

CRYPTOGRAPHIC SERVICES

The modules described in this chapter implement various algorithms of a cryptographic nature. They are available at the discretion of the installation. On Unix systems, the *crypt* module may also be available. Here's an overview:

15.1 hashlib — Secure hashes and message digests

Source code: [Lib/hashlib.py](#)

This module implements a common interface to many different secure hash and message digest algorithms. Included are the FIPS secure hash algorithms SHA1, SHA224, SHA256, SHA384, and SHA512 (defined in FIPS 180-2) as well as RSA's MD5 algorithm (defined in Internet [RFC 1321](#)). The terms “secure hash” and “message digest” are interchangeable. Older algorithms were called message digests. The modern term is secure hash.

Note: If you want the `adler32` or `crc32` hash functions, they are available in the *zlib* module.

Warning: Some algorithms have known hash collision weaknesses, refer to the “See also” section at the end.

15.1.1 Hash algorithms

There is one constructor method named for each type of *hash*. All return a hash object with the same simple interface. For example: use `sha256()` to create a SHA-256 hash object. You can now feed this object with *bytes-like objects* (normally *bytes*) using the `update()` method. At any point you can ask it for the *digest* of the concatenation of the data fed to it so far using the `digest()` or `hexdigest()` methods.

Note: For better multithreading performance, the Python *GIL* is released for data larger than 2047 bytes at object creation or on update.

Note: Feeding string objects into `update()` is not supported, as hashes work on bytes, not on characters.

Constructors for hash algorithms that are always present in this module are `sha1()`, `sha224()`, `sha256()`, `sha384()`, `sha512()`, `blake2b()`, and `blake2s()`. `md5()` is normally available as well, though it may be

missing if you are using a rare “FIPS compliant” build of Python. Additional algorithms may also be available depending upon the OpenSSL library that Python uses on your platform. On most platforms the `sha3_224()`, `sha3_256()`, `sha3_384()`, `sha3_512()`, `shake_128()`, `shake_256()` are also available.

New in version 3.6: SHA3 (Keccak) and SHAKE constructors `sha3_224()`, `sha3_256()`, `sha3_384()`, `sha3_512()`, `shake_128()`, `shake_256()`.

New in version 3.6: `blake2b()` and `blake2s()` were added.

For example, to obtain the digest of the byte string `b'Nobody inspects the spammish repetition'`:

```
>>> import hashlib
>>> m = hashlib.sha256()
>>> m.update(b"Nobody inspects")
>>> m.update(b" the spammish repetition")
>>> m.digest()
b'\x03\x1e\xdd\xAe\x15\x93\xc5\xfe\\\x00o\xa5u+7\xfd\xdf\xf7\xbcN\x84:\xa6\xaf\x0c\x95\x0fK\x94\x06'
>>> m.digest_size
32
>>> m.block_size
64
```

More condensed:

```
>>> hashlib.sha224(b"Nobody inspects the spammish repetition").hexdigest()
'a4337bc45a8fc544c03f52dc550cd6e1e87021bc896588bd79e901e2'
```

`hashlib.new(name[, data])`

Is a generic constructor that takes the string *name* of the desired algorithm as its first parameter. It also exists to allow access to the above listed hashes as well as any other algorithms that your OpenSSL library may offer. The named constructors are much faster than `new()` and should be preferred.

Using `new()` with an algorithm provided by OpenSSL:

```
>>> h = hashlib.new('ripemd160')
>>> h.update(b"Nobody inspects the spammish repetition")
>>> h.hexdigest()
'cc4a5ce1b3df48aec5d22d1f16b894a0b894eccc'
```

Hashlib provides the following constant attributes:

`hashlib.algorithms_guaranteed`

A set containing the names of the hash algorithms guaranteed to be supported by this module on all platforms. Note that ‘md5’ is in this list despite some upstream vendors offering an odd “FIPS compliant” Python build that excludes it.

New in version 3.2.

`hashlib.algorithms_available`

A set containing the names of the hash algorithms that are available in the running Python interpreter. These names will be recognized when passed to `new()`. `algorithms_guaranteed` will always be a subset. The same algorithm may appear multiple times in this set under different names (thanks to OpenSSL).

New in version 3.2.

The following values are provided as constant attributes of the hash objects returned by the constructors:

`hash.digest_size`

The size of the resulting hash in bytes.

hash.block_size

The internal block size of the hash algorithm in bytes.

A hash object has the following attributes:

hash.name

The canonical name of this hash, always lowercase and always suitable as a parameter to `new()` to create another hash of this type.

Changed in version 3.4: The name attribute has been present in CPython since its inception, but until Python 3.4 was not formally specified, so may not exist on some platforms.

A hash object has the following methods:

hash.update(data)

Update the hash object with the *bytes-like object*. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a+b)`.

Changed in version 3.1: The Python GIL is released to allow other threads to run while hash updates on data larger than 2047 bytes is taking place when using hash algorithms supplied by OpenSSL.

hash.digest()

Return the digest of the data passed to the `update()` method so far. This is a bytes object of size `digest_size` which may contain bytes in the whole range from 0 to 255.

hash.hexdigest()

Like `digest()` except the digest is returned as a string object of double length, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

hash.copy()

Return a copy (“clone”) of the hash object. This can be used to efficiently compute the digests of data sharing a common initial substring.

15.1.2 SHAKE variable length digests

The `shake_128()` and `shake_256()` algorithms provide variable length digests with `length_in_bits//2` up to 128 or 256 bits of security. As such, their digest methods require a length. Maximum length is not limited by the SHAKE algorithm.

shake.digest(length)

Return the digest of the data passed to the `update()` method so far. This is a bytes object of size `length` which may contain bytes in the whole range from 0 to 255.

shake.hexdigest(length)

Like `digest()` except the digest is returned as a string object of double length, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

15.1.3 Key derivation

Key derivation and key stretching algorithms are designed for secure password hashing. Naive algorithms such as `sha1(password)` are not resistant against brute-force attacks. A good password hashing function must be tunable, slow, and include a `salt`.

hashlib.pbkdf2_hmac(hash_name, password, salt, iterations, dklen=None)

The function provides PKCS#5 password-based key derivation function 2. It uses HMAC as pseudo-random function.

The string `hash_name` is the desired name of the hash digest algorithm for HMAC, e.g. ‘sha1’ or ‘sha256’. `password` and `salt` are interpreted as buffers of bytes. Applications and libraries should limit

password to a sensible length (e.g. 1024). *salt* should be about 16 or more bytes from a proper source, e.g. `os.urandom()`.

The number of *iterations* should be chosen based on the hash algorithm and computing power. As of 2013, at least 100,000 iterations of SHA-256 are suggested.

dklen is the length of the derived key. If *dklen* is `None` then the digest size of the hash algorithm *hash_name* is used, e.g. 64 for SHA-512.

```
>>> import hashlib, binascii
>>> dk = hashlib.pbkdf2_hmac('sha256', b'password', b'salt', 100000)
>>> binascii.hexlify(dk)
b'0394a2ede332c9a13eb82e9b24631604c31df978b4e2f0fbd2c549944f9d79a5'
```

New in version 3.4.

Note: A fast implementation of `pbkdf2_hmac` is available with OpenSSL. The Python implementation uses an inline version of `hmac`. It is about three times slower and doesn't release the GIL.

`hashlib.scrypt(password, *, salt, n, r, p, maxmem=0, dklen=64)`

The function provides scrypt password-based key derivation function as defined in [RFC 7914](#).

password and *salt* must be *bytes-like objects*. Applications and libraries should limit *password* to a sensible length (e.g. 1024). *salt* should be about 16 or more bytes from a proper source, e.g. `os.urandom()`.

n is the CPU/Memory cost factor, *r* the block size, *p* parallelization factor and *maxmem* limits memory (OpenSSL 1.1.0 defaults to 32 MiB). *dklen* is the length of the derived key.

Availability: OpenSSL 1.1+.

New in version 3.6.

15.1.4 BLAKE2

BLAKE2 is a cryptographic hash function defined in [RFC 7693](#) that comes in two flavors:

- **BLAKE2b**, optimized for 64-bit platforms and produces digests of any size between 1 and 64 bytes,
- **BLAKE2s**, optimized for 8- to 32-bit platforms and produces digests of any size between 1 and 32 bytes.

BLAKE2 supports **keyed mode** (a faster and simpler replacement for [HMAC](#)), **salted hashing**, **personalization**, and **tree hashing**.

Hash objects from this module follow the API of standard library's `hashlib` objects.

Creating hash objects

New hash objects are created by calling constructor functions:

```
hashlib.blake2b(data=b'', *, digest_size=64, key=b'', salt=b'', person=b'', fanout=1, depth=1,
                leaf_size=0, node_offset=0, node_depth=0, inner_size=0, last_node=False)
hashlib.blake2s(data=b'', *, digest_size=32, key=b'', salt=b'', person=b'', fanout=1, depth=1,
                leaf_size=0, node_offset=0, node_depth=0, inner_size=0, last_node=False)
```

These functions return the corresponding hash objects for calculating BLAKE2b or BLAKE2s. They optionally take these general parameters:

- *data*: initial chunk of data to hash, which must be *bytes-like object*. It can be passed only as positional argument.
- *digest_size*: size of output digest in bytes.
- *key*: key for keyed hashing (up to 64 bytes for BLAKE2b, up to 32 bytes for BLAKE2s).
- *salt*: salt for randomized hashing (up to 16 bytes for BLAKE2b, up to 8 bytes for BLAKE2s).
- *person*: personalization string (up to 16 bytes for BLAKE2b, up to 8 bytes for BLAKE2s).

The following table shows limits for general parameters (in bytes):

Hash	digest_size	len(key)	len(salt)	len(person)
BLAKE2b	64	64	16	16
BLAKE2s	32	32	8	8

Note: BLAKE2 specification defines constant lengths for salt and personalization parameters, however, for convenience, this implementation accepts byte strings of any size up to the specified length. If the length of the parameter is less than specified, it is padded with zeros, thus, for example, `b'salt'` and `b'salt\x00'` is the same value. (This is not the case for *key*.)

These sizes are available as module *constants* described below.

Constructor functions also accept the following tree hashing parameters:

- *fanout*: fanout (0 to 255, 0 if unlimited, 1 in sequential mode).
- *depth*: maximal depth of tree (1 to 255, 255 if unlimited, 1 in sequential mode).
- *leaf_size*: maximal byte length of leaf (0 to $2^{**}32-1$, 0 if unlimited or in sequential mode).
- *node_offset*: node offset (0 to $2^{**}64-1$ for BLAKE2b, 0 to $2^{**}48-1$ for BLAKE2s, 0 for the first, leftmost, leaf, or in sequential mode).
- *node_depth*: node depth (0 to 255, 0 for leaves, or in sequential mode).
- *inner_size*: inner digest size (0 to 64 for BLAKE2b, 0 to 32 for BLAKE2s, 0 in sequential mode).
- *last_node*: boolean indicating whether the processed node is the last one (*False* for sequential mode).

See section 2.10 in [BLAKE2 specification](#) for comprehensive review of tree hashing.

Constants

`blake2b.SALT_SIZE`

`blake2s.SALT_SIZE`

Salt length (maximum length accepted by constructors).

`blake2b.PERSON_SIZE`

`blake2s.PERSON_SIZE`

Personalization string length (maximum length accepted by constructors).

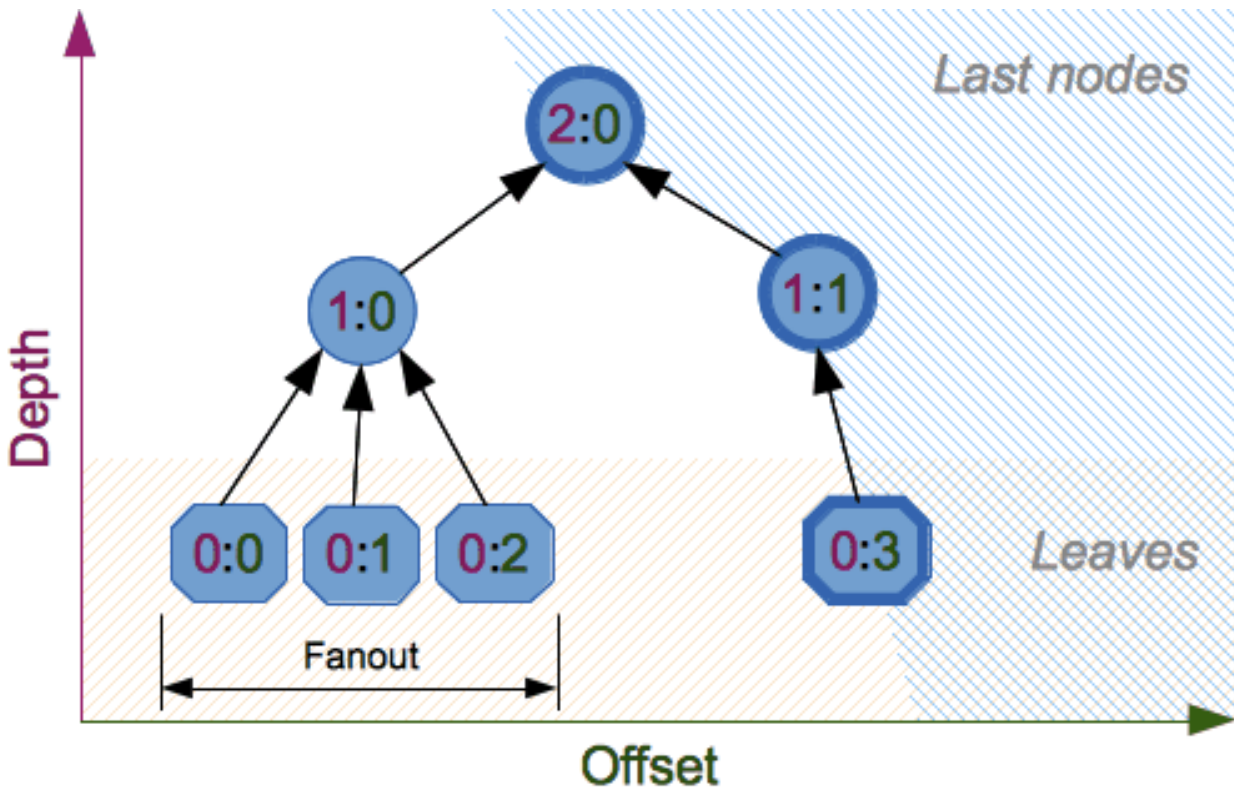
`blake2b.MAX_KEY_SIZE`

`blake2s.MAX_KEY_SIZE`

Maximum key size.

`blake2b.MAX_DIGEST_SIZE`

`blake2s.MAX_DIGEST_SIZE`



Maximum digest size that the hash function can output.

Examples

Simple hashing

To calculate hash of some data, you should first construct a hash object by calling the appropriate constructor function (`blake2b()` or `blake2s()`), then update it with the data by calling `update()` on the object, and, finally, get the digest out of the object by calling `digest()` (or `hexdigest()` for hex-encoded string).

```
>>> from hashlib import blake2b
>>> h = blake2b()
>>> h.update(b'Hello world')
>>> h.hexdigest()

↪ '6ff843ba685842aa82031d3f53c48b66326df7639a63d128974c5c14f31a0f33343a8c65551134ed1ae0f2b0dd2bb495dc81'
↪ '
```

As a shortcut, you can pass the first chunk of data to update directly to the constructor as the positional argument:

```
>>> from hashlib import blake2b
>>> blake2b(b'Hello world').hexdigest()

↪ '6ff843ba685842aa82031d3f53c48b66326df7639a63d128974c5c14f31a0f33343a8c65551134ed1ae0f2b0dd2bb495dc81'
↪ '
```

You can call `hash.update()` as many times as you need to iteratively update the hash:

```
>>> from hashlib import blake2b
>>> items = [b'Hello', b' ', b'world']
>>> h = blake2b()
>>> for item in items:
...     h.update(item)
>>> h.hexdigest()

↪ '6ff843ba685842aa82031d3f53c48b66326df7639a63d128974c5c14f31a0f33343a8c65551134ed1ae0f2b0dd2bb495dc81'
↪ '
```

Using different digest sizes

BLAKE2 has configurable size of digests up to 64 bytes for BLAKE2b and up to 32 bytes for BLAKE2s. For example, to replace SHA-1 with BLAKE2b without changing the size of output, we can tell BLAKE2b to produce 20-byte digests:

```
>>> from hashlib import blake2b
>>> h = blake2b(digest_size=20)
>>> h.update(b'Replacing SHA1 with the more secure function')
>>> h.hexdigest()
'd24f26cf8de66472d58d4e1b1774b4c9158b1f4c'
>>> h.digest_size
20
>>> len(h.digest())
20
```

Hash objects with different digest sizes have completely different outputs (shorter hashes are *not* prefixes of longer hashes); BLAKE2b and BLAKE2s produce different outputs even if the output length is the same:

```
>>> from hashlib import blake2b, blake2s
>>> blake2b(digest_size=10).hexdigest()
'6fa1d8fcfd719046d762'
>>> blake2b(digest_size=11).hexdigest()
'eb6ec15daf9546254f0809'
>>> blake2s(digest_size=10).hexdigest()
'1bf21a98c78a1c376ae9'
>>> blake2s(digest_size=11).hexdigest()
'567004bf96e4a25773ebf4'
```

Keyed hashing

Keyed hashing can be used for authentication as a faster and simpler replacement for [Hash-based message authentication code](#) (HMAC). BLAKE2 can be securely used in prefix-MAC mode thanks to the indistinguishability property inherited from BLAKE.

This example shows how to get a (hex-encoded) 128-bit authentication code for message `b'message data'` with key `b'pseudorandom key'`:

```
>>> from hashlib import blake2b
>>> h = blake2b(key=b'pseudorandom key', digest_size=16)
```

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```
>>> h.update(b'message data')
>>> h.hexdigest()
'3d363ff7401e02026f4a4687d4863ced'
```

As a practical example, a web application can symmetrically sign cookies sent to users and later verify them to make sure they weren't tampered with:

```
>>> from hashlib import blake2b
>>> from hmac import compare_digest
>>>
>>> SECRET_KEY = b'pseudorandomly generated server secret key'
>>> AUTH_SIZE = 16
>>>
>>> def sign(cookie):
...     h = blake2b(digest_size=AUTH_SIZE, key=SECRET_KEY)
...     h.update(cookie)
...     return h.hexdigest().encode('utf-8')
>>>
>>> def verify(cookie, sig):
...     good_sig = sign(cookie)
...     return compare_digest(good_sig, sig)
>>>
>>> cookie = b'user-alice'
>>> sig = sign(cookie)
>>> print("{0},{1}".format(cookie.decode('utf-8'), sig))
user-alice,b'43b3c982cf697e0c5ab22172d1ca7421'
>>> verify(cookie, sig)
True
>>> verify(b'user-bob', sig)
False
>>> verify(cookie, b'0102030405060708090a0b0c0d0e0f00')
False
```

Even though there's a native keyed hashing mode, BLAKE2 can, of course, be used in HMAC construction with `hmac` module:

```
>>> import hmac, hashlib
>>> m = hmac.new(b'secret key', digestmod=hashlib.blake2s)
>>> m.update(b'message')
>>> m.hexdigest()
'e3c8102868d28b5ff85fc35dda07329970d1a01e273c37481326fe0c861c8142'
```

Randomized hashing

By setting `salt` parameter users can introduce randomization to the hash function. Randomized hashing is useful for protecting against collision attacks on the hash function used in digital signatures.

Randomized hashing is designed for situations where one party, the message preparer, generates all or part of a message to be signed by a second party, the message signer. If the message preparer is able to find cryptographic hash function collisions (i.e., two messages producing the same hash value), then they might prepare meaningful versions of the message that would produce the same hash value and digital signature, but with different results (e.g., transferring

\$1,000,000 to an account, rather than \$10). Cryptographic hash functions have been designed with collision resistance as a major goal, but the current concentration on attacking cryptographic hash functions may result in a given cryptographic hash function providing less collision resistance than expected. Randomized hashing offers the signer additional protection by reducing the likelihood that a preparer can generate two or more messages that ultimately yield the same hash value during the digital signature generation process — even if it is practical to find collisions for the hash function. However, the use of randomized hashing may reduce the amount of security provided by a digital signature when all portions of the message are prepared by the signer.

(NIST SP-800-106 “Randomized Hashing for Digital Signatures”)

In BLAKE2 the salt is processed as a one-time input to the hash function during initialization, rather than as an input to each compression function.

Warning: *Salted hashing* (or just hashing) with BLAKE2 or any other general-purpose cryptographic hash function, such as SHA-256, is not suitable for hashing passwords. See [BLAKE2 FAQ](#) for more information.

```
>>> import os
>>> from hashlib import blake2b
>>> msg = b'some message'
>>> # Calculate the first hash with a random salt.
>>> salt1 = os.urandom(blake2b.SALT_SIZE)
>>> h1 = blake2b(salt=salt1)
>>> h1.update(msg)
>>> # Calculate the second hash with a different random salt.
>>> salt2 = os.urandom(blake2b.SALT_SIZE)
>>> h2 = blake2b(salt=salt2)
>>> h2.update(msg)
>>> # The digests are different.
>>> h1.digest() != h2.digest()
True
```

Personalization

Sometimes it is useful to force hash function to produce different digests for the same input for different purposes. Quoting the authors of the Skein hash function:

We recommend that all application designers seriously consider doing this; we have seen many protocols where a hash that is computed in one part of the protocol can be used in an entirely different part because two hash computations were done on similar or related data, and the attacker can force the application to make the hash inputs the same. Personalizing each hash function used in the protocol summarily stops this type of attack.

(The Skein Hash Function Family, p. 21)

BLAKE2 can be personalized by passing bytes to the *person* argument:

```
>>> from hashlib import blake2b
>>> FILES_HASH_PERSON = b'MyApp Files Hash'
>>> BLOCK_HASH_PERSON = b'MyApp Block Hash'
>>> h = blake2b(digest_size=32, person=FILES_HASH_PERSON)
>>> h.update(b'the same content')
```

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```
>>> h.hexdigest()
'20d9cd024d4fb086aae819a1432dd2466de12947831b75c5a30cf2676095d3b4'
>>> h = blake2b(digest_size=32, person=BLOCK_HASH_PERSON)
>>> h.update(b'the same content')
>>> h.hexdigest()
'cf68fb5761b9c44e7878bfb2c4c9aea52264a80b75005e65619778de59f383a3'
```

Personalization together with the keyed mode can also be used to derive different keys from a single one.

```
>>> from hashlib import blake2s
>>> from base64 import b64decode, b64encode
>>> orig_key = b64decode(b'Rm5EPJai72qcK3RGBpW3vPNfZy50ZothY+kHY6h21KM=')
>>> enc_key = blake2s(key=orig_key, person=b'kEncrypt').digest()
>>> mac_key = blake2s(key=orig_key, person=b'kMAC').digest()
>>> print(b64encode(enc_key).decode('utf-8'))
rbPb15S/Z9t+agffno5wuhB77VbRi6F9Iv2qIxU7WHw=
>>> print(b64encode(mac_key).decode('utf-8'))
G9GtHFE1YluXY1zWP1Yk1e/nWfuOWSEb0KRcjhDeP/o=
```

Tree mode

Here's an example of hashing a minimal tree with two leaf nodes:

```
  10
 /  \
00  01
```

This example uses 64-byte internal digests, and returns the 32-byte final digest:

```
>>> from hashlib import blake2b
>>>
>>> FANOUT = 2
>>> DEPTH = 2
>>> LEAF_SIZE = 4096
>>> INNER_SIZE = 64
>>>
>>> buf = bytearray(6000)
>>>
>>> # Left leaf
... h00 = blake2b(buf[0:LEAF_SIZE], fanout=FANOUT, depth=DEPTH,
...               leaf_size=LEAF_SIZE, inner_size=INNER_SIZE,
...               node_offset=0, node_depth=0, last_node=False)
>>> # Right leaf
... h01 = blake2b(buf[LEAF_SIZE:], fanout=FANOUT, depth=DEPTH,
...               leaf_size=LEAF_SIZE, inner_size=INNER_SIZE,
...               node_offset=1, node_depth=0, last_node=True)
>>> # Root node
... h10 = blake2b(digest_size=32, fanout=FANOUT, depth=DEPTH,
...               leaf_size=LEAF_SIZE, inner_size=INNER_SIZE,
...               node_offset=0, node_depth=1, last_node=True)
>>> h10.update(h00.digest())
```

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```
>>> h10.update(h01.digest())
>>> h10.hexdigest()
'3ad2a9b37c6070e374c7a8c508fe20ca86b6ed54e286e93a0318e95e881db5aa'
```

Credits

BLAKE2 was designed by *Jean-Philippe Aumasson*, *Samuel Neves*, *Zooko Wilcox-O’Hearn*, and *Christian Winnerlein* based on SHA-3 finalist BLAKE created by *Jean-Philippe Aumasson*, *Luca Henzen*, *Willi Meier*, and *Raphael C.-W. Phan*.

It uses core algorithm from ChaCha cipher designed by *Daniel J. Bernstein*.

The stdlib implementation is based on `pyblake2` module. It was written by *Dmitry Chestnykh* based on C implementation written by *Samuel Neves*. The documentation was copied from `pyblake2` and written by *Dmitry Chestnykh*.

The C code was partly rewritten for Python by *Christian Heimes*.

The following public domain dedication applies for both C hash function implementation, extension code, and this documentation:

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The following people have helped with development or contributed their changes to the project and the public domain according to the Creative Commons Public Domain Dedication 1.0 Universal:

- *Alexandr Sokolovskiy*

See also:

Module `hmac` A module to generate message authentication codes using hashes.

Module `base64` Another way to encode binary hashes for non-binary environments.

<https://blake2.net> Official BLAKE2 website.

<https://csrc.nist.gov/csrc/media/publications/fips/180/2/archive/2002-08-01/documents/fips180-2.pdf>
The FIPS 180-2 publication on Secure Hash Algorithms.

https://en.wikipedia.org/wiki/Cryptographic_hash_function#Cryptographic_hash_algorithms
Wikipedia article with information on which algorithms have known issues and what that means regarding their use.

<https://www.ietf.org/rfc/rfc2898.txt> PKCS #5: Password-Based Cryptography Specification Version 2.0

15.2 hmac — Keyed-Hashing for Message Authentication

Source code: `Lib/hmac.py`

This module implements the HMAC algorithm as described by [RFC 2104](#).

`hmac.new(key, msg=None, digestmod=None)`

Return a new hmac object. *key* is a bytes or bytearray object giving the secret key. If *msg* is present, the method call `update(msg)` is made. *digestmod* is the digest name, digest constructor or module for the HMAC object to use. It supports any name suitable to `hashlib.new()` and defaults to the `hashlib.md5` constructor.

Changed in version 3.4: Parameter *key* can be a bytes or bytearray object. Parameter *msg* can be of any type supported by `hashlib`. Parameter *digestmod* can be the name of a hash algorithm.

Deprecated since version 3.4, will be removed in version 3.8: MD5 as implicit default digest for *digestmod* is deprecated.

`hmac.digest(key, msg, digest)`

Return digest of *msg* for given secret *key* and *digest*. The function is equivalent to `HMAC(key, msg, digest).digest()`, but uses an optimized C or inline implementation, which is faster for messages that fit into memory. The parameters *key*, *msg*, and *digest* have the same meaning as in `new()`.

CPython implementation detail, the optimized C implementation is only used when *digest* is a string and name of a digest algorithm, which is supported by OpenSSL.

New in version 3.7.

An HMAC object has the following methods:

`HMAC.update(msg)`

Update the hmac object with *msg*. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a + b)`.

Changed in version 3.4: Parameter *msg* can be of any type supported by `hashlib`.

`HMAC.digest()`

Return the digest of the bytes passed to the `update()` method so far. This bytes object will be the same length as the *digest_size* of the digest given to the constructor. It may contain non-ASCII bytes, including NUL bytes.

Warning: When comparing the output of `digest()` to an externally-supplied digest during a verification routine, it is recommended to use the `compare_digest()` function instead of the `==` operator to reduce the vulnerability to timing attacks.

`HMAC.hexdigest()`

Like `digest()` except the digest is returned as a string twice the length containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

Warning: When comparing the output of `hexdigest()` to an externally-supplied digest during a verification routine, it is recommended to use the `compare_digest()` function instead of the `==` operator to reduce the vulnerability to timing attacks.

`HMAC.copy()`

Return a copy (“clone”) of the hmac object. This can be used to efficiently compute the digests of strings that share a common initial substring.

A hash object has the following attributes:

`HMAC.digest_size`

The size of the resulting HMAC digest in bytes.

`HMAC.block_size`

The internal block size of the hash algorithm in bytes.

New in version 3.4.

HMAC.name

The canonical name of this HMAC, always lowercase, e.g. `hmac-md5`.

New in version 3.4.

This module also provides the following helper function:

hmac.compare_digest(*a*, *b*)

Return `a == b`. This function uses an approach designed to prevent timing analysis by avoiding content-based short circuiting behaviour, making it appropriate for cryptography. *a* and *b* must both be of the same type: either *str* (ASCII only, as e.g. returned by `HMAC.hexdigest()`), or a *bytes-like object*.

Note: If *a* and *b* are of different lengths, or if an error occurs, a timing attack could theoretically reveal information about the types and lengths of *a* and *b*—but not their values.

New in version 3.3.

See also:

Module `hashlib` The Python module providing secure hash functions.

15.3 secrets — Generate secure random numbers for managing secrets

New in version 3.6.

Source code: [Lib/secrets.py](#)

The `secrets` module is used for generating cryptographically strong random numbers suitable for managing data such as passwords, account authentication, security tokens, and related secrets.

In particular, `secrets` should be used in preference to the default pseudo-random number generator in the `random` module, which is designed for modelling and simulation, not security or cryptography.

See also:

PEP 506

15.3.1 Random numbers

The `secrets` module provides access to the most secure source of randomness that your operating system provides.

class `secrets.SystemRandom`

A class for generating random numbers using the highest-quality sources provided by the operating system. See `random.SystemRandom` for additional details.

`secrets.choice(sequence)`

Return a randomly-chosen element from a non-empty sequence.

`secrets.randbelow(n)`

Return a random int in the range `[0, n)`.

`secrets.randbits(k)`

Return an int with *k* random bits.

15.3.2 Generating tokens

The `secrets` module provides functions for generating secure tokens, suitable for applications such as password resets, hard-to-guess URLs, and similar.

`secrets.token_bytes([nbytes=None])`

Return a random byte string containing *nbytes* number of bytes. If *nbytes* is `None` or not supplied, a reasonable default is used.

```
>>> token_bytes(16)
b'\xebr\x17D*t\xae\xd4\xe3S\xb6\xe2\xebP1\x8b'
```

`secrets.token_hex([nbytes=None])`

Return a random text string, in hexadecimal. The string has *nbytes* random bytes, each byte converted to two hex digits. If *nbytes* is `None` or not supplied, a reasonable default is used.

```
>>> token_hex(16)
'f9bf78b9a18ce6d46a0cd2b0b86df9da'
```

`secrets.token_urlsafe([nbytes=None])`

Return a random URL-safe text string, containing *nbytes* random bytes. The text is Base64 encoded, so on average each byte results in approximately 1.3 characters. If *nbytes* is `None` or not supplied, a reasonable default is used.

```
>>> token_urlsafe(16)
'Drmhze6EPcvOfN_81Bj-nA'
```

How many bytes should tokens use?

To be secure against [brute-force attacks](#), tokens need to have sufficient randomness. Unfortunately, what is considered sufficient will necessarily increase as computers get more powerful and able to make more guesses in a shorter period. As of 2015, it is believed that 32 bytes (256 bits) of randomness is sufficient for the typical use-case expected for the `secrets` module.

For those who want to manage their own token length, you can explicitly specify how much randomness is used for tokens by giving an *int* argument to the various `token_*` functions. That argument is taken as the number of bytes of randomness to use.

Otherwise, if no argument is provided, or if the argument is `None`, the `token_*` functions will use a reasonable default instead.

Note: That default is subject to change at any time, including during maintenance releases.

15.3.3 Other functions

`secrets.compare_digest(a, b)`

Return `True` if strings *a* and *b* are equal, otherwise `False`, in such a way as to reduce the risk of [timing attacks](#). See `hmac.compare_digest()` for additional details.

15.3.4 Recipes and best practices

This section shows recipes and best practices for using `secrets` to manage a basic level of security.

Generate an eight-character alphanumeric password:

```
import string
alphabet = string.ascii_letters + string.digits
password = ''.join(choice(alphabet) for i in range(8))
```

Note: Applications should not store passwords in a recoverable format, whether plain text or encrypted. They should be salted and hashed using a cryptographically-strong one-way (irreversible) hash function.

Generate a ten-character alphanumeric password with at least one lowercase character, at least one uppercase character, and at least three digits:

```
import string
alphabet = string.ascii_letters + string.digits
while True:
    password = ''.join(choice(alphabet) for i in range(10))
    if (any(c.islower() for c in password)
        and any(c.isupper() for c in password)
        and sum(c.isdigit() for c in password) >= 3):
        break
```

Generate an XKCD-style passphrase:

```
# On standard Linux systems, use a convenient dictionary file.
# Other platforms may need to provide their own word-list.
with open('/usr/share/dict/words') as f:
    words = [word.strip() for word in f]
    password = ' '.join(choice(words) for i in range(4))
```

Generate a hard-to-guess temporary URL containing a security token suitable for password recovery applications:

```
url = 'https://mydomain.com/reset=' + token_urlsafe()
```

