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**crypto**

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**August 8, 2023**

# 1 Crypto User's Guide

The **Crypto** application provides functions for computation of message digests, and functions for encryption and decryption.

This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit (<http://www.openssl.org/>).

This product includes cryptographic software written by Eric Young ([eyay@cryptsoft.com](mailto:eyay@cryptsoft.com)).

This product includes software written by Tim Hudson ([tjh@cryptsoft.com](mailto:tjh@cryptsoft.com)).

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# 2 Reference Manual

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The Crypto Application provides functions for computation of message digests, and encryption and decryption functions.

This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit (<http://www.openssl.org/>).

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## crypto

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Application

The purpose of the Crypto application is to provide an Erlang API to cryptographic functions, see *crypto(3)*. Note that the API is on a fairly low level and there are some corresponding API functions available in *public\_key(3)*, on a higher abstraction level, that uses the crypto application in its implementation.

### DEPENDENCIES

The current crypto implementation uses nifs to interface OpenSSLs crypto library and may work with limited functionality with as old versions as **OpenSSL** 0.9.8c. FIPS mode support requires at least version 1.0.1 and a FIPS capable OpenSSL installation. We recommend using a version that is officially supported by the OpenSSL project. API compatible backends like LibreSSL should also work.

Source releases of OpenSSL can be downloaded from the **OpenSSL** project home page, or mirror sites listed there.

### SEE ALSO

application(3)

## crypto

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Erlang module

This module provides a set of cryptographic functions.

- Hash functions - **Secure Hash Standard**, **The MD5 Message Digest Algorithm (RFC 1321)** and **The MD4 Message Digest Algorithm (RFC 1320)**
- Hmac functions - **Keyed-Hashing for Message Authentication (RFC 2104)**
- Block ciphers - DES and AES in Block Cipher Modes - **ECB, CBC, CFB, OFB, CTR and GCM**
- **RSA encryption RFC 1321**
- Digital signatures **Digital Signature Standard (DSS)** and **Elliptic Curve Digital Signature Algorithm (ECDSA)**
- **Secure Remote Password Protocol (SRP - RFC 2945)**
- gcm: Dworkin, M., "Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC", National Institute of Standards and Technology SP 800- 38D, November 2007.

## DATA TYPES

```
key_value() = integer() | binary()
```

Always `binary()` when used as return value

```
rsa_public() = [key_value()] = [E, N]
```

Where E is the public exponent and N is public modulus.

```
rsa_private() = [key_value()] = [E, N, D] | [E, N, D, P1, P2, E1, E2, C]
```

Where E is the public exponent, N is public modulus and D is the private exponent. The longer key format contains redundant information that will make the calculation faster. P1 and P2 are first and second prime factors. E1 and E2 are first and second exponents. C is the CRT coefficient. The terminology is taken from **RFC 3447**.

```
dss_public() = [key_value()] = [P, Q, G, Y]
```

Where P, Q and G are the dss parameters and Y is the public key.

```
dss_private() = [key_value()] = [P, Q, G, X]
```

Where P, Q and G are the dss parameters and X is the private key.

```
srp_public() = key_value()
```

Where is A or B from **SRP design**

```
srp_private() = key_value()
```



Where is a or b from **SRP design**

Where Verifier is v, Generator is g and Prime is N, DerivedKey is X, and Scrambler is u (optional will be generated if not provided) from **SRP design** Version = '3' | '6' | '6a'

```
dh_public() = key_value()
```

```
dh_private() = key_value()
```

```
dh_params() = [key_value()] = [P, G] | [P, G, PrivateKeyBitLength]
```

```
ecdh_public() = key_value()
```

```
ecdh_private() = key_value()
```

```
ecdh_params() = ec_named_curve() | ec_explicit_curve()
```

```
ec_explicit_curve() =  
  {ec_field(), Prime :: key_value(), Point :: key_value(), Order :: integer(), CoFactor :: none | integer() }
```

```
ec_field() = {prime_field, Prime :: integer()} |  
  {characteristic_two_field, M :: integer(), Basis :: ec_basis() }
```

```
ec_basis() = {tpbasis, K :: non_neg_integer()} |  
  {ppbasis, K1 :: non_neg_integer(), K2 :: non_neg_integer(), K3 :: non_neg_integer()} |  
  onbasis
```

```
ec_named_curve() ->  
  sect571r1| sect571k1| sect409r1| sect409k1| secp521r1| secp384r1| secp224r1| secp224k1|  
  secp192k1| secp160r2| secp128r2| secp128r1| sect233r1| sect233k1| sect193r2| sect193r1|  
  sect131r2| sect131r1| sect283r1| sect283k1| sect163r2| secp256k1| secp160k1| secp160r1|  
  secp112r2| secp112r1| sect113r2| sect113r1| sect239k1| sect163r1| sect163k1| secp256r1|  
  secp192r1|  
  brainpoolP160r1| brainpoolP160t1| brainpoolP192r1| brainpoolP192t1| brainpoolP224r1|  
  brainpoolP224t1| brainpoolP256r1| brainpoolP256t1| brainpoolP320r1| brainpoolP320t1|  
  brainpoolP384r1| brainpoolP384t1| brainpoolP512r1| brainpoolP512t1
```

Note that the **sect** curves are GF2m (characteristic two) curves and are only supported if the underlying OpenSSL has support for them. See also *crypto:supports/0*

```
stream_cipher() = rc4 | aes_ctr
```

```
block_cipher() = aes_cbc | aes_cfb8 | aes_cfb128 | aes_ige256 | blowfish_cbc |  
  blowfish_cfb64 | des_cbc | des_cfb | des3_cbc | des3_cfb | des_ede3 | rc2_cbc
```

```
aead_cipher() = aes_gcm | chacha20_poly1305
```

```
stream_key() = aes_key() | rc4_key()
```

```
block_key() = aes_key() | blowfish_key() | des_key() | des3_key()
```

```
aes_key() = iodata()
```

Key length is 128, 192 or 256 bits

```
rc4_key() = iodata()
```

Variable key length from 8 bits up to 2048 bits (usually between 40 and 256)

```
blowfish_key() = iodata()
```

Variable key length from 32 bits up to 448 bits

```
des_key() = iodata()
```

Key length is 64 bits (in CBC mode only 8 bits are used)

```
des3_key() = [binary(), binary(), binary()]
```

Each key part is 64 bits (in CBC mode only 8 bits are used)

```
digest_type() = md5 | sha | sha224 | sha256 | sha384 | sha512
```

```
hash_algorithms() = md5 | ripemd160 | sha | sha224 | sha256 | sha384 | sha512
```

md4 is also supported for hash\_init/1 and hash/2. Note that both md4 and md5 are recommended only for compatibility with existing applications.

```
cipher_algorithms() = aes_cbc | aes_cfb8 | aes_cfb128 | aes_ctr | aes_gcm |  
aes_ige256 | blowfish_cbc | blowfish_cfb64 | chacha20_poly1305 | des_cbc | des_cfb |  
des3_cbc | des3_cfb | des_ede3 | rc2_cbc | rc4
```

```
public_key_algorithms() = rsa | dss | ecdsa | dh | ecdh | ec_gf2m
```

Note that ec\_gf2m is not strictly a public key algorithm, but a restriction on what curves are supported with ecdsa and ecdh.

## Exports

`block_encrypt(Type, Key, PlainText) -> CipherText`

Types:

```
Type = des_ecb | blowfish_ecb | aes_ecb
Key = block_key()
PlainText = iodata()
```

Encrypt `PlainText` according to `Type` block cipher.

May throw exception `notsup` in case the chosen `Type` is not supported by the underlying OpenSSL implementation.

`block_decrypt(Type, Key, CipherText) -> PlainText`

Types:

```
Type = des_ecb | blowfish_ecb | aes_ecb
Key = block_key()
PlainText = iodata()
```

Decrypt `CipherText` according to `Type` block cipher.

May throw exception `notsup` in case the chosen `Type` is not supported by the underlying OpenSSL implementation.

`block_encrypt(Type, Key, Ivec, PlainText) -> CipherText`

`block_encrypt(AeadType, Key, Ivec, {AAD, PlainText}) -> {CipherText, CipherTag}`

`block_encrypt(aes_gcm, Key, Ivec, {AAD, PlainText, TagLength}) -> {CipherText, CipherTag}`

Types:

```
Type = block_cipher()
AeadType = aead_cipher()
Key = block_key()
PlainText = iodata()
AAD = IVec = CipherText = CipherTag = binary()
TagLength = 1..16
```

Encrypt `PlainText` according to `Type` block cipher. `Ivec` is an arbitrary initializing vector.

In AEAD (Authenticated Encryption with Associated Data) mode, encrypt `PlainText` according to `Type` block cipher and calculate `CipherTag` that also authenticates the AAD (Associated Authenticated Data).

May throw exception `notsup` in case the chosen `Type` is not supported by the underlying OpenSSL implementation.

`block_decrypt(Type, Key, Ivec, CipherText) -> PlainText`

`block_decrypt(AeadType, Key, Ivec, {AAD, CipherText, CipherTag}) -> PlainText | error`

Types:

```
Type = block_cipher()
AeadType = aead_cipher()
Key = block_key()
PlainText = iodata()
```

```
AAD = IVec = CipherText = CipherTag = binary()
```

Decrypt `CipherText` according to `Type` block cipher. `IVec` is an arbitrary initializing vector.

In AEAD (Authenticated Encryption with Associated Data) mode, decrypt `CipherText` according to `Type` block cipher and check the authenticity the `PlainText` and `AAD` (Associated Authenticated Data) using the `CipherTag`. May return `error` if the decryption or validation fail's

May throw exception `notsup` in case the chosen `Type` is not supported by the underlying OpenSSL implementation.

```
bytes_to_integer(Bin) -> Integer
```

Types:

```
Bin = binary() - as returned by crypto functions
```

```
Integer = integer()
```

Convert binary representation, of an integer, to an Erlang integer.

```
compute_key(Type, OthersPublicKey, MyKey, Params) -> SharedSecret
```

Types:

```
Type = dh | ecdh | srp
```

```
OthersPublicKey = dh_public() | ecdh_public() | srp_public()
```

```
MyKey = dh_private() | ecdh_private() | {srp_public(),srp_private()}
```

```
Params = dh_params() | ecdh_params() | SrpUserParams | SrpHostParams
```

```
SrpUserParams = {user, [DerivedKey::binary(), Prime::binary(),
```

```
Generator::binary(), Version::atom() | [Scrambler:binary()]}
```

```
SrpHostParams = {host, [Verifier::binary(), Prime::binary(),
```

```
Version::atom() | [Scrambler::binary[]]}
```

```
SharedSecret = binary()
```

Computes the shared secret from the private key and the other party's public key. See also *public\_key:compute\_key/2*

```
exor(Data1, Data2) -> Result
```

Types:

```
Data1, Data2 = iodata()
```

```
Result = binary()
```

Performs bit-wise XOR (exclusive or) on the data supplied.

```
generate_key(Type, Params) -> {PublicKey, PrivKeyOut}
```

```
generate_key(Type, Params, PrivKeyIn) -> {PublicKey, PrivKeyOut}
```

Types:

```
Type = dh | ecdh | srp
```

```
Params = dh_params() | ecdh_params() | SrpUserParams | SrpHostParams
```

```
SrpUserParams = {user, [Generator::binary(), Prime::binary(),  
Version::atom()]}
```

```
SrpHostParams = {host, [Verifier::binary(), Generator::binary(),  
Prime::binary(), Version::atom()]}
```

```
PublicKey = dh_public() | ecdh_public() | srp_public()
```

```
PrivKeyIn = undefined | dh_private() | ecdh_private() | srp_private()
```

```
PrivKeyOut = dh_private() | ecdh_private() | srp_private()
```

Generates public keys of type `Type`. See also *public\_key:generate\_key/1* May throw exception `low_entropy` in case the random generator failed due to lack of secure "randomness".

`hash(Type, Data) -> Digest`

Types:

```
Type = md4 | hash_algorithms()
Data = iodata()
Digest = binary()
```

Computes a message digest of type `Type` from `Data`.

May throw exception `notsup` in case the chosen `Type` is not supported by the underlying OpenSSL implementation.

`hash_init(Type) -> Context`

Types:

```
Type = md4 | hash_algorithms()
```

Initializes the context for streaming hash operations. `Type` determines which digest to use. The returned context should be used as argument to *hash\_update*.

May throw exception `notsup` in case the chosen `Type` is not supported by the underlying OpenSSL implementation.

`hash_update(Context, Data) -> NewContext`

Types:

```
Data = iodata()
```

Updates the digest represented by `Context` using the given `Data`. `Context` must have been generated using *hash\_init* or a previous call to this function. `Data` can be any length. `NewContext` must be passed into the next call to *hash\_update* or *hash\_final*.

`hash_final(Context) -> Digest`

Types:

```
Digest = binary()
```

Finalizes the hash operation referenced by `Context` returned from a previous call to *hash\_update*. The size of `Digest` is determined by the type of hash function used to generate it.

`hmac(Type, Key, Data) -> Mac`

`hmac(Type, Key, Data, MacLength) -> Mac`

Types:

```
Type = hash_algorithms() - except ripemd160
Key = iodata()
Data = iodata()
MacLength = integer()
Mac = binary()
```

Computes a HMAC of type `Type` from `Data` using `Key` as the authentication key.

`MacLength` will limit the size of the resultant `Mac`.

`hmac_init(Type, Key) -> Context`

Types:

```
Type = hash_algorithms() - except ripemd160  
Key = iodata()  
Context = binary()
```

Initializes the context for streaming HMAC operations. `Type` determines which hash function to use in the HMAC operation. `Key` is the authentication key. The key can be any length.

`hmac_update(Context, Data) -> NewContext`

Types:

```
Context = NewContext = binary()  
Data = iodata()
```

Updates the HMAC represented by `Context` using the given `Data`. `Context` must have been generated using an HMAC init function (such as `hmac_init`). `Data` can be any length. `NewContext` must be passed into the next call to `hmac_update` or to one of the functions `hmac_final` and `hmac_final_n`

### Warning:

Do not use a `Context` as argument in more than one call to `hmac_update` or `hmac_final`. The semantics of reusing old contexts in any way is undefined and could even crash the VM in earlier releases. The reason for this limitation is a lack of support in the underlying OpenSSL API.

`hmac_final(Context) -> Mac`

Types:

```
Context = Mac = binary()
```

Finalizes the HMAC operation referenced by `Context`. The size of the resultant MAC is determined by the type of hash function used to generate it.

`hmac_final_n(Context, HashLen) -> Mac`

Types:

```
Context = Mac = binary()  
HashLen = non_neg_integer()
```

Finalizes the HMAC operation referenced by `Context`. `HashLen` must be greater than zero. `Mac` will be a binary with at most `HashLen` bytes. Note that if `HashLen` is greater than the actual number of bytes returned from the underlying hash, the returned hash will have fewer than `HashLen` bytes.

`info_lib() -> [{Name, VerNum, VerStr}]`

Types:

```
Name = binary()  
VerNum = integer()  
VerStr = binary()
```

Provides the name and version of the libraries used by crypto.

Name is the name of the library. VerNum is the numeric version according to the library's own versioning scheme. VerStr contains a text variant of the version.

```
> info_lib().
[{"<<"OpenSSL">>,269484095,<<"OpenSSL 1.1.0c 10 Nov 2016">>}]
```

### Note:

From OTP R16 the **numeric version** represents the version of the OpenSSL **header files** (openssl/opensslv.h) used when crypto was compiled. The text variant represents the OpenSSL library used at runtime. In earlier OTP versions both numeric and text was taken from the library.

mod\_pow(N, P, M) -> Result

Types:

```
N, P, M = binary() | integer()
Result = binary() | error
```

Computes the function  $N^P \bmod M$ .

next\_iv(Type, Data) -> NextIVec

next\_iv(Type, Data, IVec) -> NextIVec

Types:

```
Type = des_cbc | des3_cbc | aes_cbc | des_cfb
Data = iodata()
IVec = NextIVec = binary()
```

Returns the initialization vector to be used in the next iteration of encrypt/decrypt of type Type. Data is the encrypted data from the previous iteration step. The IVec argument is only needed for des\_cfb as the vector used in the previous iteration step.

private\_decrypt(Type, CipherText, PrivateKey, Padding) -> PlainText

Types:

```
Type = rsa
CipherText = binary()
PrivateKey = rsa_private()
Padding = rsa_pkcs1_padding | rsa_pkcs1_oaep_padding | rsa_no_padding
PlainText = binary()
```

Decrypts the CipherText, encrypted with *public\_encrypt/4* (or equivalent function) using the PrivateKey, and returns the plaintext (message digest). This is a low level signature verification operation used for instance by older versions of the SSL protocol. See also *public\_key:decrypt\_private/[2,3]*

private\_encrypt(Type, PlainText, PrivateKey, Padding) -> CipherText

Types:

```
Type = rsa
```

```
PlainText = binary()
```

The size of the PlainText must be less than `byte_size(N) - 11` if `rsa_pkcs1_padding` is used, and `byte_size(N)` if `rsa_no_padding` is used, where N is public modulus of the RSA key.

```
PrivateKey = rsa_private()
```

```
Padding = rsa_pkcs1_padding | rsa_no_padding
```

```
CipherText = binary()
```

Encrypts the PlainText using the PrivateKey and returns the ciphertext. This is a low level signature operation used for instance by older versions of the SSL protocol. See also *public\_key:encrypt\_private/[2,3]*

```
public_decrypt(Type, CipherText, PublicKey, Padding) -> PlainText
```

Types:

```
Type = rsa
```

```
CipherText = binary()
```

```
PublicKey = rsa_public()
```

```
Padding = rsa_pkcs1_padding | rsa_no_padding
```

```
PlainText = binary()
```

Decrypts the CipherText, encrypted with *private\_encrypt/4* (or equivalent function) using the PrivateKey, and returns the plaintext (message digest). This is a low level signature verification operation used for instance by older versions of the SSL protocol. See also *public\_key:decrypt\_public/[2,3]*

```
public_encrypt(Type, PlainText, PublicKey, Padding) -> CipherText
```

Types:

```
Type = rsa
```

```
PlainText = binary()
```

The size of the PlainText must be less than `byte_size(N) - 11` if `rsa_pkcs1_padding` is used, and `byte_size(N)` if `rsa_no_padding` is used, where N is public modulus of the RSA key.

```
PublicKey = rsa_public()
```

```
Padding = rsa_pkcs1_padding | rsa_pkcs1_oaep_padding | rsa_no_padding
```

```
CipherText = binary()
```

Encrypts the PlainText (message digest) using the PublicKey and returns the CipherText. This is a low level signature operation used for instance by older versions of the SSL protocol. See also *public\_key:encrypt\_public/[2,3]*

```
rand_seed(Seed) -> ok
```

Types:

```
Seed = binary()
```

Set the seed for PRNG to the given binary. This calls the `RAND_seed` function from `openssl`. Only use this if the system you are running on does not have enough "randomness" built in. Normally this is when *strong\_rand\_bytes/1* returns `low_entropy`

```
rand_uniform(Lo, Hi) -> N
```

Types:

```
Lo, Hi, N = integer()
```

Generate a random number N, `Lo <= N < Hi`. Uses the `crypto` library pseudo-random number generator. Hi must be larger than Lo.



`sign(Algorithm, DigestType, Msg, Key) -> binary()`

Types:

**Algorithm** = `rsa` | `dss` | `ecdsa`

**Msg** = `binary()` | `{digest,binary()}`

The msg is either the binary "cleartext" data to be signed or it is the hashed value of "cleartext" i.e. the digest (plaintext).

**DigestType** = `digest_type()`

**Key** = `rsa_private()` | `dss_private()` | `[ecdh_private(),ecdh_params()]`

Creates a digital signature.

Algorithm `dss` can only be used together with digest type `sha`.

See also *public\_key:sign/3*.

`start() -> ok`

Equivalent to `application:start(crypto)`.

`stop() -> ok`

Equivalent to `application:stop(crypto)`.

`strong_rand_bytes(N) -> binary()`

Types:

**N** = `integer()`

Generates N bytes randomly uniform 0..255, and returns the result in a binary. Uses a cryptographically secure prng seeded and periodically mixed with operating system provided entropy. By default this is the `RAND_bytes` method from OpenSSL.

May throw exception `low_entropy` in case the random generator failed due to lack of secure "randomness".

`stream_init(Type, Key) -> State`

Types:

**Type** = `rc4`

**State** = `opaque()`

**Key** = `iodata()`

Initializes the state for use in RC4 stream encryption *stream\_encrypt* and *stream\_decrypt*

`stream_init(Type, Key, IVec) -> State`

Types:

**Type** = `aes_ctr`

**State** = `opaque()`

**Key** = `iodata()`

**IVec** = `binary()`

Initializes the state for use in streaming AES encryption using Counter mode (CTR). Key is the AES key and must be either 128, 192, or 256 bits long. IVec is an arbitrary initializing vector of 128 bits (16 bytes). This state is for use with *stream\_encrypt* and *stream\_decrypt*.

`stream_encrypt(State, PlainText) -> { NewState, CipherText }`

Types:

```
Text = iodata()
CipherText = binary()
```

Encrypts PlainText according to the stream cipher Type specified in `stream_init/3`. Text can be any number of bytes. The initial State is created using `stream_init`. NewState must be passed into the next call to `stream_encrypt`.

`stream_decrypt(State, CipherText) -> { NewState, PlainText }`

Types:

```
CipherText = iodata()
PlainText = binary()
```

Decrypts CipherText according to the stream cipher Type specified in `stream_init/3`. PlainText can be any number of bytes. The initial State is created using `stream_init`. NewState must be passed into the next call to `stream_decrypt`.

`supports() -> AlgorithmList`

Types:

```
AlgorithmList = [{hashs, [hash_algorithms()]}, {ciphers,
  [cipher_algorithms()]}, {public_keys, [public_key_algorithms()]}
```

Can be used to determine which crypto algorithms that are supported by the underlying OpenSSL library

`ec_curves() -> EllipticCurveList`

Types:

```
EllipticCurveList = [ec_named_curve()]
```

Can be used to determine which named elliptic curves are supported.

`ec_curve(NamedCurve) -> EllipticCurve`

Types:

```
NamedCurve = ec_named_curve()
EllipticCurve = ec_explicit_curve()
```

Return the defining parameters of a elliptic curve.

`verify(Algorithm, DigestType, Msg, Signature, Key) -> boolean()`

Types:

```
Algorithm = rsa | dss | ecdsa
Msg = binary() | {digest,binary()}
The msg is either the binary "cleartext" data or it is the hashed value of "cleartext" i.e. the digest (plaintext).
DigestType = digest_type()
Signature = binary()
Key = rsa_public() | dss_public() | [ecdh_public(),ecdh_params()]
```

Verifies a digital signature

Algorithm dss can only be used together with digest type sha.

See also *public\_key:verify/4*.