the K_B key and the message u_2 on the side B the parameters betta, src, K_B = H_256 (src), betta*P and u_2 take the following values:

betta=0x0d494d54fb777781d1324ed6088bb0d9d86b8b0a252aa6a3ee70af8ef44b87a6
4cea3a432b61a699bad2d9760d700c2891b6285be0b0bb90f16a40a9b2e0e36a

src:

c2 a3 1a 15 08 52 8a fb 70 be d5 7a 3a 97 9a 3a
8c ed 00 2f 1b 05 8f 99 cb ee 64 56 5c cb ae 42
c5 80 b1 39 18 04 b3 e3 34 d0 2f 70 55 18 ef 16
b7 cf 0e 79 91 76 6f 7e 22 81 f2 87 b1 df cd 34
5c 56 04 ef 1d 9a 8e b8 27 3f 2e 7a 3b fb a4 13
ad 7f 19 59 99 41 f8 f6 73 63 2b e1 43 b1 65 7f
d3 3a 3a de 7d 9f 71 6c e4 0c b5 9e 9d dd a5 0d
db 87 66 57 e7 37 8f f1 55 94 fc 7a 9e 4b 03 48

K_B:

84 14 e1 12 6c 56 a1 1e 1f 5e a0 b7 c3 bd ab e9
8b 26 8b 59 d4 08 f9 7c d0 ea d7 c2 7e e4 9c 15

betta*P:

X= 0xe247677c90ac3c74952c70da0d43f25ece4ac22eda732f7ddd772de7c3e69b22
f7679cc01cae009e442c630c7aa9403a9f11e0fb62cf7af84e77b95210a17edd
Y= 0x63be6dc920e57cb1c5b63fd8b623db6c934b87e0b14468de32c9387515cf3d35
618e945a986424708ef0515ccaa30061ac6870ab56c29c43340736a6c6179c2e

u_2:

X= 0x32260df3ddeabaa9c5c1f55248e8e9a3552cefb81a19f0ac1e10f3b7280a844c
5362b527da1c6ec7eeace2a77aa1167f5e18a4bb6bc6445b4f479ca239245002
Y= 0x04e0612a0c8cd4323535899d0698dd09bb9fc4302016f1b236c86692358ffd98
1cd082c0129763bd4749ee5bb014255d1de0fd7775decdb564213ebc7100001d

During processing a message u_2 and calculation the key on the side A the K_A key takes the following value:

K_A:

84 14 e1 12 6c 56 a1 1e 1f 5e a0 b7 c3 bd ab e9
8b 26 8b 59 d4 08 f9 7c d0 ea d7 c2 7e e4 9c 15

The message MAC_A=HMAC (K_A, 0x01 || ID_A || ind || salt || u_1 || u_2) from the side A takes the following value:

MAC_A:

53 0b 77 63 c5 9e 7c 98 52 59 ad eb af a4 16 41
c6 f4 35 47 85 01 bd c9 7e a9 cf 88 a6 9a 12 8c

The message MAC_B=HMAC (K_B, 0x02 || ID_B || ind || salt || u_1 || u_2)
from the side B takes the following value:

MAC_B:

3f 48 65 b8 8c 81 e5 ac 56 1e 31 c1 b3 d1 d9 0c
57 e1 e7 4b ac 77 b1 63 ac 60 74 82 4e 99 d3 cc

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