cryptography includes both high level recipes and low level interfaces to common cryptographic algorithms such as symmetric ciphers, message digests, and key derivation functions. For example, to encrypt something with cryptography's high level symmetric encryption recipe:

```python
>>> from cryptography.fernet import Fernet
>>> # Put this somewhere safe!
>>> key = Fernet.generate_key()
>>> f = Fernet(key)
>>> token = f.encrypt(b"A really secret message. Not for prying eyes.")
>>> token
b'
...'
>>> f.decrypt(token)
b'A really secret message. Not for prying eyes.'
```

If you are interested in learning more about the field of cryptography, we recommend Crypto 101, by Laurens Van Houtven and The Cryptopals Crypto Challenges.
You can install cryptography with pip:

```
$ pip install cryptography
```

See *Installation* for more information.
cryptography is broadly divided into two levels. One with safe cryptographic recipes that require little to no configuration choices. These are safe and easy to use and don’t require developers to make many decisions.

The other level is low-level cryptographic primitives. These are often dangerous and can be used incorrectly. They require making decisions and having an in-depth knowledge of the cryptographic concepts at work. Because of the potential danger in working at this level, this is referred to as the “hazardous materials” or “hazmat” layer. These live in the cryptography.hazmat package, and their documentation will always contain an admonition at the top.

We recommend using the recipes layer whenever possible, and falling back to the hazmat layer only when necessary.

2.1 Fernet (symmetric encryption)

Fernet guarantees that a message encrypted using it cannot be manipulated or read without the key. Fernet is an implementation of symmetric (also known as “secret key”) authenticated cryptography. Fernet also has support for implementing key rotation via MultiFernet.

class cryptography.fernet.Fernet(key)

This class provides both encryption and decryption facilities.

```python
>>> from cryptography.fernet import Fernet
>>> key = Fernet.generate_key()
>>> f = Fernet(key)
>>> token = f.encrypt(b"my deep dark secret")
>>> token
b'...'
>>> f.decrypt(token)
'b'my deep dark secret'
```

Parameters

- key (bytes or str) – A URL-safe base64-encoded 32-byte key. This must be kept secret. Anyone with this key is able to create and read messages.

class method generate_key()

Generates a fresh fernet key. Keep this some place safe! If you lose it you’ll no longer be able to decrypt messages; if anyone else gains access to it, they’ll be able to decrypt all of your messages, and they’ll also be able forge arbitrary messages that will be authenticated and decrypted.

encrypt(data)

Encrypts data passed. The result of this encryption is known as a “Fernet token” and has strong privacy and authenticity guarantees.
Parameters

**data (bytes)** – The message you would like to encrypt.

Returns **bytes**

A secure message that cannot be read or altered without the key. It is URL-safe base64-encoded. This is referred to as a “Fernet token”.

Raises

**TypeError** – This exception is raised if *data* is not *bytes*.

---

**Note:** The encrypted message contains the current time when it was generated in plaintext, the time a message was created will therefore be visible to a possible attacker.

---

**encrypt_at_time**(data, current_time)

New in version 3.0.

Encrypts data passed using explicitly passed current time. See **encrypt()** for the documentation of the *data* parameter, the return type and the exceptions raised.

The motivation behind this method is for the client code to be able to test token expiration. Since this method can be used in an insecure manner one should make sure the correct time (**int**(time.time())) is passed as *current_time* outside testing.

Parameters

**current_time** (**int**) – The current time.

---

**Note:** Similarly to **encrypt()** the encrypted message contains the timestamp in plaintext, in this case the timestamp is the value of the *current_time* parameter.

---

**decrypt**(token, ttl=None)

Decrypts a Fernet token. If successfully decrypted you will receive the original plaintext as the result, otherwise an exception will be raised. It is safe to use this data immediately as Fernet verifies that the data has not been tampered with prior to returning it.

Parameters

- **token** (**bytes** or **str**) – The Fernet token. This is the result of calling **encrypt()**.
- **ttl** (**int**) – Optionally, the number of seconds old a message may be for it to be valid. If the message is older than *ttl* seconds (from the time it was originally created) an exception will be raised. If *ttl* is not provided (or is None), the age of the message is not considered.

Returns **bytes**

The original plaintext.

Raises

- **cryptography.fernet.InvalidToken** – If the *token* is in any way invalid, this exception is raised. A token may be invalid for a number of reasons: it is older than the *ttl*, it is malformed, or it does not have a valid signature.
- **TypeError** – This exception is raised if *token* is not *bytes* or *str*.

**decrypt_at_time**(token, ttl, current_time)

New in version 3.0.

Decrypts a token using explicitly passed current time. See **decrypt()** for the documentation of the *token* and *ttl* parameters (ttl is required here), the return type and the exceptions raised.
The motivation behind this method is for the client code to be able to test token expiration. Since this method can be used in an insecure manner one should make sure the correct time (\(\text{int}(\text{time}.\text{time}())\)) is passed as `current_time` outside testing.

**Parameters**

- `current_time` (*int*) – The current time.

**extract_timestamp**(*token*)

New in version 2.3.

Returns the timestamp for the token. The caller can then decide if the token is about to expire and, for example, issue a new token.

**Parameters**

- `token` (*bytes or str*) – The Fernet token. This is the result of calling `encrypt()`.

**Returns** *int*

The Unix timestamp of the token.

**Raises**

- `cryptography.fernet.InvalidToken` – If the token’s signature is invalid this exception is raised.

- `TypeError` – This exception is raised if `token` is not bytes or str.

**class cryptography.fernet.MultiFernet(*fernets*)**

New in version 0.7.

This class implements key rotation for Fernet. It takes a list of Fernet instances and implements the same API with the exception of one additional method: `MultiFernet.rotate()`:

```python
>>> from cryptography.fernet import Fernet, MultiFernet
>>> key1 = Fernet(Fernet.generate_key())
>>> key2 = Fernet(Fernet.generate_key())
>>> f = MultiFernet([key1, key2])
>>> token = f.encrypt(b"Secret message!"

>>> token
b'...'
>>> f.decrypt(token)

b'Secret message!'
```

MultiFernet performs all encryption options using the first key in the list provided. MultiFernet attempts to decrypt tokens with each key in turn. A `cryptography.fernet.InvalidToken` exception is raised if the correct key is not found in the list provided.

Key rotation makes it easy to replace old keys. You can add your new key at the front of the list to start encrypting new messages, and remove old keys as they are no longer needed.

Token rotation as offered by `MultiFernet.rotate()` is a best practice and manner of cryptographic hygiene designed to limit damage in the event of an undetected event and to increase the difficulty of attacks. For example, if an employee who had access to your company’s fernet keys leaves, you’ll want to generate new fernet key, rotate all of the tokens currently deployed using that new key, and then retire the old fernet key(s) to which the employee had access.

**rotate**(*msg*)

New in version 2.2.

Rotates a token by re-encrypting it under the `MultiFernet` instance’s primary key. This preserves the timestamp that was originally saved with the token. If a token has successfully been rotated then the rotated token will be returned. If rotation fails this will raise an exception.

2.1. Fernet (symmetric encryption)
>>> from cryptography.fernet import Fernet, MultiFernet
>>> key1 = Fernet(Fernet.generate_key())
>>> key2 = Fernet(Fernet.generate_key())
>>> f = MultiFernet([key1, key2])
>>> token = f.encrypt(b"Secret message!")
>>> token
b'...

>>> f.decrypt(token)
b'Secret message!

>>> f2 = MultiFernet([key3, key1, key2])
>>> rotated = f2.rotate(token)
>>> f2.decrypt(rotated)
b'Secret message!

Parameters

msg (bytes or str) – The token to re-encrypt.

Returns bytes

A secure message that cannot be read or altered without the key. This is URL-safe base64-encoded. This is referred to as a “Fernet token”.

Raises

- cryptography.fernet.InvalidToken – If a token is in any way invalid this exception is raised.
- TypeError – This exception is raised if the msg is not bytes or str.

class cryptography.fernet.InvalidToken
See Fernet.decrypt() for more information.

2.1.1 Using passwords with Fernet

It is possible to use passwords with Fernet. To do this, you need to run the password through a key derivation function such as PBKDF2HMAC, bcrypt or Scrypt.

>>> import base64
>>> import os
>>> from cryptography.fernet import Fernet
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.pbkdf2 import PBKDF2HMAC

>>> password = b"password"
>>> salt = os.urandom(16)
>>> kdf = PBKDF2HMAC(... algorithm=hashes.SHA256(),
... length=32,
... salt=salt,
... iterations=480000,
... )
>>> key = base64.urlsafe_b64encode(kdf.derive(password))
>>> f = Fernet(key)
>>> token = f.encrypt(b"Secret message!")
In this scheme, the salt has to be stored in a retrievable location in order to derive the same key from the password in the future.

The iteration count used should be adjusted to be as high as your server can tolerate. A good default is at least 480,000 iterations, which is what Django recommends as of December 2022.

### 2.1.2 Implementation

Fernet is built on top of a number of standard cryptographic primitives. Specifically it uses:

- **AES** in **CBC** mode with a 128-bit key for encryption; using **PKCS7** padding.
- **HMAC** using **SHA256** for authentication.
- Initialization vectors are generated using `os.urandom()`.

For complete details consult the specification.

### 2.1.3 Limitations

Fernet is ideal for encrypting data that easily fits in memory. As a design feature it does not expose unauthenticated bytes. This means that the complete message contents must be available in memory, making Fernet generally unsuitable for very large files at this time.

### 2.2 X.509

X.509 is an ITU-T standard for a public key infrastructure. X.509v3 is defined in RFC 5280 (which obsoletes RFC 2459 and RFC 3280). X.509 certificates are commonly used in protocols like TLS.

#### 2.2.1 Tutorial

X.509 certificates are used to authenticate clients and servers. The most common use case is for web servers using HTTPS.

**Creating a Certificate Signing Request (CSR)**

When obtaining a certificate from a certificate authority (CA), the usual flow is:

1. You generate a private/public key pair.
2. You create a request for a certificate, which is signed by your key (to prove that you own that key).
3. You give your CSR to a CA (but not the private key).
4. The CA validates that you own the resource (e.g. domain) you want a certificate for.
5. The CA gives you a certificate, signed by them, which identifies your public key, and the resource you are authenticated for.
6. You configure your server to use that certificate, combined with your private key, to server traffic.

If you want to obtain a certificate from a typical commercial CA, here’s how. First, you’ll need to generate a private key, we’ll generate an RSA key (these are the most common types of keys on the web right now):

```python
>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import rsa

>>> # Generate our key
>>> key = rsa.generate_private_key(
...     public_exponent=65537,
...     key_size=2048,
... )

>>> # Write our key to disk for safe keeping
>>> with open("path/to/store/key.pem", "wb") as f:
...     f.write(key.private_bytes(
...         encoding=serialization.Encoding.PEM,
...         format=serialization.PrivateFormat.TraditionalOpenSSL,
...         encryption_algorithm=serialization.BestAvailableEncryption(b"passphrase"),
...     ))
```

If you’ve already generated a key you can load it with `load_pem_private_key()`.

Next we need to generate a certificate signing request. A typical CSR contains a few details:

- Information about our public key (including a signature of the entire body).
- Information about who we are.
- Information about what domains this certificate is for.

```python
>>> from cryptography import x509
>>> from cryptography.x509.oid import NameOID
>>> from cryptography.hazmat.primitives import hashes

>>> # Generate a CSR
>>> csr = x509.CertificateSigningRequestBuilder().subject_name(x509.Name([
...     # Provide various details about who we are.
...     x509.NameAttribute(NameOID.COUNTRY_NAME, "US"),
...     x509.NameAttribute(NameOID.STATE_OR_PROVINCE_NAME, "California"),
...     x509.NameAttribute(NameOID.LOCALITY_NAME, "San Francisco"),
...     x509.NameAttribute(NameOID.ORGANIZATION_NAME, "My Company"),
...     x509.NameAttribute(NameOID.COMMON_NAME, "mysite.com"),
... ])).add_extension(
...     x509.SubjectAlternativeName([  
...         # Describe what sites we want this certificate for.
...         x509.DNSName("mysite.com"),
...         x509.DNSName("www.mysite.com"),
...         x509.DNSName("subdomain.mysite.com"),
...     ]),
...     critical=False,
... ).sign(key, hashes.SHA256())

>>> # Write our CSR out to disk.
>>> with open("path/to/csr.pem", "wb") as f:
...     f.write(csr.public_bytes(serialization.Encoding.PEM))
```

Now we can give our CSR to a CA, who will give a certificate to us in return.
Creating a self-signed certificate

While most of the time you want a certificate that has been signed by someone else (i.e. a certificate authority), so that trust is established, sometimes you want to create a self-signed certificate. Self-signed certificates are not issued by a certificate authority, but instead they are signed by the private key corresponding to the public key they embed.

This means that other people don’t trust these certificates, but it also means they can be issued very easily. In general the only use case for a self-signed certificate is local testing, where you don’t need anyone else to trust your certificate.

Like generating a CSR, we start with creating a new private key:

```
>>> # Generate our key
>>> key = rsa.generate_private_key(
...     public_exponent=65537,
...     key_size=2048,
... )
```

Then we generate the certificate itself:

```
>>> # Various details about who we are. For a self-signed certificate the
>>> # subject and issuer are always the same.
>>> subject = issuer = x509.Name(
...     x509.NameAttribute(NameOID.COUNTRY_NAME, "US"),
...     x509.NameAttribute(NameOID.STATE_OR_PROVINCE_NAME, "California"),
...     x509.NameAttribute(NameOID.LOCALITY_NAME, "San Francisco"),
...     x509.NameAttribute(NameOID.ORGANIZATION_NAME, "My Company"),
...     x509.NameAttribute(NameOID.COMMON_NAME, "mysite.com"),
... )
>>> cert = x509.CertificateBuilder().subject_name(
...     subject
... ).issuer_name(
...     issuer
... ).public_key(
...     key.public_key()
... ).serial_number(
...     x509.random_serial_number()
... ).not_valid_before(
...     datetime.datetime.now(datetime.timezone.utc)
... ).not_valid_after(
...     # Our certificate will be valid for 10 days
...     datetime.datetime.now(datetime.timezone.utc) + datetime.timedelta(days=10)
... ).add_extension(
...     x509.SubjectAlternativeName([x509.DNSName("localhost")]),
...     critical=False,
...     # Sign our certificate with our private key
... ).sign(key, hashes.SHA256())
```

(continues on next page)
And now we have a private key and certificate that can be used for local testing.

**Determining Certificate or Certificate Signing Request Key Type**

Certificates and certificate signing requests can be issued with multiple key types. You can determine what the key type is by using `isinstance` checks:

```python
>>> public_key = cert.public_key()
>>> if isinstance(public_key, rsa.RSAPublicKey):
...    # Do something RSA specific
... elif isinstance(public_key, ec.EllipticCurvePublicKey):
...    # Do something EC specific
... else:
...    # Remember to handle this case
```

### 2.2.2 Certificate Transparency

Certificate Transparency is a set of protocols specified in [RFC 6962](https://tools.ietf.org/html/rfc6962) which allow X.509 certificates to be sent to append-only logs and have small cryptographic proofs that a certificate has been publicly logged. This allows for external auditing of the certificates that a certificate authority has issued.

```python
class cryptography.x509.certificate_transparency.SignedCertificateTimestamp
```

New in version 2.0.

SignedCertificateTimestamps (SCTs) are small cryptographically signed assertions that the specified certificate has been submitted to a Certificate Transparency Log, and that it will be part of the public log within some time period, this is called the “maximum merge delay” (MMD) and each log specifies its own.

- **version**: Type `Version`
  The SCT version as an enumeration. Currently only one version has been specified.

- **log_id**: Type `bytes`
  An opaque identifier, indicating which log this SCT is from. This is the SHA256 hash of the log’s public key.

- **timestamp**: Type `datetime.datetime`
  A naïve datetime representing the time in UTC at which the log asserts the certificate had been submitted to it.
entry_type

Type
LogEntryType

The type of submission to the log that this SCT is for. Log submissions can either be certificates themselves or “pre-certificates” which indicate a binding-intent to issue a certificate for the same data, with SCTs embedded in it.

signature_hash_algorithm

Type
HashAlgorithm

The hashing algorithm used by this SCT’s signature.

signature_algorithm

Type
SignatureAlgorithm

The signing algorithm used by this SCT’s signature.

signature

Type
bytes

The raw bytes of the signatures embedded in the SCT.

extension_bytes

Type
bytes

Any raw extension bytes.

class cryptography.x509.certificate_transparency.Version

New in version 2.0.

An enumeration for SignedCertificateTimestamp versions.

v1

For version 1 SignedCertificateTimestamps.

class cryptography.x509.certificate_transparency.LogEntryType

New in version 2.0.

An enumeration for SignedCertificateTimestamp log entry types.

X509_CERTIFICATE

For SCTs corresponding to X.509 certificates.

PRE_CERTIFICATE

For SCTs corresponding to pre-certificates.
class cryptography.x509.certificate_transparency.SignatureAlgorithm

New in version 38.0.0.

An enumeration for SignedCertificateTimestamp signature algorithms.

These are exactly the same as SignatureAlgorithm in RFC 5246 (TLS 1.2).

ANONYMOUS

RSA

DSA

ECDSA

2.2.3 OCSP

OCSP (Online Certificate Status Protocol) is a method of checking the revocation status of certificates. It is specified in RFC 6960, as well as other obsoleted RFCs.

Loading Requests

cryptography.x509.ocsp.load_der_ocsp_request(data)

New in version 2.4.

Deserialize an OCSP request from DER encoded data.

Parameters

data (bytes) – The DER encoded OCSP request data.

Returns

An instance of OCSPRequest.

```python
>>> from cryptography.x509 import ocsp
>>> ocsp_req = ocsp.load_der_ocsp_request(der_ocsp_req)
>>> print(ocsp_req.serial_number)
872625873161273451176241581705670534707360122361
```

Creating Requests

class cryptography.x509.ocsp.OCSPRequestBuilder

New in version 2.4.

This class is used to create OCSPRequest objects.

add_certificate(cert, issuer, algorithm)

Adds a request using a certificate, issuer certificate, and hash algorithm. You can call this method or add_certificate_by_hash only once.

Parameters

- cert – The Certificate whose validity is being checked.
- issuer – The issuer Certificate of the certificate that is being checked.
- algorithm – A HashAlgorithm instance. For OCSP only SHA1, SHA224, SHA256, SHA384, and SHA512 are allowed.
**add_certificate_by_hash** *(issuer_name_hash, issuer_key_hash, serial_number, algorithm)*

New in version 39.0.0.

Adds a request using the issuer's name hash, key hash, the certificate serial number and hash algorithm. You can call this method or `add_certificate` only once.

**Parameters**

- **issuer_name_hash** *(bytes)* – The hash of the issuer’s DER encoded name using the same hash algorithm as the one specified in the `algorithm` parameter.
- **issuer_key_hash** *(bytes)* – The hash of the issuer’s public key bit string DER encoding using the same hash algorithm as the one specified in the `algorithm` parameter.
- **serial_number** *(int)* – The serial number of the certificate being checked.
- **algorithm** – A `HashAlgorithm` instance. For OCSP only `SHA1`, `SHA224`, `SHA256`, `SHA384`, and `SHA512` are allowed.

**add_extension**(extval, critical)

Adds an extension to the request.

**Parameters**

- **extval** – An extension conforming to the `ExtensionType` interface.
- **critical** – Set to True if the extension must be understood and handled.

**build()**

**Returns**

A new `OCSPRequest`.

```python
def add_certificate(cert, issuer, algorithm):
    builder = ocsp.OCSPRequestBuilder()
    builder = builder.add_certificate(cert, issuer, algorithm())
    req = builder.build()
    return base64.b64encode(req.public_bytes(serialization.Encoding.DER))
```
Loading Responses

cryptography.x509.ocsp.load_der_ocsp_response(data)

New in version 2.4.

Deserialize an OCSP response from DER encoded data.

Parameters

data (bytes) – The DER encoded OCSP response data.

Returns

An instance of OCSPResponse.

```python
>>> from cryptography.x509 import ocsp
>>> ocsp_resp = ocsp.load_der_ocsp_response(der_ocsp_resp_unauth)
>>> print(ocsp_resp.response_status)
OCSPResponseStatus.UNAUTHORIZED
```

Creating Responses

class cryptography.x509.ocsp.OCSPResponseBuilder

New in version 2.4.

This class is used to create OCSPResponse objects. You cannot set produced_at on OCSP responses at this time. Instead the field is set to current UTC time when calling sign. For unsuccessful statuses call the class method build_unsuccessful().

add_response(cert, issuer, algorithm, cert_status, this_update, next_update, revocation_time, revocation_reason)

This method adds status information about the certificate that was requested to the response.

Parameters

- cert – The Certificate whose validity is being checked.
- issuer – The issuer Certificate of the certificate that is being checked.
- algorithm – A HashAlgorithm instance. For OCSP only SHA1, SHA224, SHA256, SHA384, and SHA512 are allowed.
- cert_status – An item from the OCSPCertStatus enumeration.
- this_update – A naïve datetime.datetime object representing the most recent time in UTC at which the status being indicated is known by the responder to be correct.
- next_update – A naïve datetime.datetime object or None. The time in UTC at or before which newer information will be available about the status of the certificate.
- revocation_time – A naïve datetime.datetime object or None if the cert is not revoked. The time in UTC at which the certificate was revoked.
- revocation_reason – An item from the ReasonFlags enumeration or None if the cert is not revoked.

Certificates(certs)

Add additional certificates that should be used to verify the signature on the response. This is typically used when the responder utilizes an OCSP delegate.

Parameters

certs (list) – A list of Certificate objects.
responder_id(encoding, responder_cert)

Set the responderID on the OCSP response. This is the data a client will use to determine what certificate signed the response.

Parameters

- **responder_cert** – The Certificate object for the certificate whose private key will sign the OCSP response. If the certificate and key do not match an error will be raised when calling sign.
- **encoding** – Either HASH or NAME.

add_extension(extval, critical)

Adds an extension to the response.

Parameters

- **extval** – An extension conforming to the ExtensionType interface.
- **critical** – Set to True if the extension must be understood and handled.

sign(private_key, algorithm)

Creates the OCSP response that can then be serialized and sent to clients. This method will create a SUCCESSFUL response.

Parameters

- **private_key** – The RSAPrivateKey, DSAPrivateKey, EllipticCurvePrivateKey, Ed25519PrivateKey or Ed448PrivateKey that will be used to sign the response.
- **algorithm** – The HashAlgorithm that will be used to generate the signature. This must be None if the private_key is an Ed25519PrivateKey or an Ed448PrivateKey and an instance of a HashAlgorithm otherwise.

Returns

A new OCSPResponse.

```python
>>> import datetime
>>> from cryptography.hazmat.primitives import hashes, serialization
>>> from cryptography.x509 import load_pem_x509_certificate, ocsp
>>>
cert = load_pem_x509_certificate(pem_cert)
>>> issuer = load_pem_x509_certificate(pem_issuer)
>>> responder_cert = load_pem_x509_certificate(pem_responder_cert)
>>> responder_key = serialization.load_pem_private_key(pem_responder_key, None)
>>> builder = ocsp.OCSPResponseBuilder()
>>> # SHA256 is in this example because while RFC 5019 originally
>>> # required SHA1 RFC 6960 updates that to SHA256.
>>> # However, depending on your requirements you may need to use SHA1
>>> # for compatibility reasons.
>>> builder = builder.add_response(
...   cert=cert, issuer=issuer, algorithm=hashes.SHA256(),
...   cert_status=ocsp.OCSPCertStatus.GOOD,
...   this_update=datetime.datetime.now(),
...   next_update=datetime.datetime.now(),
...   revocation_time=None, revocation_reason=None
... ).responder_id(
...   ocsp.OCSPResponderEncoding.HASH, responder_cert
... )
>>> response = builder.sign(responder_key, hashes.SHA256())
```
>>> response.certificate_status
<OCSPCertStatus.GOOD: 0>

**class method build_unsuccessful**(response_status)

Creates an unsigned OCSP response which can then be serialized and sent to clients. build_unsuccessful may only be called with a OCSPResponseStatus that is not SUCCESSFUL. Since this is a class method note that no other methods can or should be called as unsuccessful statuses do not encode additional data.

**Returns**

A new OCSPResponse.

```python
>>> from cryptography.hazmat.primitives import hashes, serialization
>>> from cryptography.x509 import load_pem_x509_certificate, ocsp

>>> response = ocsp.OCSPResponseBuilder.build_unsuccessful(...
  ocsp.OCSPResponseStatus.UNAUTHORIZED
...)
```

**Interfaces**

**class cryptography.x509.ocsp.OCSPRequest**

New in version 2.4.

An OCSPRequest is an object containing information about a certificate whose status is being checked.

**issuer_key_hash**

**Type** bytes

The hash of the certificate issuer’s key. The hash algorithm used is defined by the hash_algorithm property.

**issuer_name_hash**

**Type** bytes

The hash of the certificate issuer’s name. The hash algorithm used is defined by the hash_algorithm property.

**hash_algorithm**

**Type** HashAlgorithm

The algorithm used to generate the issuer_key_hash and issuer_name_hash.

**serial_number**

**Type** int

The serial number of the certificate to check.
extensions

Type

Extensions

The extensions encoded in the request.

public_bytes(encoding)

Parameters

encoding – The encoding to use. Only DER is supported.

Return bytes

The serialized OCSP request.

class cryptography.x509.ocsp.OCSPResponse

New in version 2.4.

An OCSPResponse is the data provided by an OCSP responder in response to an OCSPRequest.

response_status

Type

OCSPResponseStatus

The status of the response.

signature_algorithm_oid

Type

ObjectIdentifier

Returns the object identifier of the signature algorithm used to sign the response. This will be one of the OIDs from SignatureAlgorithmOID.

Raises

ValueError – If response_status is not SUCCESSFUL.

signature_hash_algorithm

New in version 2.5.

Type

HashAlgorithm

Returns the HashAlgorithm which was used in signing this response. Can be None if signature did not use separate hash (ED25519, ED448).

signature

Type

bytes

The signature bytes.

Raises

ValueError – If response_status is not SUCCESSFUL.

tbs_response_bytes

Type

bytes

The DER encoded bytes payload that is hashed and then signed. This data may be used to validate the signature on the OCSP response.
Raises

**ValueError** – If `response_status` is not *SUCCESSFUL*.

certificates

*Type*

`list`

A list of zero or more `Certificate` objects used to help build a chain to verify the OCSP response. This situation occurs when the OCSP responder uses a delegate certificate.

Raises

**ValueError** – If `response_status` is not *SUCCESSFUL*.

responder_key_hash

*Type*

`bytes` or `None`

The responder’s key hash or `None` if the response has a `responder_name`.

Raises

**ValueError** – If `response_status` is not *SUCCESSFUL*.

responder_name

*Type*

`Name` or `None`

The responder’s `Name` or `None` if the response has a `responder_key_hash`.

Raises

**ValueError** – If `response_status` is not *SUCCESSFUL*.

produced_at

*Type*

`datetime.datetime`

A naïve datetime representing the time when the response was produced.

Raises

**ValueError** – If `response_status` is not *SUCCESSFUL*.

certificate_status

*Type*

`OCSPCertStatus`

The status of the certificate being checked.

 Raises

**ValueError** – If `response_status` is not *SUCCESSFUL* or if multiple SINGLERESP are present.

revocation_time

*Type*

`datetime.datetime` or `None`

A naïve datetime representing the time when the certificate was revoked or `None` if the certificate has not been revoked.
Raises
  ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

revocation_reason

  Type
  `ReasonFlags` or None

  The reason the certificate was revoked or None if not specified or not revoked.

  Raises
  ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

this_update

  Type
  `datetime.datetime`

  A naïve datetime representing the most recent time at which the status being indicated is known by the responder to have been correct.

  Raises
  ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

next_update

  Type
  `datetime.datetime`

  A naïve datetime representing the time when newer information will be available.

  Raises
  ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

issuer_key_hash

  Type
  `bytes`

  The hash of the certificate issuer’s key. The hash algorithm used is defined by the hash_algorithm property.

  Raises
  ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

issuer_name_hash

  Type
  `bytes`

  The hash of the certificate issuer’s name. The hash algorithm used is defined by the hash_algorithm property.

  Raises
  ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.
hash_algorithm

Type

HashAlgorithm

The algorithm used to generate the issuer_key_hash and issuer_name_hash.

Raises

ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

serial_number

Type

int

The serial number of the certificate that was checked.

Raises

ValueError – If response_status is not SUCCESSFUL or if multiple SINGLERESPs are present.

extensions

Type

Extensions

The extensions encoded in the response.

single_extensions

New in version 2.9.

Type

Extensions

The single extensions encoded in the response.

responses

New in version 37.0.0.

Type

an iterator over OCSPSingleResponse

An iterator to access individual SINGLERESP structures.

public_bytes(encoding)

Parameters

encoding – The encoding to use. Only DER is supported.

Return bytes

The serialized OCSP response.

class cryptography.x509.ocsp.OCSPResponseStatus

New in version 2.4.

An enumeration of response statuses.

SUCCESSFUL

Represents a successful OCSP response.

MALFORMED_REQUEST

May be returned by an OCSP responder that is unable to parse a given request.
INTERNAL_ERROR
May be returned by an OCSP responder that is currently experiencing operational problems.

TRY_LATER
May be returned by an OCSP responder that is overloaded.

SIG_REQUIRED
May be returned by an OCSP responder that requires signed OCSP requests.

UNAUTHORIZED
May be returned by an OCSP responder when queried for a certificate for which the responder is unaware or an issuer for which the responder is not authoritative.

class cryptography.x509.ocsp.OCSPCertStatus
New in version 2.4.
An enumeration of certificate statuses in an OCSP response.

GOOD
The value for a certificate that is not revoked.

REVOKED
The certificate being checked is revoked.

UNKNOWN
The certificate being checked is not known to the OCSP responder.

class cryptography.x509.ocsp.OCSPResponderEncoding
New in version 2.4.
An enumeration of responderID encodings that can be passed to responder_id().

HASH
Encode the hash of the public key whose corresponding private key signed the response.

NAME
Encode the X.509 Name of the certificate whose private key signed the response.

class cryptography.x509.ocsp.OCSPSingleResponse
New in version 37.0.0.
A class representing a single certificate response bundled into a larger OCSPResponse. Accessed via OCSPResponse.responses.

certificate_status
Type
OCSPCertStatus
The status of the certificate being checked.

revocation_time
Type
datetime.datetime or None
A naïve datetime representing the time when the certificate was revoked or None if the certificate has not been revoked.
revocation_reason

Type
    ReasonFlags or None

The reason the certificate was revoked or None if not specified or not revoked.

date

Type
datetime.datetime

A naive datetime representing the most recent time at which the status being indicated is known by the responder to have been correct.

next_update

Type
datetime.datetime

A naive datetime representing the time when newer information will be available.

issuer_key_hash

Type
    bytes

The hash of the certificate issuer's key. The hash algorithm used is defined by the hash_algorithm property.

issuer_name_hash

Type
    bytes

The hash of the certificate issuer's name. The hash algorithm used is defined by the hash_algorithm property.

hash_algorithm

Type
    HashAlgorithm

The algorithm used to generate the issuer_key_hash and issuer_name_hash.

serial_number

Type
    int

The serial number of the certificate that was checked.

2.2.4 X.509 Verification

Support for X.509 certificate verification, also known as path validation or chain building.

---

Note: While usable, these APIs should be considered unstable and not yet subject to our backwards compatibility policy.

---

Example usage, with certifi providing the root of trust:
from cryptography.x509 import Certificate, DNSName, load_pem_x509_certificates
from cryptography.x509.verification import PolicyBuilder, Store
import certifi

with open(certifi.where(), "rb") as pems:
    store = Store(load_pem_x509_certificates(pems.read()))

builder = PolicyBuilder().store(store)
verifier = builder().build_server_verifier(DNSName("cryptography.io"))

chain = verifier.verify(peer, untrusted_intermediates)

class cryptography.x509.verification.Store(certs)

    New in version 42.0.0.

    A Store is an opaque set of public keys and subject identifiers that are considered trusted \textit{a priori}. Stores are typically created from the host OS's root of trust, from a well-known source such as a browser CA bundle, or from a small set of manually pre-trusted entities.

    Parameters
    
    certs -- A list of one or more \texttt{cryptography.x509.Certificate} instances.

class cryptography.x509.verification.Subject

    New in version 42.0.0.

    Type alias: A union of all subject types supported: \texttt{cryptography.x509.general_name.DNSName}, \texttt{cryptography.x509.general_name.IPAddress}.

class cryptography.x509.verification.ServerVerifier

    New in version 42.0.0.

    A ServerVerifier verifies server certificates.

    It contains and describes various pieces of configurable path validation logic, such as which subject to expect, how deep prospective validation chains may go, which signature algorithms are allowed, and so forth.

    ServerVerifier instances cannot be constructed directly; \texttt{PolicyBuilder} must be used.

    subject

        Type
        
        Subject
        
        The verifier's subject.

    validation_time

        Type
        
        datetime.datetime
        
        The verifier's validation time.

    max_chain_depth

        Type
        
        int
        
        The verifier's maximum intermediate CA chain depth.
store

Type

Store

The verifier’s trust store.

verify(leaf, intermediates)

Performs path validation on `leaf`, returning a valid path if one exists. The path is returned in leaf-first order: the first member is `leaf`, followed by the intermediates used (if any), followed by a member of the store.

Parameters

- `leaf` – The leaf `Certificate` to validate
- `intermediates` – A list of intermediate `Certificate` to attempt to use

Returns

A list containing a valid chain from `leaf` to a member of `ServerVerifier.store`.

Raises

`VerificationError` – If a valid chain cannot be constructed

class cryptography.x509.verification.VerificationError

New in version 42.0.0.

The error raised when path validation fails.

class cryptography.x509.verification.PolicyBuilder

New in version 42.0.0.

A PolicyBuilder provides a builder-style interface for constructing a Verifier.

time(new_time)

Sets the verifier’s verification time.

If not called explicitly, this is set to `datetime.datetime.now()` when `build_server_verifier()` is called.

Parameters

- `new_time` – The `datetime.datetime` to use in the verifier

Returns

A new instance of `PolicyBuilder`

store(new_store)

Sets the verifier’s trust store.

Parameters

- `new_store` – The `Store` to use in the verifier

Returns

A new instance of `PolicyBuilder`

max_chain_depth(new_max_chain_depth)

Sets the verifier’s maximum chain building depth.

This depth behaves tracks the length of the intermediate CA chain: a maximum depth of zero means that the leaf must be directly issued by a member of the store, a depth of one means no more than one intermediate CA, and so forth. Note that self-issued intermediates don’t count against the chain depth, per RFC 5280.
Parameters
new_max_chain_depth – The maximum depth to allow in the verifier

Returns
A new instance of PolicyBuilder

build_server_verifier(subject)
Builds a verifier for verifying server certificates.

Parameters
subject – A Subject to use in the verifier

Returns
An instance of ServerVerifier

2.2.5 X.509 Reference

Loading Certificates
cryptography.x509.load_pem_x509_certificate(data)
New in version 0.7.
Deserializes a certificate from PEM encoded data. PEM certificates are base64 decoded and have delimiters that look like -----BEGIN CERTIFICATE-----.

Parameters
data (bytes) – The PEM encoded certificate data.

Returns
An instance of Certificate.

```python
>>> from cryptography import x509
>>> cert = x509.load_pem_x509_certificate(pem_data)
>>> cert.serial_number
2
```
cryptography.x509.load_pem_x509_certificates(data)
New in version 39.0.0.
Deserializes one or more certificates from PEM encoded data.
This is like load_pem_x509_certificate(), but allows for loading multiple certificates (as adjacent PEMs) at once.

Parameters
data (bytes) – One or more PEM-encoded certificates.

Returns
list of Certificate

Raises
ValueError – If there isn’t at least one certificate, or if any certificate is malformed.
cryptography.x509.load_der_x509_certificate(data)
New in version 0.7.
Deserializes a certificate from DER encoded data. DER is a binary format and is commonly found in files with the .cer extension (although file extensions are not a guarantee of encoding type).
Parameters

data (bytes) – The DER encoded certificate data.

Returns

An instance of Certificate.

Loading Certificate Revocation Lists

cryptography.x509.load_pem_x509_crl(data)

New in version 1.1.

Deserialize a certificate revocation list (CRL) from PEM encoded data. PEM requests are base64 decoded and
have delimiters that look like -----BEGIN X509 CRL-----.

Parameters

data (bytes) – The PEM encoded request data.

Returns

An instance of CertificateRevocationList.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes
>>> crl = x509.load_pem_x509_crl(pem_crl_data)
>>> isinstance(crl.signature_hash_algorithm, hashes.SHA256)
True
```

cryptography.x509.load_der_x509_crl(data)

New in version 1.1.

Deserialize a certificate revocation list (CRL) from DER encoded data. DER is a binary format.

Parameters

data (bytes) – The DER encoded request data.

Returns

An instance of CertificateRevocationList.

Loading Certificate Signing Requests

cryptography.x509.load_pem_x509_csr(data)

New in version 0.9.

Deserialize a certificate signing request (CSR) from PEM encoded data. PEM requests are base64 decoded
and have delimiters that look like -----BEGIN CERTIFICATE REQUEST-----. This format is also known as
PKCS#10.

Parameters

data (bytes) – The PEM encoded request data.

Returns

An instance of CertificateSigningRequest.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes
>>> csr = x509.load_pem_x509_csr(pem_req_data)
>>> isinstance(csr.signature_hash_algorithm, hashes.SHA256)
True
```
cryptography.x509.load_der_x509_csr(data)
    New in version 0.9.
    Deserialze a certificate signing request (CSR) from DER encoded data. DER is a binary format and is not
    commonly used with CSRs.
    Parameters
        data (bytes) – The DER encoded request data.
    Returns
        An instance of CertificateSigningRequest.

X.509 Certificate Object

class cryptography.x509.Certificate
    New in version 0.7.

    version
        Type
            Version
        The certificate version as an enumeration. Version 3 certificates are the latest version and also the only type
        you should see in practice.
        Raises
            cryptography.x509.InvalidVersion – If the version in the certificate is not a known
            X.509 version.

>>> cert.version
<Version.v3: 2>

    fingerprint(algorithm)
        Parameters
            algorithm – The HashAlgorithm that will be used to generate the fingerprint.
        Return bytes
            The fingerprint using the supplied hash algorithm, as bytes.

>>> from cryptography.hazmat.primitives import hashes
>>> cert.fingerprint(hashes.SHA256())
b'\x86\xd2\x187Gc\xfc\xe7\[+E9\x8d\xb4\x8f\x10\xe55\xda\x18u\xbe)a\x03\x08[\xac\n˓→xa@4?'

    serial_number
        Type
            int
        The serial as a Python integer.

>>> cert.serial_number
2

    public_key()
        The public key associated with the certificate.
Returns

One of `CertificatePublicKeyTypes`.

```python
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> public_key = cert.public_key()
>>> isinstance(public_key, rsa.RSAPublicKey)
True
```

`not_valid_before`

**Type**

`datetime.datetime`

**Warning:** This property is deprecated and will be removed in a future version. Please switch to the timezone-aware variant `not_valid_before_utc()`.

A naive datetime representing the beginning of the validity period for the certificate in UTC. This value is inclusive.

```python
>>> cert.not_valid_before
datetime.datetime(2010, 1, 1, 8, 30)
```

`not_valid_before_utc`

New in version 42.0.0.

**Type**

`datetime.datetime`

A timezone-aware datetime representing the beginning of the validity period for the certificate in UTC. This value is inclusive.

```python
>>> cert.not_valid_before_utc
datetime.datetime(2010, 1, 1, 8, 30, tzinfo=datetime.timezone.utc)
```

`not_valid_after`

**Type**

`datetime.datetime`

**Warning:** This property is deprecated and will be removed in a future version. Please switch to the timezone-aware variant `not_valid_after_utc()`.

A naive datetime representing the end of the validity period for the certificate in UTC. This value is inclusive.

```python
>>> cert.not_valid_after
datetime.datetime(2030, 12, 31, 8, 30)
```

`not_valid_after_utc`

New in version 42.0.0.

**Type**

`datetime.datetime`
A timezone-aware datetime representing the end of the validity period for the certificate in UTC. This value is inclusive.

```python
>>> cert.not_valid_after_utc
datetime.datetime(2030, 12, 31, 8, 30, tzinfo=datetime.timezone.utc)
```

**issuer**

New in version 0.8.

**Type**

*Name*

The *Name* of the issuer.

**subject**

New in version 0.8.

**Type**

*Name*

The *Name* of the subject.

**signature_hash_algorithm**

**Type**

*HashAlgorithm*

Returns the *HashAlgorithm* which was used in signing this certificate. Can be *None* if signature did not use separate hash *(ED25519, ED448)*.

```python
>>> from cryptography.hazmat.primitives import hashes
>>> isinstance(cert.signature_hash_algorithm, hashes.SHA256)
True
```

**signature_algorithm_oid**

New in version 1.6.

**Type**

*ObjectIdentifier*

Returns the *ObjectIdentifier* of the signature algorithm used to sign the certificate. This will be one of the OIDs from *SignatureAlgorithmOID*.

```python
>>> cert.signature_algorithm_oid
<ObjectIdentifier(oid=1.2.840.113549.1.1.11, name=sha256WithRSAEncryption)>
```

**signature_algorithm_parameters**

New in version 41.0.0.

Returns the parameters of the signature algorithm used to sign the certificate. For RSA signatures it will return either a *PKCS1v15* or *PSS* object.

For ECDSA signatures it will return an *ECDSA*.

For EdDSA and DSA signatures it will return *None*.

These objects can be used to verify signatures on the certificate.

**Returns**

*None, PKCS1v15, PSS, or ECDSA*
>>> from cryptography.hazmat.primitives.asymmetric import padding
>>> pss_cert = x509.load_pem_x509_certificate(rsa_pss_pem_cert)
>>> isinstance(pss_cert.signature_algorithm_parameters, padding.PSS)
True

extensions

Type

Extensions

The extensions encoded in the certificate.

Raises

- cryptography.x509.DuplicateExtension – If more than one extension of the same
type is found within the certificate.

- cryptography.x509.UnsupportedGeneralNameType – If an extension contains a gen-
eral name that is not supported.

  >>> for ext in cert.extensions:
  ...   print(ext)
  ...  # Extension information...

signature

New in version 1.2.

Type

bytes

The bytes of the certificate’s signature.

tbs_certificate_bytes

New in version 1.2.

Type

bytes

The DER encoded bytes payload (as defined by RFC 5280) that is hashed and then signed by
the private key of the certificate’s issuer. This data may be used to validate a signature, but use
extreme caution as certificate validation is a complex problem that involves much more than just signature checks.

To validate the signature on a certificate you can do the following. Note: This only verifies that the certificate was signed with the private key associated with the public key provided and does not perform any of the other checks needed for secure certificate validation. Additionally, this example will only work for RSA public keys with PKCS1v15 signatures, and so it can’t be used for general purpose signature verification.

```
>>> from cryptography.hazmat.primitives.serialization import load_pem_public_key
>>> from cryptography.hazmat.primitives.asymmetric import padding
>>> issuer_public_key = load_pem_public_key(pem_issuer_public_key)
>>> cert_to_check = x509.load_pem_x509_certificate(pem_data_to_check)
>>> issuer_public_key.verify(...
...  cert_to_check.signature,
...  cert_to_check.tbs_certificate_bytes,
...  # Depends on the algorithm used to create the certificate
...  padding.PKCS1v15(),
...  cert_to_check.signature_hash_algorithm,
... )
```

An `InvalidSignature` exception will be raised if the signature fails to verify.

`verify_directly_issued_by(issuer)`

New in version 40.0.0.

**Parameters**

`issuer` *(Certificate)* – The issuer certificate to check against.

**Warning:** This method verifies that the certificate issuer name matches the issuer subject name and that the certificate is signed by the issuer’s private key. **No other validation is performed.** Callers are responsible for performing any additional validations required for their use case (e.g. checking the validity period, whether the signer is allowed to issue certificates, that the issuing certificate has a strong public key, etc).

Validates that the certificate is signed by the provided issuer and that the issuer’s subject name matches the issuer name of the certificate.

**Returns**

None

**Raises**

- `ValueError` – If the issuer name on the certificate does not match the subject name of the issuer or the signature algorithm is unsupported.
- `TypeError` – If the issuer does not have a supported public key type.
- `cryptography.exceptions.InvalidSignature` – If the signature fails to verify.

`tbs_precertificate_bytes`

New in version 38.0.0.

**Type**

`bytes`
Cryptography Documentation, Release 42.0.0.dev1

Raises

ValueError – If the certificate doesn’t have the expected Certificate Transparency extensions.

The DER encoded bytes payload (as defined by RFC 6962) that is hashed and then signed by the private key of the pre-certificate’s issuer. This data may be used to validate a Signed Certificate Timestamp’s signature, but use extreme caution as SCT validation is a complex problem that involves much more than just signature checks.

This method is primarily useful in the context of programs that interact with and verify the products of Certificate Transparency logs, as specified in RFC 6962. If you are not directly interacting with a Certificate Transparency log, this method unlikely to be what you want. To make unintentional misuse less likely, it raises a ValueError if the underlying certificate does not contain the expected Certificate Transparency extensions.

public_bytes(encoding)

New in version 1.0.

Parameters

encoding – The Encoding that will be used to serialize the certificate.

Return bytes

The data that can be written to a file or sent over the network to be verified by clients.

X.509 CRL (Certificate Revocation List) Object

class cryptography.x509.CertificateRevocationList

New in version 1.0.

A CertificateRevocationList is an object representing a list of revoked certificates. The object is iterable and will yield the RevokedCertificate objects stored in this CRL.

>>> len(crl)
1
>>> revoked_certificate = crl[0]
>>> type(revoked_certificate)
<class '...RevokedCertificate'>
>>> for r in crl:
...     print(r.serial_number)
0

fingerprint(algorithm)

Parameters

algorithm – The HashAlgorithm that will be used to generate the fingerprint.

Return bytes

The fingerprint using the supplied hash algorithm, as bytes.

>>> from cryptography.hazmat.primitives import hashes
>>> crl.fingerprint(hashes.SHA256())
...b'\xe3\x1d\xb5P\x18\x9ed\x9f\x160\x9dm\xc1>\x8c\xca\xb1\xc6x?T\x9f\xe9t_\x1d\n\x8dF8V\xf78'

get_revoked_certificate_by_serial_number(serial_number)

New in version 2.3.
Parameters

`serial_number` – The serial as a Python integer.

Returns

RevokedCertificate if the `serial_number` is present in the CRL or None if it is not.

`signature_hash_algorithm`

Type

HashAlgorithm

Returns the HashAlgorithm which was used in signing this CRL. Can be None if signature did not use separate hash (ED25519, ED448).

```python
>>> from cryptography.hazmat.primitives import hashes
>>> isinstance(crl.signature_hash_algorithm, hashes.SHA256)
True
```

`signature_algorithm_oid`

New in version 1.6.

Type

ObjectIdentifier

Returns the ObjectIdentifier of the signature algorithm used to sign the CRL. This will be one of the OIDs from SignatureAlgorithmOID.

```python
>>> crl.signature_algorithm_oid
<ObjectIdentifier(oid=1.2.840.113549.1.1.11, name=sha256WithRSAEncryption)>
```

`signature_algorithm_parameters`

New in version 42.0.0.

Returns the parameters of the signature algorithm used to sign the certificate revocation list. For RSA signatures it will return either a PKCS1v15 or PSS object.

For ECDSA signatures it will return an ECDSA.

For EdDSA and DSA signatures it will return None.

These objects can be used to verify the CRL signature.

Returns

None, PKCS1v15, PSS, or ECDSA

`issuer`

Type

Name

The Name of the issuer.

```python
>>> crl.issuer
<Name(C=US,CN=cryptography.io)>
```

`next_update`

Type

datetime.datetime

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A naïve datetime representing when the next update to this CRL is expected.

```python
>>> crl.next_update
datetime.datetime(2016, 1, 1, 0, 0)
```

**next_update_utc**

New in version 42.0.0.

**Type**

`datetime.datetime`

A timezone-aware datetime representing when the next update to this CRL is expected.

```python
>>> crl.next_update_utc
datetime.datetime(2016, 1, 1, 0, 0, tzinfo=datetime.timezone.utc)
```

**last_update**

**Type**

`datetime.datetime`

**Warning:** This property is deprecated and will be removed in a future version. Please switch to the timezone-aware variant `last_update_utc()`.

A naïve datetime representing when this CRL was last updated.

```python
>>> crl.last_update
datetime.datetime(2015, 1, 1, 0, 0)
```

**last_update_utc**

New in version 42.0.0.

**Type**

`datetime.datetime`

A timezone-aware datetime representing when this CRL was last updated.

```python
>>> crl.last_update_utc
datetime.datetime(2015, 1, 1, 0, 0, tzinfo=datetime.timezone.utc)
```

**extensions**

**Type**

`Extensions`

The extensions encoded in the CRL.

**signature**

New in version 1.2.

**Type**

`bytes`
The bytes of the CRL’s signature.

**tbs_certlist_bytes**

New in version 1.2.

**Type**

*bytes*

The DER encoded bytes payload (as defined by [RFC 5280](https://tools.ietf.org/html/rfc5280)) that is hashed and then signed by the private key of the CRL’s issuer. This data may be used to validate a signature, but use extreme caution as CRL validation is a complex problem that involves much more than just signature checks.

**public_bytes**(encoding)

New in version 1.2.

**Parameters**

- **encoding**: The *Encoding* that will be used to serialize the certificate revocation list.

**Return**

*bytes*

The data that can be written to a file or sent over the network and used as part of a certificate verification process.

**is_signature_valid**(public_key)

New in version 2.1.

**Warning**: Checking the validity of the signature on the CRL is insufficient to know if the CRL should be trusted. More details are available in [RFC 5280](https://tools.ietf.org/html/rfc5280).

Returns True if the CRL signature is correct for given public key, False otherwise.

### X.509 Certificate Builder

**class cryptography.x509.CertificateBuilder**

New in version 1.0.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> from cryptography.x509.oid import NameOID
>>> import datetime

>>> one_day = datetime.timedelta(1, 0, 0)

>>> private_key = rsa.generate_private_key(...
...   public_exponent=65537,
...   key_size=2048,
... )

>>> public_key = private_key.public_key()

>>> builder = x509.CertificateBuilder()

>>> builder = builder.subject_name(x509.Name([...
...   x509.NameAttribute(NameOID.COMMON_NAME, 'cryptography.io'),
... ]))

>>> builder = builder.issuer_name(x509.Name([...
...   x509.NameAttribute(NameOID.COMMON_NAME, 'cryptography.io'),
... ]))

>>> builder = builder.not_valid_before(datetime.datetime.today() - one_day)
```

(continues on next page)
builder = builder.not_valid_after(datetime.datetime.today() + (one_day * 30))
builder = builder.serial_number(x509.random_serial_number())
builder = builder.public_key(public_key)
>>> builder = builder.add_extension(
...     x509.SubjectAlternativeName(
...         [x509.DNSName('cryptography.io')],
...         critical=False
...     ),
...     critical=False
... )
>>> builder = builder.add_extension(
...     x509.BasicConstraints(ca=False, path_length=None), critical=True,
... )
>>> certificate = builder.sign(
...     private_key=private_key, algorithm=hashes.SHA256(),
... )
>>> isinstance(certificate, x509.Certificate)
True

**issuer_name(name)**

Sets the issuer’s distinguished name.

Parameters

    name – The Name that describes the issuer (CA).

**subject_name(name)**

Sets the subject’s distinguished name.

Parameters

    name – The Name that describes the subject.

**public_key(public_key)**

Sets the subject’s public key.

Parameters

    public_key – The subject’s public key. This can be one of CertificatePublicKeyTypes.

**serial_number(serial_number)**

Sets the certificate’s serial number (an integer). The CA’s policy determines how it attributes serial numbers to certificates. This number must uniquely identify the certificate given the issuer. CABForum Guidelines require entropy in the serial number to provide protection against hash collision attacks. For more information on secure random number generation, see Random number generation.

Parameters

    serial_number – Integer number that will be used by the CA to identify this certificate (most notably during certificate revocation checking). Users should consider using random_serial_number() when possible.

**not_valid_before(time)**

Sets the certificate’s activation time. This is the time from which clients can start trusting the certificate. It may be different from the time at which the certificate was created.

Parameters

    time – The datetime.datetime object (in UTC) that marks the activation time for the certificate. The certificate may not be trusted clients if it is used before this time.
**not_valid_after**(time)

Sets the certificate’s expiration time. This is the time from which clients should no longer trust the certificate. The CA’s policy will determine how long the certificate should remain in use.

**Parameters**
- **time** – The `datetime.datetime` object (in UTC) that marks the expiration time for the certificate. The certificate may not be trusted clients if it is used after this time.

**add_extension**(extval, critical)

Adds an X.509 extension to the certificate.

**Parameters**
- **extval** – An extension conforming to the `ExtensionType` interface.
- **critical** – Set to `True` if the extension must be understood and handled by whoever reads the certificate.

**sign**(private_key, algorithm, *, rsa_padding=None)

Sign the certificate using the CA’s private key.

**Parameters**
- **private_key** – The key that will be used to sign the certificate, one of `CertificateIssuerPrivateKeyTypes`.
- **algorithm** – The `HashAlgorithm` that will be used to generate the signature. This must be `None` if the `private_key` is an `Ed25519PrivateKey` or an `Ed448PrivateKey` and an instance of a `HashAlgorithm` otherwise.
- **rsa_padding** (None, `PKCS1v15`, or `PSS`) – New in version 41.0.0.

This is a keyword-only argument. If `private_key` is an `RSAPrivateKey` then this can be set to either `PKCS1v15` or `PSS` to sign with those respective paddings. If this is `None` then RSA keys will default to PKCS1v15 padding. All other key types must not pass a value other than `None`.

**Returns**
- `Certificate`

---

**X.509 CSR (Certificate Signing Request) Object**

**class cryptography.x509.CertificateSigningRequest**

New in version 0.9.

**public_key()**

The public key associated with the request.

**Returns**
- One of `CertificatePublicKeyTypes`.

```python
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> public_key = csr.public_key()
>>> isinstance(public_key, rsa.RSAPublicKey)
True
```

**subject**

**Type**

*Name*
The **Name** of the subject.

**signature_hash_algorithm**

**Type**

*HashAlgorithm*

Returns the **HashAlgorithm** which was used in signing this request. Can be **None** if signature did not use separate hash (`ED25519, ED448`).

```python
>>> from cryptography.hazmat.primitives import hashes
>>> isinstance(csr.signature_hash_algorithm, hashes.SHA256)
True
```

**signature_algorithm_oid**

New in version 1.6.

**Type**

*ObjectIdentifier*

Returns the **ObjectIdentifier** of the signature algorithm used to sign the request. This will be one of the OIDs from **SignatureAlgorithmOID**.

```python
>>> csr.signature_algorithm_oid
<ObjectIdentifier(oid=1.2.840.113549.1.1.11, name=sha256WithRSAEncryption)>
```

**signature_algorithm_parameters**

New in version 42.0.0.

Returns the parameters of the signature algorithm used to sign the certificate signing request. For RSA signatures it will return either a **PKCS1v15** or **PSS** object.

For ECDSA signatures it will return an **ECDSA**.

For EdDSA and DSA signatures it will return **None**.

These objects can be used to verify signatures on the signing request.

**Returns**

**None, PKCS1v15, PSS,** or **ECDSA**

**extensions**

**Type**

*Extensions*

The extensions encoded in the certificate signing request.

**Raises**

- **cryptography.x509.DuplicateExtension** – If more than one extension of the same type is found within the certificate signing request.

- **cryptography.x509.UnsupportedGeneralNameType** – If an extension contains a general name that is not supported.

**attributes**

New in version 36.0.0.

**Type**

*Attributes*

The attributes encoded in the certificate signing request.
**public_bytes**(encoding)
New in version 1.0.

**Parameters**
- **encoding** – The Encoding that will be used to serialize the certificate request.

**Return bytes**
The data that can be written to a file or sent over the network to be signed by the certificate authority.

**signature**
New in version 1.2.

**Type**
- bytes

The bytes of the certificate signing request’s signature.

**tbs_certrequest_bytes**
New in version 1.2.

**Type**
- bytes

The DER encoded bytes payload (as defined by RFC 2986) that is hashed and then signed by the private key (corresponding to the public key embedded in the CSR). This data may be used to validate the CSR signature.

**is_signature_valid**
New in version 1.3.

Returns True if the CSR signature is correct, False otherwise.

---

**X.509 Certificate Revocation List Builder**

**class** cryptography.x509.CertificateRevocationListBuilder
New in version 1.2.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> from cryptography.x509.oid import NameOID
>>> import datetime

>>> one_day = datetime.timedelta(1, 0, 0)

>>> private_key = rsa.generate_private_key(...
...     public_exponent=65537,
...     key_size=2048,
... )

>>> builder = x509.CertificateRevocationListBuilder()

>>> builder = builder.issuer_name(x509.Name([...
...     x509.NameAttribute(NameOID.COMMON_NAME, 'cryptography.io CA'),
... ]))

>>> builder = builder.last_update(datetime.datetime.today())

>>> revoked_cert = x509.RevokedCertificateBuilder().serial_number(...
...     333
```
... ).revocation_date(
...     datetime.datetime.today()
... ).build()
>>> builder = builder.add_revoked_certificate(revoked_cert)
>>> crl = builder.sign(
...     private_key=private_key, algorithm=hashes.SHA256(),
... )
>>> len(crl)
1

**issuer_name**(*name*)

Sets the issuer’s distinguished name.

**Parameters**

- **name** – The *Name* that describes the issuer (CA).

**last_update**(*time*)

Sets this CRL’s activation time. This is the time from which clients can start trusting this CRL. It may be different from the time at which this CRL was created. This is also known as the thisUpdate time.

**Parameters**

- **time** – The *datetime.datetime* object (in UTC) that marks the activation time for this CRL. The CRL may not be trusted if it is used before this time.

**next_update**(*time*)

Sets this CRL’s next update time. This is the time by which a new CRL will be issued. The CA is allowed to issue a new CRL before this date, however clients are not required to check for it.

**Parameters**

- **time** – The *datetime.datetime* object (in UTC) that marks the next update time for this CRL.

**add_extension**(*extval, critical*)

Adds an X.509 extension to this CRL.

**Parameters**

- **extval** – An extension with the *ExtensionType* interface.
- **critical** – Set to True if the extension must be understood and handled by whoever reads the CRL.

**add_revoked_certificate**(*revoked_certificate*)

Adds a revoked certificate to this CRL.

**Parameters**

- **revoked_certificate** – An instance of *RevokedCertificate*. These can be obtained from an existing CRL or created with *RevokedCertificateBuilder*.

**sign**(*private_key, algorithm, *, rsa_padding=None*)

Sign this CRL using the CA’s private key.

**Parameters**

- **private_key** – The private key that will be used to sign the certificate, one of *CertificateIssuerPrivateKeyTypes*. 
- **algorithm** – The `HashAlgorithm` that will be used to generate the signature. This must be `None` if the `private_key` is an `Ed25519PrivateKey` or an `Ed448PrivateKey` and an instance of a `HashAlgorithm` otherwise.

- **rsa_padding** (`None`, `PKCS1v15`, or `PSS`) – New in version 42.0.0.
  This is a keyword-only argument. If `private_key` is an `RSAPrivateKey` then this can be set to either `PKCS1v15` or `PSS` to sign with those respective paddings. If this is `None` then RSA keys will default to `PKCS1v15` padding. All other key types **must** not pass a value other than `None`.

**Returns**

`CertificateRevocationList`

---

**X.509 Revoked Certificate Object**

class cryptography.x509.RevokedCertificate

New in version 1.0.

- **serial_number**

  Type

  `int`

  An integer representing the serial number of the revoked certificate.

  ```python
  >>> revoked_certificate.serial_number
  0
  ```

- **revocation_date**

  Type

  `datetime.datetime`

  A naïve datetime representing the date this certificates was revoked.

  ```python
  >>> revoked_certificate.revocation_date
  datetime.datetime(2015, 1, 1, 0, 0)
  ```

- **revocation_date_utc**

  New in version 42.0.0.

  Type

  `datetime.datetime`

  A timezone-aware datetime representing the date this certificates was revoked.

  ```python
  >>> revoked_certificate.revocation_date_utc
  datetime.datetime(2015, 1, 1, 0, 0, tzinfo=datetime.timezone.utc)
  ```

- **extensions**

  Type

  `Extensions`
The extensions encoded in the revoked certificate.

```python
>>> for ext in revoked_certificate.extensions:
...    print(ext)
<Extension(oid=<ObjectIdentifier(oid=2.5.29.24, name=invalidityDate)>,
    critical=False, value=<InvalidityDate(invalidity_date=2015-01-01 00:00:00)>)>
<Extension(oid=<ObjectIdentifier(oid=2.5.29.21, name=cRLReason)>,
    critical=False, value=<CRLReason(reason=ReasonFlags.key_compromise)>)>
```

### X.509 Revoked Certificate Builder

*class* cryptography.x509.RevokedCertificateBuilder*

This class is used to create *RevokedCertificate* objects that can be used with the *CertificateRevocationListBuilder*.

New in version 1.2.

```python
>>> from cryptography import x509
global import datetime

>>> builder = x509.RevokedCertificateBuilder()
>>> builder = builder.revocation_date(datetime.datetime.today())
>>> builder = builder.serial_number(3333)
>>> revoked_certificate = builder.build()
>>> isinstance(revoked_certificate, x509.RevokedCertificate)
True
```

**serial_number**(serial_number)

Sets the revoked certificate’s serial number.

**Parameters**

- **serial_number** – Integer number that is used to identify the revoked certificate.

**revocation_date**(time)

Sets the certificate’s revocation date.

**Parameters**

- **time** – The *datetime.datetime* object (in UTC) that marks the revocation time for the certificate.

**add_extension**(extval, critical)

Adds an X.509 extension to this revoked certificate.

**Parameters**

- **extval** – An instance of one of the *CRL entry extensions*.
- **critical** – Set to *True* if the extension must be understood and handled.

**build**( )

Create a revoked certificate object.

**Returns**

*RevokedCertificate*
X.509 CSR (Certificate Signing Request) Builder Object

class cryptography.x509.CertificateSigningRequestBuilder

New in version 1.0.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> from cryptography.x509.oid import AttributeOID, NameOID

>>> private_key = rsa.generate_private_key(
...     public_exponent=65537,
...     key_size=2048,
... )

>>> builder = x509.CertificateSigningRequestBuilder()

>>> builder = builder.subject_name(x509.Name([
...     x509.NameAttribute(NameOID.COMMON_NAME, 'cryptography.io'),
... ]))

>>> builder = builder.add_extension(
...     x509.BasicConstraints(ca=False, path_length=None), critical=True,
... )

>>> builder = builder.add_attribute(
...     AttributeOID.CHALLENGE_PASSWORD, b"changeit"
... )

>>> request = builder.sign(private_key, hashes.SHA256())

>>> isinstance(request, x509.CertificateSigningRequest)
True
```

subject_name(name)

Parameters

- name – The Name of the certificate subject.

Returns

A new CertificateSigningRequestBuilder.

add_extension(extension, critical)

Parameters

- extension – An extension conforming to the ExtensionType interface.
- critical – Set to True if the extension must be understood and handled by whoever reads the certificate.

Returns

A new CertificateSigningRequestBuilder.

add_attribute(oid, value)

New in version 3.0.

Parameters

- oid – An ObjectIdentifier instance.
- value (bytes) – The value of the attribute.
Returns

A new CertificateSigningRequestBuilder.

\texttt{sign(private\_key, algorithm, *, rsa\_padding=None)}

**Parameters**

- **private\_key** – The private key that will be used to sign the request. When the request is signed by a certificate authority, the private key's associated public key will be stored in the resulting certificate. One of CertificateIssuerPrivateKeyTypes.

- **algorithm** – The HashAlgorithm that will be used to generate the request signature. This must be None if the private\_key is an Ed25519PrivateKey or an Ed448PrivateKey and an instance of a HashAlgorithm otherwise.

- **rsa\_padding** (None, PKCS1v15, or PSS) – New in version 42.0.0.

  This is a keyword-only argument. If private\_key is an RSAPrivateKey then this can be set to either PKCS1v15 or PSS to sign with those respective paddings. If this is None then RSA keys will default to PKCS1v15 padding. All other key types must not pass a value other than None.

Returns

A new CertificateSigningRequest.

class cryptography.x509.

\texttt{Name}

New in version 0.8.

An X509 Name is an ordered list of attributes. The object is iterable to get every attribute or you can use \texttt{Name.get\_attributes\_for\_oid()} to obtain the specific type you want. Names are sometimes represented as a slash or comma delimited string (e.g. /CN=mydomain.com/O=My Org/C=US or CN=mydomain.com,O=My Org,C=US).

Technically, a Name is a list of sets of attributes, called Relative Distinguished Names or RDNs, although multi-valued RDNs are rarely encountered. The iteration order of values within a multi-valued RDN is preserved. If you need to handle multi-valued RDNs, the \texttt{rdns} property gives access to an ordered list of RelativeDistinguishedName objects.

A Name can be initialized with an iterable of NameAttribute (the common case where each RDN has a single attribute) or an iterable of RelativeDistinguishedName objects (in the rare case of multi-valued RDNs).

```python
>>> len(cert.subject)
3
>>> for attribute in cert.subject:
...    print(attribute)
...<NameAttribute(oid=<ObjectIdentifier(oid=2.5.4.6, name=countryName)>, value='US')>
<NameAttribute(oid=<ObjectIdentifier(oid=2.5.4.10, name=organizationName)>, value='Test Certificates 2011')>
<NameAttribute(oid=<ObjectIdentifier(oid=2.5.4.3, name=commonName)>, value='Good CA')>
```

\texttt{rdns}

New in version 1.6.

**Type**

list of RelativeDistinguishedName

classmethod from_rfc4514_string(data, attr_name_overrides=None)

**Parameters**
• **data** *(str)* – An RFC 4514 string.

• **attr_name_overrides** – Specify custom OID to name mappings, which can be used to match vendor-specific extensions. See *NameOID* for common attribute OIDs.

**get_attributes_for_oid** *(oid)*

**Parameters**

oid – An *ObjectIdentifier* instance.

**Returns**

A list of *NameAttribute* instances that match the OID provided. If nothing matches an empty list will be returned.

```python
>>> cert.subject.get_attributes_for_oid(NameOID.COMMON_NAME)
[<NameAttribute(oid=<ObjectIdentifier(oid=2.5.4.3, name=commonName)>, value='Good CA')>]
```

**public_bytes** *

New in version 1.6.

**Returns**

The DER encoded name.

**rfc4514_string** *(attr_name_overrides=None)*

New in version 2.5.

Changed in version 36.0.0: Added *attr_name_overrides* parameter.

Format the given name as a RFC 4514 Distinguished Name string, for example `CN=mydomain.com,O=My Org,C=US`

By default, attributes CN, L, ST, O, OU, C, STREET, DC, UID are represented by their short name. Unrecognized attributes are formatted as dotted OID strings.

**Example:**

```python
>>> name = x509.Name([
...     x509.NameAttribute(NameOID.EMAIL_ADDRESS, "santa@north.pole"),
...     x509.NameAttribute(NameOID.COMMON_NAME, "Santa Claus"),
... ])
>>> name.rfc4514_string()
'CN=Santa Claus,1.2.840.113549.1.9.1=santa@north.pole'
>>> name.rfc4514_string({NameOID.EMAIL_ADDRESS: "E"})
'CN=Santa Claus,E=santa@north.pole'
```

**Parameters**

*attr_name_overrides* (Dict-like mapping from *ObjectIdentifier* to str) – Specify custom OID to name mappings, which can be used to match vendor-specific extensions. See *NameOID* for common attribute OIDs.
Return type
str

class cryptography.x509.Version
New in version 0.7.
An enumeration for X.509 versions.

v1
For version 1 X.509 certificates.

v3
For version 3 X.509 certificates.

class cryptography.x509.NameAttribute
New in version 0.8.
An X.509 name consists of a list of RelativeDistinguishedName instances, which consist of a set of NameAttribute instances.

oid
Type
ObjectIdentifier
The attribute OID.

value
Type
str or bytes
The value of the attribute. This will generally be a str, the only times it can be a bytes is when oid is X500_UNIQUE_IDENTIFIER.

rfc4514_attribute_name
New in version 35.0.0.

Type
str
The RFC 4514 short attribute name (for example “CN”), or the OID dotted string if a short name is unavailable.

rfc4514_string(attr_name_overrides=None)
New in version 2.5.
Changed in version 36.0.0: Added attr_name_overrides parameter.

Return str
Format the given attribute as a RFC 4514 Distinguished Name string.

Parameters
attr_name_overrides (Dict-like mapping from ObjectIdentifier to str) – Specify custom OID to name mappings, which can be used to match vendor-specific extensions.

class cryptography.x509.RelativeDistinguishedName(attributes)
New in version 1.6.
A relative distinguished name is a non-empty set of name attributes. The object is iterable to get every attribute, preserving the original order. Passing duplicate attributes to the constructor raises ValueError.
get_attributes_for_oid(oid)
  Parameters
  oid – An ObjectIdentifier instance.
  Returns
  A list of NameAttribute instances that match the OID provided. The list should contain
  zero or one values.
rfc4514_string(attr_name_overrides=None)
  New in version 2.5.
  Changed in version 36.0.0: Added attr_name_overrides parameter.
  Returns str
  Format the given RDN set as a RFC 4514 Distinguished Name string.
  Parameters
  attr_name_overrides (Dict-like mapping from ObjectIdentifier to str) – Specify
  custom OID to name mappings, which can be used to match vendor-specific extensions.

class cryptography.x509.ObjectIdentifier
  New in version 0.8.
  Object identifiers (frequently seen abbreviated as OID) identify the type of a value (see: NameAttribute).

dotted_string
  Type
  str
  The dotted string value of the OID (e.g. "2.5.4.3")

General Name Classes

class cryptography.x509.GeneralName
  New in version 0.9.
  This is the generic interface that all the following classes are registered against.

class cryptography.x509.RFC822Name(value)
  New in version 0.9.
  Changed in version 3.1: U-label support has been removed. Encode them to A-label before use.
  This corresponds to an email address. For example, user@example.com.
  Parameters
    value – The email address. If the address contains an internationalized domain name then it
    must be encoded to an A-label string before being passed.
  Raises
    ValueError – If the provided string is not an A-label.
  value
    Type
    str
class cryptography.x509.DNSName(value)

New in version 0.9.

Changed in version 3.1: *U-label* support has been removed. Encode them to *A-label* before use.

This corresponds to a domain name. For example, cryptography.io.

Parameters

value – The domain name. If it is an internationalized domain name then it must be encoded to an *A-label* string before being passed.

Raises

ValueError – If the provided string is not an *A-label*.

type

str

value

Type

str

class cryptography.x509.DirectoryName(value)

New in version 0.9.

This corresponds to a directory name.

value

Type

Name

class cryptography.x509.UniformResourceIdentifier(value)

New in version 0.9.

Changed in version 3.1: *U-label* support has been removed. Encode them to *A-label* before use.

This corresponds to a uniform resource identifier. For example, https://cryptography.io.

Parameters

value – The URI. If it contains an internationalized domain name then it must be encoded to an *A-label* string before being passed.

Raises

ValueError – If the provided string is not an *A-label*.

value

Type

str

class cryptography.x509.IPAddress(value)

New in version 0.9.

This corresponds to an IP address.

value

Type

IPv4Address, IPv6Address, IPv4Network, or IPv6Network.
class cryptography.x509.RegisteredID(value)

New in version 0.9.
This corresponds to a registered ID.

value

Type

ObjectIdentifier

class cryptography.x509.OtherName(type_id, value)

New in version 1.0.
This corresponds to an otherName. An otherName has a type identifier and a value represented in binary DER format.

Type

ObjectIdentifier

value

Type

bytes

X.509 Extensions

class cryptography.x509.Extensions

New in version 0.9.

An X.509 Extensions instance is an ordered list of extensions. The object is iterable to get every extension.

get_extension_for_oid(oid)

Parameters

oid – An ObjectIdentifier instance.

Returns

An instance of Extension.

Raises

cryptography.x509.ExtensionNotFound – If the certificate does not have the extension requested.

get_extension_for_class(extclass)

New in version 1.1.

Parameters

extclass – An extension class.

Returns

An instance of Extension.
Raises

`cryptography.x509.ExtensionNotFound` – If the certificate does not have the extension requested.

```py
>>> from cryptography import x509
>>> cert.extensions.get_extension_for_class(x509.BasicConstraints)
<Extension(oid=<ObjectIdentifier(oid=2.5.29.19, name=basicConstraints)>,
critical=True, value=<BasicConstraints(ca=True, path_length=None)>)>
```

class cryptography.x509.Extension

New in version 0.9.

**oid**

Type

`ObjectIdentifier`

One of the `ExtensionOID` OIDs.

**critical**

Type

`bool`

Determines whether a given extension is critical or not. RFC 5280 requires that “A certificate-using system MUST reject the certificate if it encounters a critical extension it does not recognize or a critical extension that contains information that it cannot process”.

**value**

Returns an instance of the extension type corresponding to the OID.

class cryptography.x509.ExtensionType

New in version 1.0.

This is the interface against which all the following extension types are registered.

**oid**

Type

`ObjectIdentifier`

Returns the OID associated with the given extension type.

**public_bytes()**

New in version 36.0.0.

**Return bytes**

A bytes string representing the extension’s DER encoded value.

class cryptography.x509.KeyUsage(`digital_signature`, `content_commitment`, `key_encipherment`, `data_encipherment`, `key_agreement`, `key_cert_sign`, `crl_sign`, `encipher_only`, `decipher_only`)

New in version 0.9.

The key usage extension defines the purpose of the key contained in the certificate. The usage restriction might be employed when a key that could be used for more than one operation is to be restricted.

**oid**

New in version 1.0.
digital_signature

Type
bool

This purpose is set to true when the subject public key is used for verifying digital signatures, other than signatures on certificates (key_cert_sign) and CRLs (crl_sign).

content_commitment

Type
bool

This purpose is set to true when the subject public key is used for verifying digital signatures, other than signatures on certificates (key_cert_sign) and CRLs (crl_sign). It is used to provide a non-repudiation service that protects against the signing entity falsely denying some action. In the case of later conflict, a reliable third party may determine the authenticity of the signed data. This was called non_repudiation in older revisions of the X.509 specification.

key_encipherment

Type
bool

This purpose is set to true when the subject public key is used for enciphering private or secret keys.

data_encipherment

Type
bool

This purpose is set to true when the subject public key is used for directly enciphering raw user data without the use of an intermediate symmetric cipher.

key_agreement

Type
bool

This purpose is set to true when the subject public key is used for key agreement. For example, when a Diffie-Hellman key is to be used for key management, then this purpose is set to true.

key_cert_sign

Type
bool

This purpose is set to true when the subject public key is used for verifying signatures on public key certificates. If this purpose is set to true then ca must be true in the BasicConstraints extension.

crl_sign

Type
bool

This purpose is set to true when the subject public key is used for verifying signatures on certificate revocation lists.
encipher_only

Type
    bool

When this purposes is set to true and the key_agreement purpose is also set, the subject public key may be used only for enciphering data while performing key agreement.

Raises
    ValueError – This is raised if accessed when key_agreement is false.

decipher_only

Type
    bool

When this purposes is set to true and the key_agreement purpose is also set, the subject public key may be used only for deciphering data while performing key agreement.

Raises
    ValueError – This is raised if accessed when key_agreement is false.

class cryptography.x509.BasicConstraints(ca, path_length)

New in version 0.9.

Basic constraints is an X.509 extension type that defines whether a given certificate is allowed to sign additional certificates and what path length restrictions may exist.

oid

New in version 1.0.

Type
    ObjectIdentifier

Returns BASIC_CONSTRAINTS.

case

Type
    bool

Whether the certificate can sign certificates.

path_length

Type
    int or None

The maximum path length for certificates subordinate to this certificate. This attribute only has meaning if ca is true. If ca is true then a path length of None means there’s no restriction on the number of subordinate CAs in the certificate chain. If it is zero or greater then it defines the maximum length for a subordinate CA’s certificate chain. For example, a path_length of 1 means the certificate can sign a subordinate CA, but the subordinate CA is not allowed to create subordinates with ca set to true.

class cryptography.x509.ExtendedKeyUsage(usages)

New in version 0.9.

This extension indicates one or more purposes for which the certified public key may be used, in addition to or in place of the basic purposes indicated in the key usage extension. The object is iterable to obtain the list of ExtendedKeyUsageOID OIDs present.

Parameters
    usages (list) – A list of ExtendedKeyUsageOID OIDs.
oid
New in version 1.0.

Type
ObjectIdentifier

Returns EXTENDED_KEY_USAGE.

class cryptography.x509.OCSPNoCheck
New in version 1.0.

This presence of this extension indicates that an OCSP client can trust a responder for the lifetime of the responder’s certificate. CAs issuing such a certificate should realize that a compromise of the responder’s key is as serious as the compromise of a CA key used to sign CRLs, at least for the validity period of this certificate. CA’s may choose to issue this type of certificate with a very short lifetime and renew it frequently. This extension is only relevant when the certificate is an authorized OCSP responder.

oid
New in version 1.0.

Type
ObjectIdentifier

Returns OCSP_NO_CHECK.

class cryptography.x509.TLSFeature(features)
New in version 2.1.

The TLS Feature extension is defined in RFC 7633 and is used in certificates for OCSP Must-Staple. The object is iterable to get every element.

Parameters

features (list) – A list of features to enable from the TLSFeatureType enum. At this time only status_request or status_request_v2 are allowed.

oid

Type
ObjectIdentifier

Returns TLS_FEATURE.

class cryptography.x509.TLSFeatureType
New in version 2.1.

An enumeration of TLS Feature types.

status_request
This feature type is defined in RFC 6066 and, when embedded in an X.509 certificate, signals to the client that it should require a stapled OCSP response in the TLS handshake. Commonly known as OCSP Must-Staple in certificates.

status_request_v2
This feature type is defined in RFC 6961. This value is not commonly used and if you want to enable OCSP Must-Staple you should use status_request.

class cryptography.x509.NameConstraints(permitted_subtrees, excluded_subtrees)
New in version 1.0.

The name constraints extension, which only has meaning in a CA certificate, defines a name space within which all subject names in certificates issued beneath the CA certificate must (or must not) be in. For specific details on the way this extension should be processed see RFC 5280.
oid
New in version 1.0.
Type
ObjectIdentifier
Returns NAME_CONSTRAINTS.

permitted_subtrees
Type
list of GeneralName objects or None
The set of permitted name patterns. If a name matches this and an element in excluded_subtrees it is invalid. At least one of permitted_subtrees and excluded_subtrees will be non-None.

excluded_subtrees
Type
list of GeneralName objects or None
Any name matching a restriction in the excluded_subtrees field is invalid regardless of information appearing in the permitted_subtrees. At least one of permitted_subtrees and excluded_subtrees will be non-None.

class cryptography.x509.AuthorityKeyIdentifier(key_identifier, authority_cert_issuer, authority_cert_serial_number)
New in version 0.9.
The authority key identifier extension provides a means of identifying the public key corresponding to the private key used to sign a certificate. This extension is typically used to assist in determining the appropriate certificate chain. For more information about generation and use of this extension see RFC 5280 section 4.2.1.1.

oid
New in version 1.0.
Type
ObjectIdentifier
Returns AUTHORITY_KEY_IDENTIFIER.

key_identifier
Type
bytes
A value derived from the public key used to verify the certificate’s signature.

authority_cert_issuer
Type
A list of GeneralName instances or None
The GeneralName (one or multiple) of the issuer’s issuer.

authority_cert_serial_number
Type
int or None
The serial number of the issuer’s issuer.
classmethod from_issuer_public_key(public_key)

New in version 1.0.

Note: This method should be used if the issuer certificate does not contain a SubjectKeyIdentifier. Otherwise, use from_issuer_subject_key_identifier().

Creates a new AuthorityKeyIdentifier instance using the public key provided to generate the appropriate digest. This should be the issuer's public key. The resulting object will contain key_identifier, but authority_cert_issuer and authority_cert_serial_number will be None. The generated key_identifier is the SHA1 hash of the subjectPublicKey ASN.1 bit string. This is the first recommendation in RFC 5280 section 4.2.1.2.

Parameters

- public_key – One of CertificateIssuerPublicKeyTypes.

```python
>>> from cryptography import x509
>>> issuer_cert = x509.load_pem_x509_certificate(pem_data)
>>> x509.AuthorityKeyIdentifier.from_issuer_public_key(issuer_cert.public_key())
<AuthorityKeyIdentifier(key_identifier=b'X\x01\x84$\x1b\xbc+R\x94]=\xa5\x10r\n\x14Q\xf5\xaf:\xc9', authority_cert_issuer=None, authority_cert_serial_number=None)>
```

classmethod from_issuer_subject_key_identifier(ski)

New in version 1.3.

Note: This method should be used if the issuer certificate contains a SubjectKeyIdentifier. Otherwise, use from_issuer_public_key().

Creates a new AuthorityKeyIdentifier instance using the SubjectKeyIdentifier from the issuer certificate. The resulting object will contain key_identifier, but authority_cert_issuer and authority_cert_serial_number will be None.

Parameters

- ski – The SubjectKeyIdentifier from the issuer certificate.

```python
>>> from cryptography import x509
>>> issuer_cert = x509.load_pem_x509_certificate(pem_data)
>>> ski_ext = issuer_cert.extensions.get_extension_for_class(x509.SubjectKeyIdentifier)
>>> x509.AuthorityKeyIdentifier.from_issuer_subject_key_identifier(ski_ext.value)
<AuthorityKeyIdentifier(key_identifier=b'X\x01\x84$\x1b\xbc+R\x94]=\xa5\x10r\n\x14Q\xf5\xaf:\xc9', authority_cert_issuer=None, authority_cert_serial_number=None)>
```

class cryptography.x509.SubjectKeyIdentifier(digest)

New in version 0.9.

The subject key identifier extension provides a means of identifying certificates that contain a particular public key.

oid

New in version 1.0.
Type

*ObjectIdentifier*

Returns *SUBJECT_KEY_IDENTIFIER*.

**key_identifier**

New in version 35.0.0.

Type

*bytes*

The binary value of the identifier.

**digest**

Type

*bytes*

The binary value of the identifier. An alias of *key_identifier*.

**classmethod from_public_key(public_key)**

New in version 1.0.

Creates a new SubjectKeyIdentifier instance using the public key provided to generate the appropriate digest. This should be the public key that is in the certificate. The generated digest is the SHA1 hash of the subjectPublicKey ASN.1 bit string. This is the first recommendation in *RFC 5280* section 4.2.1.2.

Parameters

*public_key* – One of *CertificatePublicKeyTypes*.

```python
>>> from cryptography import x509
>>> csr = x509.load_pem_x509_csr(pem_req_data)
>>> x509.SubjectKeyIdentifier.from_public_key(csr.public_key())
<SubjectKeyIdentifier(digest=b'\x8c"\x98\xe2\xb5\xbf]\xe8*2\xf8\xd2\'?\x00\xd2\n\xe4c')>
```

**class cryptography.x509.SubjectAlternativeName(general_names)**

New in version 0.9.

Subject alternative name is an X.509 extension that provides a list of *general name* instances that provide a set of identities for which the certificate is valid. The object is iterable to get every element.

Parameters

*general_names* (*list*) – A list of *GeneralName* instances.

**oid**

New in version 1.0.

Type

*ObjectIdentifier*

Returns *SUBJECT_ALTERNATIVE_NAME*.

**get_values_for_type(type)**

Parameters

*type* – A *GeneralName* instance. This is one of the *general name classes*.

Returns

A list of values extracted from the matched general names. The type of the returned values depends on the *GeneralName*. 

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```python
cert = x509.load_pem_x509_certificate(cryptography_cert_pem)
# Get the subjectAltName extension from the certificate
ext = cert.extensions.get_extension_for_oid(x509.OID_SUBJECT_ALTERNATIVE_NAME)
# Get the dNSName entries from the SAN extension
ext.value.get_values_for_type(x509.DNSName)
```

```python
class cryptography.x509.IssuerAlternativeName(general_names)

New in version 1.0.

Issuer alternative name is an X.509 extension that provides a list of general name instances that provide a set of identities for the certificate issuer. The object is iterable to get every element.

**Parameters**

- `general_names (list)` – A list of GeneralName instances.

**oid**

New in version 1.0.

- **Type** `ObjectIdentifier`
- **Returns** `ISSUER_ALTERNATIVE_NAME`.

**get_values_for_type(type)**

- **Parameters**
  - `type` – A GeneralName instance. This is one of the general name classes.
- **Returns**
  - A list of values extracted from the matched general names.

class cryptography.x509.PrecertificateSignedCertificateTimestamps(scts)

New in version 2.0.

This extension contains SignedCertificateTimestamp instances which were issued for the pre-certificate corresponding to this certificate. These can be used to verify that the certificate is included in a public Certificate Transparency log.

It is an iterable containing one or more SignedCertificateTimestamp objects.

**Parameters**

- `scts (list)` – A list of SignedCertificateTimestamp objects.

**oid**

- **Type** `ObjectIdentifier`
- **Returns** `PRECERT_SIGNED_CERTIFICATE_TIMESTAMPS`.

class cryptography.x509.PrecertPoison

New in version 2.4.

This extension indicates that the certificate should not be treated as a certificate for the purposes of validation, but is instead for submission to a certificate transparency log in order to obtain SCTs which will be embedded in a PrecertificateSignedCertificateTimestamps extension on the final certificate.
oid

Type

ObjectIdentifier

Returns PRECERT_POISON.

class cryptography.x509.SignedCertificateTimestamps(scts)

New in version 3.0.

This extension contains SignedCertificateTimestamp instances. These can be used to verify that the certificate is included in a public Certificate Transparency log. This extension is only found in OCSP responses. For SCTs in an X.509 certificate see PrecertificateSignedCertificateTimestamps.

It is an iterable containing one or more SignedCertificateTimestamp objects.

Parameters

scts (list) – A list of SignedCertificateTimestamp objects.

oid

Type

ObjectIdentifier

Returns SIGNED_CERTIFICATE_TIMESTAMPS.

class cryptography.x509.DeltaCRLIndicator(crl_number)

New in version 2.1.

The delta CRL indicator is a CRL extension that identifies a CRL as being a delta CRL. Delta CRLs contain updates to revocation information previously distributed, rather than all the information that would appear in a complete CRL.

Parameters

crl_number (int) – The CRL number of the complete CRL that the delta CRL is updating.

oid

Type

ObjectIdentifier

Returns DELTA_CRL_INDICATOR.

crl_number

Type

int

class cryptography.x509.AuthorityInformationAccess(descriptions)

New in version 0.9.

The authority information access extension indicates how to access information and services for the issuer of the certificate in which the extension appears. Information and services may include online validation services (such as OCSP) and issuer data. It is an iterable, containing one or more AccessDescription instances.

Parameters

descriptions (list) – A list of AccessDescription objects.

oid

New in version 1.0.

Type

ObjectIdentifier
Returns \texttt{AUTHORITY_INFORMATION_ACCESS}.

\textbf{class} \texttt{cryptography.x509.SubjectInformationAccess}(\textit{descriptions})

New in version 3.0.

The subject information access extension indicates how to access information and services for the subject of the certificate in which the extension appears. When the subject is a CA, information and services may include certificate validation services and CA policy data. When the subject is an end entity, the information describes the type of services offered and how to access them. It is an iterable, containing one or more \texttt{AccessDescription} instances.

Parameters
\textbf{descriptions (list)} – A list of \texttt{AccessDescription} objects.

\textbf{oid}

Type \texttt{ObjectIdentifier}

Returns \texttt{SUBJECT_INFORMATION_ACCESS}.

\textbf{class} \texttt{cryptography.x509.AccessDescription}(\textit{access_method}, \textit{access_location})

New in version 0.9.

\textbf{access_method}

Type \texttt{ObjectIdentifier}

The access method defines what the \textit{access_location} means. It must be \texttt{OCSP} or \texttt{CA_ISSUERS} when used with \texttt{AuthorityInformationAccess} or \texttt{CA_REPOSITORY} when used with \texttt{SubjectInformationAccess}.

If it is \texttt{OCSP} the access location will be where to obtain OCSP information for the certificate. If it is \texttt{CA_ISSUERS} the access location will provide additional information about the issuing certificate. Finally, if it is \texttt{CA_REPOSITORY} the access location will be the location of the CA's repository.

\textbf{access_location}

Type \texttt{GeneralName}

Where to access the information defined by the access method.

\textbf{class} \texttt{cryptography.x509.FreshestCRL}(\textit{distribution_points})

New in version 2.1.

The freshest CRL extension (also known as Delta CRL Distribution Point) identifies how delta CRL information is obtained. It is an iterable, containing one or more \texttt{DistributionPoint} instances.

Parameters
\textbf{distribution_points (list)} – A list of \texttt{DistributionPoint} instances.

\textbf{oid}

Type \texttt{ObjectIdentifier}

Returns \texttt{FRESHEST_CRL}.
class cryptography.x509.CRLDistributionPoints(distribution_points)

New in version 0.9.

The CRL distribution points extension identifies how CRL information is obtained. It is an iterable, containing one or more DistributionPoint instances.

Parameters

distribution_points (list) – A list of DistributionPoint instances.

oid

New in version 1.0.

Type

ObjectIdentifier

Returns CRL_DISTRIBUTION_POINTS.

class cryptography.x509.DistributionPoint(full_name, relative_name, reasons, crl_issuer)

New in version 0.9.

full_name

Type

list of GeneralName instances or None

This field describes methods to retrieve the CRL. At most one of full_name or relative_name will be non-None.

relative_name

Type

RelativeDistinguishedName or None

This field describes methods to retrieve the CRL relative to the CRL issuer. At most one of full_name or relative_name will be non-None.

Changed in version 1.6: Changed from Name to RelativeDistinguishedName.

crl_issuer

Type

list of GeneralName instances or None

Information about the issuer of the CRL.

reasons

Type

frozenset of ReasonFlags or None

The reasons a given distribution point may be used for when performing revocation checks.

class cryptography.x509.ReasonFlags

New in version 0.9.

An enumeration for CRL reasons.

unspecified

It is unspecified why the certificate was revoked. This reason cannot be used as a reason flag in a DistributionPoint.

key_compromise

This reason indicates that the private key was compromised.
ca_compromise
This reason indicates that the CA issuing the certificate was compromised.

affiliation_changed
This reason indicates that the subject’s name or other information has changed.

superseded
This reason indicates that a certificate has been superseded.

cessation_of_operation
This reason indicates that the certificate is no longer required.

certificate_hold
This reason indicates that the certificate is on hold.

privilege_withdrawn
This reason indicates that the privilege granted by this certificate have been withdrawn.

aa_compromise
When an attribute authority has been compromised.

remove_from_crl
This reason indicates that the certificate was on hold and should be removed from the CRL. This reason cannot be used as a reason flag in a DistributionPoint.

class cryptography.x509.InhibitAnyPolicy(skip_certs)
New in version 1.0.

The inhibit anyPolicy extension indicates that the special OID ANY_POLICY, is not considered an explicit match for other CertificatePolicies except when it appears in an intermediate self-issued CA certificate. The value indicates the number of additional non-self-issued certificates that may appear in the path before ANY_POLICY is no longer permitted. For example, a value of one indicates that ANY_POLICY may be processed in certificates issued by the subject of this certificate, but not in additional certificates in the path.

oid
New in version 1.0.

    Type
    ObjectIdentifier

    Returns INHIBIT_ANY_POLICY.

skip_certs

    Type
    int

class cryptography.x509.PolicyConstraints
New in version 1.3.

The policy constraints extension is used to inhibit policy mapping or require that each certificate in a chain contain an acceptable policy identifier. For more information about the use of this extension see RFC 5280.

oid

    Type
    ObjectIdentifier

    Returns POLICY_CONSTRAINTS.
require_explicit_policy

Type
int or None

If this field is not None, the value indicates the number of additional certificates that may appear in the chain before an explicit policy is required for the entire path. When an explicit policy is required, it is necessary for all certificates in the chain to contain an acceptable policy identifier in the certificate policies extension. An acceptable policy identifier is the identifier of a policy required by the user of the certification path or the identifier of a policy that has been declared equivalent through policy mapping.

inhibit_policy_mapping

Type
int or None

If this field is not None, the value indicates the number of additional certificates that may appear in the chain before policy mapping is no longer permitted. For example, a value of one indicates that policy mapping may be processed in certificates issued by the subject of this certificate, but not in additional certificates in the chain.

class cryptography.x509.CRLNumber(crl_number)

New in version 1.2.

The CRL number is a CRL extension that conveys a monotonically increasing sequence number for a given CRL scope and CRL issuer. This extension allows users to easily determine when a particular CRL supersedes another CRL. RFC 5280 requires that this extension be present in conforming CRLs.

oid

Type
ObjectIdentifier

Returns CRL_NUMBER.

crl_number

Type
int

class cryptography.x509.IssuingDistributionPoint(full_name, relative_name, only_contains_user_certs, only_contains_ca_certs, only_some_reasons, indirect_crl, only_contains_attribute_certs)

New in version 2.5.

Issuing distribution point is a CRL extension that identifies the CRL distribution point and scope for a particular CRL. It indicates whether the CRL covers revocation for end entity certificates only, CA certificates only, attribute certificates only, or a limited set of reason codes. For specific details on the way this extension should be processed see RFC 5280.

oid

Type
ObjectIdentifier

Returns ISSUING_DISTRIBUTION_POINT.

only_contains_user_certs

Type
bool
Set to `True` if the CRL this extension is embedded within only contains information about user certificates.

```python
only_contains_ca_certs
```

Type

```
bool
```

Set to `True` if the CRL this extension is embedded within only contains information about CA certificates.

```python
indirect_crl
```

Type

```
bool
```

Set to `True` if the CRL this extension is embedded within includes certificates issued by one or more authorities other than the CRL issuer.

```python
only_contains_attribute_certs
```

Type

```
bool
```

Set to `True` if the CRL this extension is embedded within only contains information about attribute certificates.

```python
only_some_reasons
```

Type

```
frozenset of ReasonFlags or None
```

The reasons for which the issuing distribution point is valid. None indicates that it is valid for all reasons.

```python
full_name
```

Type

```
list of GeneralName instances or None
```

This field describes methods to retrieve the CRL. At most one of `full_name` or `relative_name` will be non-None.

```python
relative_name
```

Type

```
RelativeDistinguishedName or None
```

This field describes methods to retrieve the CRL relative to the CRL issuer. At most one of `full_name` or `relative_name` will be non-None.

```python
class cryptography.x509.UnrecognizedExtension
```

New in version 1.2.

A generic extension class used to hold the raw value of extensions that `cryptography` does not know how to parse. This can also be used when creating new certificates, CRLs, or OCSP requests and responses to encode extensions that `cryptography` does not know how to generate.

```python
oid
```

Type

```
ObjectIdentifier
```

Returns the OID associated with this extension.
value

    Type
    bytes

    Returns the DER encoded bytes payload of the extension.

class cryptography.x509.MSCertificateTemplate(template_id, major_version, minor_version)

    New in version 41.0.0.

    The Microsoft certificate template extension is a proprietary Microsoft PKI extension that is used to provide
    information about the template associated with the certificate.

oid

    Type
    ObjectIdentifier

    Returns MS_CERTIFICATE_TEMPLATE.

template_id

    Type
    ObjectIdentifier

major_version

    Type
    int or None

minor_version

    Type
    int or None

class cryptography.x509.CertificatePolicies(policies)

    New in version 0.9.

    The certificate policies extension is an iterable, containing one or more PolicyInformation instances.

    Parameters
    policies (list) – A list of PolicyInformation instances.

    As an example of how CertificatePolicies might be used, if you wanted to check if a certificate contained
    the CAB Forum’s “domain-validated” policy, you might write code like:

    ```python
    def contains_domain_validated(policies):
        return any(
            policy.policy_identifier.dotted_string == "2.23.140.1.2.1"
            for policy in policies
        )
    ```

oid

    New in version 1.0.

    Type
    ObjectIdentifier

    Returns CERTIFICATE_POLICIES.
Certificate Policies Classes

These classes may be present within a CertificatePolicies instance.

```python
class cryptography.x509.PolicyInformation(policy_identifier, policy_qualifiers)
```

New in version 0.9.

Contains a policy identifier and an optional list of qualifiers.

- **policy_identifier**
  - Type: ObjectIdentifier

- **policy_qualifiers**
  - Type: list
    - A list consisting of str and/or UserNotice objects. If the value is str it is a pointer to the practice statement published by the certificate authority. If it is a user notice it is meant for display to the relying party when the certificate is used.

```python
class cryptography.x509.UserNotice(notice_reference, explicit_text)
```

New in version 0.9.

User notices are intended for display to a relying party when a certificate is used. In practice, few if any UIs expose this data and it is a rarely encoded component.

- **notice_reference**
  - Type: NoticeReference or None
    - The notice reference field names an organization and identifies, by number, a particular statement prepared by that organization.

- **explicit_text**
  - This field includes an arbitrary textual statement directly in the certificate.
    - Type: str

```python
class cryptography.x509.NoticeReference(organization, notice_numbers)
```

New in version 0.9.

Notice reference can name an organization and provide information about notices related to the certificate. For example, it might identify the organization name and notice number 1. Application software could have a notice file containing the current set of notices for the named organization; the application would then extract the notice text from the file and display it. In practice this is rarely seen.

- **organization**
  - Type: str

- **notice_numbers**
  - Type: list
    - A list of integers.
CRL Entry Extensions

These extensions are only valid within a `RevokedCertificate` object.

```python
class cryptography.x509.CertificateIssuer(general_names)

New in version 1.2.

The certificate issuer is an extension that is only valid inside `RevokedCertificate` objects. If the `indirectCRL` property of the parent CRL's IssuingDistributionPoint extension is set, then this extension identifies the certificate issuer associated with the revoked certificate. The object is iterable to get every element.

Parameters

- `general_names (list)` – A list of `GeneralName` instances.

```
oid

Type

ObjectIdentifier

Returns `CERTIFICATE_ISSUER`.
```

```python
def get_values_for_type(type)

Parameters

- `type` – A `GeneralName` instance. This is one of the general name classes.

Returns

A list of values extracted from the matched general names. The type of the returned values depends on the `GeneralName`.
```

```python
class cryptography.x509.CRLReason(reason)

New in version 1.2.

CRL reason (also known as `reasonCode`) is an extension that is only valid inside `RevokedCertificate` objects. It identifies a reason for the certificate revocation.

Parameters

- `reason` – An element from `ReasonFlags`.

```
oid

Type

ObjectIdentifier

Returns `CRL_REASON`.
```

```python
def reason

Type

An element from `ReasonFlags`.
```

```python
class cryptography.x509.InvalidityDate(invalidity_date)

New in version 1.2.

Invalidity date is an extension that is only valid inside `RevokedCertificate` objects. It provides the date on which it is known or suspected that the private key was compromised or that the certificate otherwise became invalid. This date may be earlier than the revocation date in the CRL entry, which is the date at which the CA processed the revocation.

Parameters

- `invalidity_date` – The `datetime.datetime` when it is known or suspected that the private key was compromised.
```
```
oid

  Type
  ObjectIdentifier

  Returns INVALIDITY_DATE.

invalidity_date

  Type
  datetime.datetime

OCSP Extensions

class cryptography.x509.OCSPNonce(nonce)

  New in version 2.4.

  OCSP nonce is an extension that is only valid inside OCSPRequest and OCSPResponse objects. The nonce cryptographically binds a request and a response to prevent replay attacks. In practice nonces are rarely used in OCSP due to the desire to precompute OCSP responses at large scale.

oid

  Type
  ObjectIdentifier

  Returns NONCE.

nonce

  Type
  bytes

class cryptography.x509.OCSPAcceptableResponses(response)

  New in version 41.0.0.

  OCSP acceptable responses is an extension that is only valid inside OCSPRequest objects. This allows an OCSP client to tell the server what types of responses it supports. In practice this is rarely used, because there is only one kind of OCSP response in wide use.

oid

  Type
  ObjectIdentifier

  Returns ACCEPTABLE_RESPONSES.

nonce

  Type
  bytes
**X.509 Request Attributes**

```python
class cryptography.x509.Attributes
```

New in version 36.0.0.

An Attributes instance is an ordered list of attributes. The object is iterable to get every attribute. Each returned element is an `Attribute`.

```python
def get_attribute_for_oid(oid)
```

New in version 36.0.0.

**Parameters**

- `oid` – An `ObjectIdentifier` instance.

**Returns**

The `Attribute` or an exception if not found.

**Raises**

`cryptography.x509.AttributeNotFound` – If the request does not have the attribute requested.

```python
class cryptography.x509.Attribute
```

New in version 36.0.0.

An attribute associated with an X.509 request.

```python
oid
```

**Type**

`ObjectIdentifier`

Returns the object identifier for the attribute.

```python
value
```

**Type**

`bytes`

Returns the value of the attribute.

**Object Identifiers**

X.509 elements are frequently identified by `ObjectIdentifier` instances. The following common OIDs are available as constants.

```python
class cryptography.x509.oid.NameOID
```

These OIDs are typically seen in X.509 names.

New in version 1.0.

**COMMON_NAME**

Corresponds to the dotted string "2.5.4.3". Historically the domain name would be encoded here for server certificates. **RFC 2818** deprecates this practice and names of that type should now be located in a `SubjectAlternativeName` extension.

**COUNTRY_NAME**

Corresponds to the dotted string "2.5.4.6".

**LOCALITY_NAME**

Corresponds to the dotted string "2.5.4.7".
STATE_OR_PROVINCE_NAME
Corresponds to the dotted string "2.5.4.8".

STREET_ADDRESS
New in version 1.6.
Corresponds to the dotted string "2.5.4.9".

ORGANIZATION_IDENTIFIER
New in version 42.0.0.
Corresponds to the dotted string "2.5.4.97".

ORGANIZATION_NAME
Corresponds to the dotted string "2.5.4.10".

ORGANIZATIONAL_UNIT_NAME
Corresponds to the dotted string "2.5.4.11".

SERIAL_NUMBER
Corresponds to the dotted string "2.5.4.5". This is distinct from the serial number of the certificate itself (which can be obtained with `serial_number`).

SURNAME
Corresponds to the dotted string "2.5.4.4".

GIVEN_NAME
Corresponds to the dotted string "2.5.4.42".

TITLE
Corresponds to the dotted string "2.5.4.12".

INITIALS
New in version 41.0.0.
Corresponds to the dotted string "2.5.4.43".

GENERATION_QUALIFIER
Corresponds to the dotted string "2.5.4.44".

X500_UNIQUE_IDENTIFIER
New in version 1.6.
Corresponds to the dotted string "2.5.4.45".

DN_QUALIFIER
Corresponds to the dotted string "2.5.4.46". This specifies disambiguating information to add to the relative distinguished name of an entry. See RFC 2256.

PSEUDONYM
Corresponds to the dotted string "2.5.4.65".

USER_ID
New in version 1.6.
Corresponds to the dotted string "0.9.2342.19200300.100.1.1".

DOMAIN_COMPONENT
Corresponds to the dotted string "0.9.2342.19200300.100.1.25". A string holding one component of a domain name. See RFC 4519.
**EMAIL_ADDRESS**
Corresponds to the dotted string "1.2.840.113549.1.9.1".

**JURISDICTION_COUNTRY_NAME**
Corresponds to the dotted string "1.3.6.1.4.1.311.60.2.1.3".

**JURISDICTION_LOCALITY_NAME**
Corresponds to the dotted string "1.3.6.1.4.1.311.60.2.1.1".

**JURISDICTION_STATE_OR_PROVINCE_NAME**
Corresponds to the dotted string "1.3.6.1.4.1.311.60.2.1.2".

**BUSINESS_CATEGORY**
Corresponds to the dotted string "2.5.4.15".

**POSTAL_ADDRESS**
New in version 1.6.
Corresponds to the dotted string "2.5.4.16".

**POSTAL_CODE**
New in version 1.6.
Corresponds to the dotted string "2.5.4.17".

**UNSTRUCTURED_NAME**
New in version 3.0.
Corresponds to the dotted string "1.2.840.113549.1.9.2".

class cryptography.x509.oid.SignatureAlgorithmOID
New in version 1.0.

**RSA_WITH_MD5**
Corresponds to the dotted string "1.2.840.113549.1.1.4". This is an MD5 digest signed by an RSA key.

**RSA_WITH_SHA1**
Corresponds to the dotted string "1.2.840.113549.1.1.5". This is a SHA1 digest signed by an RSA key.

**RSA_WITH_SHA224**
Corresponds to the dotted string "1.2.840.113549.1.1.14". This is a SHA224 digest signed by an RSA key.

**RSA_WITH_SHA256**
Corresponds to the dotted string "1.2.840.113549.1.1.11". This is a SHA256 digest signed by an RSA key.

**RSA_WITH_SHA384**
Corresponds to the dotted string "1.2.840.113549.1.1.12". This is a SHA384 digest signed by an RSA key.

**RSA_WITH_SHA512**
Corresponds to the dotted string "1.2.840.113549.1.1.13". This is a SHA512 digest signed by an RSA key.
RSA_WITH_SHA3_224
Corresponds to the dotted string "2.16.840.1.101.3.4.3.13". This is a SHA3-224 digest signed by an RSA key.

RSA_WITH_SHA3_256
Corresponds to the dotted string "2.16.840.1.101.3.4.3.14". This is a SHA3-256 digest signed by an RSA key.

RSA_WITH_SHA3_384
Corresponds to the dotted string "2.16.840.1.101.3.4.3.15". This is a SHA3-384 digest signed by an RSA key.

RSA_WITH_SHA3_512
Corresponds to the dotted string "2.16.840.1.101.3.4.3.16". This is a SHA3-512 digest signed by an RSA key.

RSASSA_PSS
New in version 2.3.
Corresponds to the dotted string "1.2.840.113549.1.1.10". This is signed by an RSA key using the Probabilistic Signature Scheme (PSS) padding from RFC4055. The hash function and padding are defined by signature algorithm parameters.

ECDSA_WITH_SHA1
Corresponds to the dotted string "1.2.840.10045.4.1". This is a SHA1 digest signed by an ECDSA key.

ECDSA_WITH_SHA224
Corresponds to the dotted string "1.2.840.10045.4.3.1". This is a SHA224 digest signed by an ECDSA key.

ECDSA_WITH_SHA256
Corresponds to the dotted string "1.2.840.10045.4.3.2". This is a SHA256 digest signed by an ECDSA key.

ECDSA_WITH_SHA384
Corresponds to the dotted string "1.2.840.10045.4.3.3". This is a SHA384 digest signed by an ECDSA key.

ECDSA_WITH_SHA512
Corresponds to the dotted string "1.2.840.10045.4.3.4". This is a SHA512 digest signed by an ECDSA key.

ECDSA_WITH_SHA3_224
Corresponds to the dotted string "2.16.840.1.101.3.4.3.9". This is a SHA3-224 digest signed by an ECDSA key.

ECDSA_WITH_SHA3_256
Corresponds to the dotted string "2.16.840.1.101.3.4.3.10". This is a SHA3-256 digest signed by an ECDSA key.

ECDSA_WITH_SHA3_384
Corresponds to the dotted string "2.16.840.1.101.3.4.3.11". This is a SHA3-384 digest signed by an ECDSA key.

ECDSA_WITH_SHA3_512
Corresponds to the dotted string "2.16.840.1.101.3.4.3.12". This is a SHA3-512 digest signed by an ECDSA key.
**DSA_WITH_SHA1**
Corresponds to the dotted string "1.2.840.10040.4.3". This is a SHA1 digest signed by a DSA key.

**DSA_WITH_SHA224**
Corresponds to the dotted string "2.16.840.1.101.3.4.3.1". This is a SHA224 digest signed by a DSA key.

**DSA_WITH_SHA256**
Corresponds to the dotted string "2.16.840.1.101.3.4.3.2". This is a SHA256 digest signed by a DSA key.

**DSA_WITH_SHA384**
New in version 36.0.0.
Corresponds to the dotted string "2.16.840.1.101.3.4.3.3". This is a SHA384 digest signed by a DSA key.

**DSA_WITH_SHA512**
New in version 36.0.0.
Corresponds to the dotted string "2.16.840.1.101.3.4.3.4". This is a SHA512 digest signed by a DSA key.

**ED25519**
New in version 2.8.
Corresponds to the dotted string "1.3.101.112". This is a signature using an ed25519 key.

**ED448**
New in version 2.8.
Corresponds to the dotted string "1.3.101.113". This is a signature using an ed448 key.

**class cryptography.x509.oid.ExtendedKeyUsageOID**
New in version 1.0.

**SERVER_AUTH**
Corresponds to the dotted string "1.3.6.1.5.5.7.3.1". This is used to denote that a certificate may be used for TLS web server authentication.

**CLIENT_AUTH**
Corresponds to the dotted string "1.3.6.1.5.5.7.3.2". This is used to denote that a certificate may be used for TLS web client authentication.

**CODE_SIGNING**
Corresponds to the dotted string "1.3.6.1.5.5.7.3.3". This is used to denote that a certificate may be used for code signing.

**EMAIL_PROTECTION**
Corresponds to the dotted string "1.3.6.1.5.5.7.3.4". This is used to denote that a certificate may be used for email protection.

**TIME_STAMPING**
Corresponds to the dotted string "1.3.6.1.5.5.7.3.8". This is used to denote that a certificate may be used for time stamping.

**OCSP_SIGNING**
Corresponds to the dotted string "1.3.6.1.5.5.7.3.9". This is used to denote that a certificate may be used for signing OCSP responses.
**ANY_EXTENDED_KEY_USAGE**

New in version 2.0.

Corresponds to the dotted string "2.5.29.37.0". This is used to denote that a certificate may be used for _any_ purposes. However, RFC 5280 additionally notes that applications that require the presence of a particular purpose _MAY_ reject certificates that include the anyExtendedKeyUsage OID but not the particular OID expected for the application. Therefore, the presence of this OID does not mean a given application will accept the certificate for all purposes.

**SMARTCARD_LOGON**

New in version 35.0.0.

Corresponds to the dotted string "1.3.6.1.4.1.311.20.2.2". This is used to denote that a certificate may be used for PKINIT access on Windows.

**KERBEROS_PKINIT_KDC**

New in version 35.0.0.

Corresponds to the dotted string "1.3.6.1.5.2.3.5". This is used to denote that a certificate may be used as a Kerberos domain controller certificate authorizing PKINIT access. For more information see RFC 4556.

**IPSEC_IKE**

New in version 37.0.0.

Corresponds to the dotted string "1.3.6.1.5.5.7.3.17". This is used to denote that a certificate may be assigned to an IPSEC SA, and can be used by the assignee to initiate an IPSec Internet Key Exchange. For more information see RFC 4945.

**CERTIFICATE_TRANSPARENCY**

New in version 38.0.0.

Corresponds to the dotted string "1.3.6.1.4.1.11129.2.4.4". This is used to denote that a certificate may be used as a pre-certificate signing certificate for Certificate Transparency log operation purposes. For more information see RFC 6962.

**class cryptography.x509.oid.AuthorityInformationAccessOID**

New in version 1.0.

**OCSP**

Corresponds to the dotted string "1.3.6.1.5.5.7.48.1". Used as the identifier for OCSP data in AccessDescription objects.

**CA_ISSUERS**

Corresponds to the dotted string "1.3.6.1.5.5.7.48.2". Used as the identifier for CA issuer data in AccessDescription objects.

**class cryptography.x509.oid.SubjectInformationAccessOID**

New in version 3.0.

**CA_REPOSITORY**

Corresponds to the dotted string "1.3.6.1.5.5.7.48.5". Used as the identifier for CA repository data in AccessDescription objects.

**class cryptography.x509.oid.CertificatePoliciesOID**

New in version 1.0.

**CPS_QUALIFIER**

Corresponds to the dotted string "1.3.6.1.5.5.7.2.1".

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CPS_USER_NOTICE
Corresponds to the dotted string "1.3.6.1.5.5.7.2.2".

ANY_POLICY
Corresponds to the dotted string "2.5.29.32.0".

class cryptography.x509.oid.ExtensionOID
New in version 1.0.

BASIC_CONSTRAINTS
Corresponds to the dotted string "2.5.29.19". The identifier for the BasicConstraints extension type.

KEY_USAGE
Corresponds to the dotted string "2.5.29.15". The identifier for the KeyUsage extension type.

SUBJECT_ALTERNATIVE_NAME
Corresponds to the dotted string "2.5.29.17". The identifier for the SubjectAlternativeName extension type.

ISSUER_ALTERNATIVE_NAME
Corresponds to the dotted string "2.5.29.18". The identifier for the IssuerAlternativeName extension type.

SUBJECT_KEY_IDENTIFIER
Corresponds to the dotted string "2.5.29.14". The identifier for the SubjectKeyIdentifier extension type.

NAME_CONSTRAINTS
Corresponds to the dotted string "2.5.29.30". The identifier for the NameConstraints extension type.

CRL_DISTRIBUTION_POINTS
Corresponds to the dotted string "2.5.29.31". The identifier for the CRLDistributionPoints extension type.

CERTIFICATE_POLICIES
Corresponds to the dotted string "2.5.29.32". The identifier for the CertificatePolicies extension type.

EXTENSIONS
Corresponds to the dotted string "2.5.29.35". The identifier for the AuthorityKeyIdentifier extension type.

AUTHORITY_INFORMATION_ACCESS
Corresponds to the dotted string "1.3.6.1.5.5.7.1.1". The identifier for the AuthorityInformationAccess extension type.

SUBJECT_INFORMATION_ACCESS
New in version 3.0.
Corresponds to the dotted string "1.3.6.1.5.5.7.1.11". The identifier for the SubjectInformationAccess extension type.

INHIBIT_ANY_POLICY
Corresponds to the dotted string "2.5.29.54". The identifier for the InhibitAnyPolicy extension type.
Conforms to the dotted string "1.3.6.1.5.5.7.48.1.5". The identifier for the OCSPNoCheck extension type.

**TLS_FEATURE**
Corresponds to the dotted string "1.3.6.1.5.5.7.1.24". The identifier for the TLSFeature extension type.

**CRL_NUMBER**
Corresponds to the dotted string "2.5.29.20". The identifier for the CRLNumber extension type. This extension only has meaning for certificate revocation lists.

**DELTA_CRL_INDICATOR**
New in version 2.1.
Corresponds to the dotted string "2.5.29.27". The identifier for the DeltaCRLIndicator extension type. This extension only has meaning for certificate revocation lists.

**PRECERT_SIGNED_CERTIFICATE_TIMESTAMPS**
New in version 1.9.
Corresponds to the dotted string "1.3.6.1.4.1.11129.2.4.2".

**PRECERT_POISON**
New in version 2.4.
Corresponds to the dotted string "1.3.6.1.4.1.11129.2.4.3".

**SIGNED_CERTIFICATE_TIMESTAMPS**
New in version 3.0.
Corresponds to the dotted string "1.3.6.1.4.1.11129.2.4.5".

**POLICY_CONSTRAINTS**
Corresponds to the dotted string "2.5.29.36". The identifier for the PolicyConstraints extension type.

**FRESHEST_CRL**
Corresponds to the dotted string "2.5.29.46". The identifier for the FreshestCRL extension type.

**ISSUING_DISTRIBUTION_POINT**
New in version 2.4.
Corresponds to the dotted string "2.5.29.28".

**POLICY_MAPPINGS**
Corresponds to the dotted string "2.5.29.33".

**SUBJECT_DIRECTORY_ATTRIBUTES**
Corresponds to the dotted string "2.5.29.9".

**MS_CERTIFICATE_TEMPLATE**
New in version 41.0.0.
Corresponds to the dotted string "1.3.6.1.4.1.311.21.7".

**class cryptography.x509.oid.CRLEntryExtensionOID**
New in version 1.2.
CERTIFICATE_ISSUER
Corresponds to the dotted string "2.5.29.29".

CRL_REASON
Corresponds to the dotted string "2.5.29.21".

INVALIDITY_DATE
Corresponds to the dotted string "2.5.29.24".

class cryptography.x509.oid.OCSPExtensionOID
New in version 2.4.

NONCE
Corresponds to the dotted string "1.3.6.1.5.5.7.48.1.2".

ACCEPTABLE_RESPONSES
New in version 41.0.0.
Corresponds to the dotted string "1.3.6.1.5.5.7.48.1.4".

class cryptography.x509.oid.AttributeOID
New in version 3.0.

CHALLENGE_PASSWORD
Corresponds to the dotted string "1.2.840.113549.1.9.7".

UNSTRUCTURED_NAME
Corresponds to the dotted string "1.2.840.113549.1.9.2".

Helper Functions

cryptography.x509.random_serial_number()
New in version 1.6.
Generates a random serial number suitable for use when constructing certificates.

Exceptions

class cryptography.x509.InvalidVersion
This is raised when an X.509 certificate has an invalid version number.

parsed_version
Type
int
Returns the raw version that was parsed from the certificate.

class cryptography.x509.DuplicateExtension
This is raised when more than one X.509 extension of the same type is found within a certificate.

oid
Type
ObjectIdentifier
Returns the OID.
class cryptography.x509.ExtensionNotFound

This is raised when calling `Extensions.get_extension_for_oid()` with an extension OID that is not present in the certificate.

    oid

    Type
        ObjectIdentifier

    Returns the OID.

class cryptography.x509.AttributeNotFound

This is raised when calling `Attributes.get_attribute_for_oid()` with an attribute OID that is not present in the request.

    oid

    Type
        ObjectIdentifier

    Returns the OID.

class cryptography.x509.UnsupportedGeneralNameType

This is raised when a certificate contains an unsupported general name type in an extension.

    type

    Type
        int

    The integer value of the unsupported type. The complete list of types can be found in RFC 5280 section 4.2.1.6.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

### 2.3 Primitives

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.
2.3.1 Authenticated encryption

Authenticated encryption with associated data (AEAD) are encryption schemes which provide both confidentiality and integrity for their ciphertext. They also support providing integrity for associated data which is not encrypted.

class cryptography.hazmat.primitives.ciphers.aead.Chacha20Poly1305(key)

New in version 2.0.

The ChaCha20Poly1305 construction is defined in RFC 7539 section 2.8. It is a stream cipher combined with a MAC that offers strong integrity guarantees.

Parameters

- key (bytes-like) – A 32-byte key. This must be kept secret.

Raises

cryptography.exceptions.UnsupportedAlgorithm – If the version of OpenSSL does not support ChaCha20Poly1305.

>>> import os
>>> from cryptography.hazmat.primitives.ciphers.aead import ChaCha20Poly1305
>>> data = b"a secret message"
>>> aad = b"authenticated but unencrypted data"
>>> key = ChaCha20Poly1305.generate_key()
>>> chacha = ChaCha20Poly1305(key)
>>> nonce = os.urandom(12)
>>> ct = chacha.encrypt(nonce, data, aad)
>>> chacha.decrypt(nonce, ct, aad)
b'a secret message'

classmethod generate_key()

Securely generates a random ChaCha20Poly1305 key.

Returns bytes

A 32 byte key.

encrypt(nonce, data, associated_data)

Warning: Reuse of a nonce with a given key compromises the security of any message with that nonce and key pair.

Encrypts the data provided and authenticates the associated_data. The output of this can be passed directly to the decrypt method.

Parameters

- nonce (bytes-like) – A 12 byte value. NEVER REUSE A NONCE with a key.
- data (bytes-like) – The data to encrypt.
- associated_data (bytes-like) – Additional data that should be authenticated with the key, but does not need to be encrypted. Can be None.

Returns bytes

The ciphertext bytes with the 16 byte tag appended.

Raises

OverflowError – If data or associated_data is larger than $2^{31} - 1$ bytes.
decrypt\((nonce, data, associated\_data)\)

Decrypts the data and authenticates the associated\_data. If you called encrypt with associated\_data you must pass the same associated\_data in decrypt or the integrity check will fail.

Parameters

- **nonce** \((bytes-like)\) – A 12 byte value. NEVER REUSE A NONCE with a key.
- **data** \((bytes-like)\) – The data to decrypt (with tag appended).
- **associated\_data** \((bytes-like)\) – Additional data to authenticate. Can be None if none was passed during encryption.

Returns bytes

The original plaintext.

Raises

cryptography.exceptions.InvalidTag – If the authentication tag doesn’t validate this exception will be raised. This will occur when the ciphertext has been changed, but will also occur when the key, nonce, or associated data are wrong.

class cryptography.hazmat.primitives.ciphers.aead.AESGCM\((key)\)

New in version 2.0.

The AES-GCM construction is composed of the AES block cipher utilizing Galois Counter Mode (GCM).

Parameters

- **key** \((bytes-like)\) – A 128, 192, or 256-bit key. This must be kept secret.

>>> import os
>>> from cryptography.hazmat.primitives.ciphers.aead import AESGCM
>>> data = b"a secret message"
>>> aad = b"authenticated but unencrypted data"
>>> key = AESGCM.generate_key(bit_length=128)
>>> aesgcm = AESGCM(key)
>>> nonce = os.urandom(12)
>>> ct = aesgcm.encrypt(nonce, data, aad)
>>> aesgcm.decrypt(nonce, ct, aad)
b'a secret message'

classmethod generate_key\((bit\_length)\)

Securely generates a random AES-GCM key.

Parameters

- **bit\_length** – The bit length of the key to generate. Must be 128, 192, or 256.

Returns bytes

The generated key.

encrypt\((nonce, data, associated\_data)\)

Warning: Reuse of a nonce with a given key compromises the security of any message with that nonce and key pair.

Encrypts and authenticates the data provided as well as authenticating the associated\_data. The output of this can be passed directly to the decrypt method.
Parameters

- **nonce** *(bytes-like)* – NIST recommends a 96-bit IV length for best performance but it can be up to $2^{64} - 1$ bits. **NEVER REUSE A NONCE** with a key.

- **data** *(bytes-like)* – The data to encrypt.

- **associated_data** *(bytes-like)* – Additional data that should be authenticated with the key, but is not encrypted. Can be None.

**Returns** *bytes*

The ciphertext bytes with the 16 byte tag appended.

**Raises**

- **OverflowError** – If data or associated_data is larger than $2^{31} - 1$ bytes.

**decrypt**(nonce, data, associated_data)

Decrypts the data and authenticates the associated_data. If you called encrypt with associated_data you must pass the same associated_data in decrypt or the integrity check will fail.

Parameters

- **nonce** *(bytes-like)* – NIST recommends a 96-bit IV length for best performance but it can be up to $2^{64} - 1$ bits. **NEVER REUSE A NONCE** with a key.

- **data** *(bytes-like)* – The data to decrypt (with tag appended).

- **associated_data** *(bytes-like)* – Additional data to authenticate. Can be None if none was passed during encryption.

**Returns** *bytes*

The original plaintext.

**Raises**

- **cryptography.exceptions.InvalidTag** – If the authentication tag doesn’t validate this exception will be raised. This will occur when the ciphertext has been changed, but will also occur when the key, nonce, or associated data are wrong.

**class** cryptography.hazmat.primitives.ciphers.aead.AESGCMSIV(*key*)

New in version 42.0.0.

The AES-GCM-SIV construction is defined in RFC 8452 and is composed of the AES block cipher utilizing Galois Counter Mode (GCM) and a synthetic initialization vector (SIV).

Parameters

- **key** *(bytes-like)* – A 128, 192, or 256-bit key. This **must** be kept secret.

**Raises**

- **cryptography.exceptions.UnsupportedAlgorithm** – If the version of OpenSSL does not support AES-GCM-SIV.

```python
>>> import os
>>> from cryptography.hazmat.primitives.ciphers.aead import AESGCMSIV
>>> data = b"a secret message"
>>> aad = b"authenticated but unencrypted data"
>>> key = AESGCMSIV.generate_key(bit_length=128)
>>> aesgcmsiv = AESGCMSIV(key)
>>> nonce = os.urandom(12)
>>> ct = aesgcmsiv.encrypt(nonce, data, aad)
```
classmethod generate_key(bit_length)

Securely generates a random AES-GCM-SIV key.

Parameters

bit_length – The bit length of the key to generate. Must be 128, 192, or 256.

Returns bytes

The generated key.

encrypt(nonce, data, associated_data)

Encrypts and authenticates the data provided as well as authenticating the associated_data. The output of this can be passed directly to the decrypt method.

Parameters

• nonce (bytes-like) – A 12-byte value.
• data (bytes-like) – The data to encrypt.
• associated_data (bytes-like) – Additional data that should be authenticated with the key, but is not encrypted. Can be None.

Returns bytes

The ciphertext bytes with the 16 byte tag appended.

Raises

OverflowError – If data or associated_data is larger than $2^{32}$ - 1 bytes.

decrypt(nonce, data, associated_data)

Decrypts the data and authenticates the associated_data. If you called encrypt with associated_data you must pass the same associated_data in decrypt or the integrity check will fail.

Parameters

• nonce (bytes-like) – A 12-byte value.
• data (bytes-like) – The data to decrypt (with tag appended).
• associated_data (bytes-like) – Additional data to authenticate. Can be None if none was passed during encryption.

Returns bytes

The original plaintext.

Raises

cryptography.exceptions.InvalidTag – If the authentication tag doesn’t validate this exception will be raised. This will occur when the ciphertext has been changed, but will also occur when the key, nonce, or associated data are wrong.

class cryptography.hazmat.primitives.ciphers.aead.AESOCB3(key)

New in version 36.0.0.

The OCB3 construction is defined in RFC 7253. It is an AEAD mode that offers strong integrity guarantees and good performance.

Parameters

key (bytes-like) – A 128, 192, or 256-bit key. This must be kept secret.
Raises

cryptography.exceptions.UnsupportedAlgorithm – If the version of OpenSSL does not
support AES-OCB3.

```python
>>> import os
>>> from cryptography.hazmat.primitives.ciphers.aead import AESOCB3
>>> data = b"a secret message"
>>> aad = b"authenticated but unencrypted data"
>>> key = AESOCB3.generate_key(bit_length=128)
>>> aesocb = AESOCB3(key)
>>> nonce = os.urandom(12)
>>> ct = aesocb.encrypt(nonce, data, aad)
>>> aesocb.decrypt(nonce, ct, aad)
b'a secret message'
```

classmethod generate_key(bit_length)

Securely generates a random AES-OCB3 key.

Parameters

- `bit_length` – The bit length of the key to generate. Must be 128, 192, or 256.

Returns bytes

The generated key.

encrypt(nonce, data, associated_data)

Encrypts and authenticates the data provided as well as authenticating the associated_data. The output
of this can be passed directly to the decrypt method.

Parameters

- `nonce` ([bytes-like]) – A 12-15 byte value. NEVER REUSE A NONCE with a key.
- `data` ([bytes-like]) – The data to encrypt.
- `associated_data` ([bytes-like]) – Additional data that should be authenticated with the key,
  but is not encrypted. Can be None.

Returns bytes

The ciphertext bytes with the 16 byte tag appended.

Raises

OverflowError – If data or associated_data is larger than $2^{31} - 1$ bytes.

decrypt(nonce, data, associated_data)

Decrypts the data and authenticates the associated_data. If you called encrypt with
associated_data you must pass the same associated_data in decrypt or the integrity check
will fail.

Parameters

- `nonce` ([bytes-like]) – A 12 byte value. NEVER REUSE A NONCE with a key.
- `data` ([bytes-like]) – The data to decrypt (with tag appended).
• **associated_data** *(bytes-like)* – Additional data to authenticate. Can be `None` if none was passed during encryption.

**Returns** bytes
The original plaintext.

**Raises**
* `cryptography.exceptions.InvalidTag` – If the authentication tag doesn’t validate this exception will be raised. This will occur when the ciphertext has been changed, but will also occur when the key, nonce, or associated data are wrong.

```python
>>> import os
>>> from cryptography.hazmat.primitives.ciphers.aead import AESSIV
>>> data = b"a secret message"
>>> nonce = os.urandom(16)
>>> aad = [b"authenticated but unencrypted data", nonce]
>>> key = AESSIV.generate_key(bit_length=512)  # AES256 requires 512-bit keys for SIV
>>> aessiv = AESSIV(key)
>>> ct = aessiv.encrypt(data, aad)
>>> aessiv.decrypt(ct, aad)
b'a secret message'
```

**classmethod** `generate_key(bit_length)`
Securely generates a random AES-SIV key.

**Parameters**
* `bit_length` – The bit length of the key to generate. Must be 256, 384, or 512. AES-SIV splits the key into an encryption and MAC key, so these lengths correspond to AES 128, 192, and 256.

**Returns** bytes
The generated key.

**encrypt** *(data, associated_data)*

**Note:**  SIV performs nonce-based authenticated encryption when a component of the associated data is a nonce. The final associated data in the list is used for the nonce.

Random nonces should have at least 128-bits of entropy. If a nonce is reused with SIV authenticity is retained and confidentiality is only compromised to the extent that an attacker can determine that the same plaintext (and same associated data) was protected with the same nonce and key.

---

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If you do not supply a nonce encryption is deterministic and the same (plaintext, key) pair will always produce the same ciphertext.

Encrypts and authenticates the data provided as well as authenticating the associated_data. The output of this can be passed directly to the decrypt method.

Parameters

- **data** *(bytes-like)* – The data to encrypt.
- **associated_data** *(list)* – An optional list of bytes-like objects. This is additional data that should be authenticated with the key, but is not encrypted. Can be None. In SIV mode the final element of this list is treated as a nonce.

Returns **bytes**

The ciphertext bytes with the 16 byte tag appended.

Raises

- **cryptography.exceptions.UnsupportedAlgorithm** – If the version of OpenSSL does not support AES-CCM.

**decrypt**(data, associated_data)

Decrypts the data and authenticates the associated_data. If you called encrypt with associated_data you must pass the same associated_data in decrypt or the integrity check will fail.

Parameters

- **data** *(bytes)* – The data to decrypt (with tag appended).
- **associated_data** *(list)* – An optional list of bytes-like objects. This is additional data that should be authenticated with the key, but is not encrypted. Can be None if none was used during encryption.

Returns **bytes**

The original plaintext.

Raises

- **cryptography.exceptions.InvalidTag** – If the authentication tag doesn’t validate this exception will be raised. This will occur when the ciphertext has been changed, but will also occur when the key or associated data are wrong.

**class** cryptography.hazmat.primitives.ciphers.aead.AECCM(key, tag_length=16)

New in version 2.0.

The AES-CCM construction is composed of the AES block cipher utilizing Counter with CBC-MAC (CCM) (specified in RFC 3610).

Parameters

- **key** *(bytes-like)* – A 128, 192, or 256-bit key. This must be kept secret.
- **tag_length** *(int)* – The length of the authentication tag. This defaults to 16 bytes and it is strongly recommended that you do not make it shorter unless absolutely necessary. Valid tag lengths are 4, 6, 8, 10, 12, 14, and 16.

Raises

- **cryptography.exceptions.UnsupportedAlgorithm** – If the version of OpenSSL does not support AES-CCM.
```python
>>> import os
>>> from cryptography.hazmat.primitives.ciphers.aead import AESCCM

>>> data = b"a secret message"
>>> aad = b"authenticated but unencrypted data"
>>> key = AESCCM.generate_key(bit_length=128)
>>> aesccm = AESCCM(key)
>>> nonce = os.urandom(13)
>>> ct = aesccm.encrypt(nonce, data, aad)
>>> aesccm.decrypt(nonce, ct, aad)
b'a secret message'
```

classmethod `generate_key(bit_length)`

Securely generates a random AES-CCM key.

Parameters

- `bit_length` – The bit length of the key to generate. Must be 128, 192, or 256.

Returns bytes

The generated key.

`encrypt(nonce, data, associated_data)`

Warning: Reuse of a nonce with a given key compromises the security of any message with that nonce and key pair.

Encrypts and authenticates the data provided as well as authenticating the associated_data. The output of this can be passed directly to the `decrypt` method.

Parameters

- `nonce (bytes-like)` – A value of between 7 and 13 bytes. The maximum length is determined by the length of the ciphertext you are encrypting and must satisfy the condition: `len(data) < 2 ** (8 * (15 - len(nonce)))` NEVER REUSE A NONCE with a key.
- `data (bytes-like)` – The data to encrypt.
- `associated_data (bytes-like)` – Additional data that should be authenticated with the key, but is not encrypted. Can be None.

Returns bytes

The ciphertext bytes with the tag appended.

Raises

`OverflowError` – If data or associated_data is larger than $2^{31}$ - 1 bytes.

`decrypt(nonce, data, associated_data)`

Decrypts the data and authenticates the associated_data. If you called encrypt with associated_data you must pass the same associated_data in decrypt or the integrity check will fail.

Parameters

- `nonce (bytes-like)` – A value of between 7 and 13 bytes. This is the same value used when you originally called encrypt. NEVER REUSE A NONCE with a key.
- `data (bytes-like)` – The data to decrypt (with tag appended).
• **associated_data** (*bytes-like*) – Additional data to authenticate. Can be `None` if none was passed during encryption.

**Returns** `bytes`

The original plaintext.

**Raises**

`cryptography.exceptions.InvalidTag` – If the authentication tag doesn’t validate this exception will be raised. This will occur when the ciphertext has been changed, but will also occur when the key, nonce, or associated data are wrong.

---

This is a “Hazardous Materials” module. You should **ONLY** use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

### 2.3.2 Asymmetric algorithms

Asymmetric cryptography is a branch of cryptography where a secret key can be divided into two parts, a **public key** and a **private key**. The public key can be given to anyone, trusted or not, while the private key must be kept secret (just like the key in symmetric cryptography).

Asymmetric cryptography has two primary use cases: authentication and confidentiality. Using asymmetric cryptography, messages can be signed with a private key, and then anyone with the public key is able to verify that the message was created by someone possessing the corresponding private key. This can be combined with a **proof of identity** system to know what entity (person or group) actually owns that private key, providing authentication.

Encryption with asymmetric cryptography works in a slightly different way from symmetric encryption. Someone with the public key is able to encrypt a message, providing confidentiality, and then only the person in possession of the private key is able to decrypt it.

---

This is a “Hazardous Materials” module. You should **ONLY** use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

### Ed25519 signing

Ed25519 is an elliptic curve signing algorithm using EdDSA and Curve25519. If you do not have legacy interoperability concerns then you should strongly consider using this signature algorithm.

**Signing & Verification**

```python
>>> from cryptography.hazmat.primitives.asymmetric.ed25519 import Ed25519PrivateKey
>>> private_key = Ed25519PrivateKey.generate()
>>> signature = private_key.sign(b"my authenticated message")
>>> public_key = private_key.public_key()
>>> # Raises InvalidSignature if verification fails
>>> public_key.verify(signature, b"my authenticated message")
```
Key interfaces

class cryptography.hazmat.primitives.asymmetric.ed25519.Ed25519PrivateKey

New in version 2.6.

    classmethod generate()
        Generate an Ed25519 private key.

        Returns
        Ed25519PrivateKey

    classmethod from_private_bytes(data)

        Parameters
        data (bytes-like) – 32 byte private key.

        Returns
        Ed25519PrivateKey

        Raises
        • ValueError – This is raised if the private key is not 32 bytes long.
        • cryptography.exceptions.UnsupportedAlgorithm – If Ed25519 is not supported
          by the OpenSSL version cryptography is using.

>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import ed25519

>>> private_key = ed25519.Ed25519PrivateKey.generate()

>>> private_bytes = private_key.private_bytes(...
...    encoding=serialization.Encoding.Raw,
...    format=serialization.PrivateFormat.Raw,
...    encryption_algorithm=serialization.NoEncryption()...
...)

>>> loaded_private_key = ed25519.Ed25519PrivateKey.from_private_bytes(private_bytes)

public_key()

        Returns
        Ed25519PublicKey

sign(data)

        Parameters
        data (bytes) – The data to sign.

        Returns bytes
        The 64 byte signature.

private_bytes(encoding, format, encryption_algorithm)

        Allows serialization of the key to bytes. Encoding ( PEM, DER, or Raw) and
        format ( PKCS8, OpenSSH or Raw ) are chosen to define the exact serialization.

        Parameters
        • encoding – A value from the Encoding enum.
        • format – A value from the PrivateFormat enum. If the encoding is Raw then format
          must be Raw . otherwise it must be PKCS8 or OpenSSH.
• **encryption_algorithm** – An instance of an object conforming to the `KeySerializationEncryption` interface.

**Return bytes**

Serialized key.

`private_bytes_raw()`

New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling `private_bytes()` with Raw encoding, Raw format, and NoEncryption.

**Return bytes**

Raw key.

class cryptography.hazmat.primitives.asymmetric.ed25519.Ed25519PublicKey

New in version 2.6.

classmethod from_public_bytes(data)

**Parameters**

data (bytes) – 32 byte public key.

**Returns**

`Ed25519PublicKey`

**Raises**

- **ValueError** – This is raised if the public key is not 32 bytes long.

- **cryptography.exceptions.UnsupportedAlgorithm** – If Ed25519 is not supported by the OpenSSL version cryptography is using.

```python
>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import ed25519

private_key = ed25519.Ed25519PrivateKey.generate()
public_key = private_key.public_key()
public_bytes = public_key.public_bytes(
    encoding=serialization.Encoding.Raw,
    format=serialization.PublicFormat.Raw
)
loaded_public_key = ed25519.Ed25519PublicKey.from_public_bytes(public_bytes)
```

`public_bytes(encoding, format)`

Allows serialization of the key to bytes. Encoding (PEM, DER, OpenSSH, or Raw) and format (SubjectPublicKeyInfo, OpenSSH, or Raw) are chosen to define the exact serialization.

**Parameters**

- **encoding** – A value from the `Encoding` enum.

- **format** – A value from the `PublicFormat` enum. If the encoding is Raw then format must be Raw. If encoding is OpenSSH then format must be OpenSSH. In all other cases format must be SubjectPublicKeyInfo.

**Returns bytes**

The public key bytes.

`public_bytes_raw()`

New in version 40.
Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling `public_bytes()` with `Raw` encoding and `Raw` format.

**Return bytes**
Raw key.

**verify**(signature, data)

**Parameters**
- `signature` *(bytes)* – The signature to verify.
- `data` *(bytes)* – The data to verify.

**Returns**
None

**Raises**
`cryptography.exceptions.InvalidSignature` – Raised when the signature cannot be verified.

---

This is a “Hazardous Materials” module. You should **ONLY** use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

---

**X25519 key exchange**

X25519 is an elliptic curve Diffie-Hellman key exchange using Curve25519. It allows two parties to jointly agree on a shared secret using an insecure channel.

**Exchange Algorithm**

For most applications the `shared_key` should be passed to a key derivation function. This allows mixing of additional information into the key, derivation of multiple keys, and destroys any structure that may be present.

```python
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric.x25519 import X25519PrivateKey
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF

>>> # Generate a private key for use in the exchange.
>>> private_key = X25519PrivateKey.generate()

>>> # In a real handshake the peer_public_key will be received from the other party. For this example we'll generate another private key and get a public key from that. Note that in a DH handshake both peers must agree on a common set of parameters.
>>> peer_public_key = X25519PrivateKey.generate().public_key()

>>> shared_key = private_key.exchange(peer_public_key)

>>> # Perform key derivation.
>>> derived_key = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
... ).derive(shared_key)
```

(continues on next page)
For the next handshake we MUST generate another private key.

```python
>>> private_key_2 = X25519PrivateKey.generate()
>>> peer_public_key_2 = X25519PrivateKey.generate().public_key()
>>> shared_key_2 = private_key_2.exchange(peer_public_key_2)
>>> derived_key_2 = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
... ).derive(shared_key_2)
```

Key interfaces

class cryptography.hazmat.primitives.asymmetric.x25519.X25519PrivateKey

New in version 2.0.

classmethod generate()

Generate an X25519 private key.

Returns

X25519PrivateKey
classmethod from_private_bytes(data)

New in version 2.5.

A class method for loading an X25519 key encoded as Raw.

Parameters
data (bytes) – 32 byte private key.

Returns

X25519PrivateKey

```
>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import x25519
>>> private_key = x25519.X25519PrivateKey.generate()
>>> private_bytes = private_key.private_bytes(
...     encoding=serialization.Encoding.Raw,
...     format=serialization.PrivateFormat.Raw,
...     encryption_algorithm=serialization.NoEncryption()
... )
>>> loaded_private_key = x25519.X25519PrivateKey.from_private_bytes(private_bytes)
```

classmethod public_key()

Returns

X25519PublicKey
classmethod exchange(peer_public_key)

Parameters

peer_public_key (X25519PublicKey) – The public key for the peer.

Returns bytes

A shared key.
private_bytes(encoding, format, encryption_algorithm)
New in version 2.5.

Allows serialization of the key to bytes. Encoding (PEM, DER, or Raw) and format (PKCS8 or Raw) are chosen to define the exact serialization.

Parameters
- encoding – A value from the Encoding enum.
- format – A value from the PrivateFormat enum. If the encoding is Raw then format must be Raw, otherwise it must be PKCS8.
- encryption_algorithm – An instance of an object conforming to the KeySerializationEncryption interface.

Returns bytes
Serialized key.

private_bytes_raw()
New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling private_bytes() with Raw encoding, Raw format, and NoEncryption.

Returns bytes
Raw key.

class cryptography.hazmat.primitives.asymmetric.x25519.X25519PublicKey
New in version 2.0.

classmethod from_public_bytes(data)

Parameters
- data (bytes) – 32 byte public key.

Returns
X25519PublicKey

```python
>>> from cryptography.hazmat.primitives.asymmetric import x25519
>>> private_key = x25519.X25519PrivateKey.generate()
>>> public_key = private_key.public_key()
>>> public_bytes = public_key.public_bytes(...
...     encoding=serialization.Encoding.Raw,
...     format=serialization.PublicFormat.Raw
... )
>>> loaded_public_key = x25519.X25519PublicKey.from_public_bytes(public_bytes)
```

classmethod from_public_bytes(encoding, format)

Allows serialization of the key to bytes. Encoding (PEM, DER, or Raw) and format (SubjectPublicKeyInfo or Raw) are chosen to define the exact serialization.

Parameters
- encoding – A value from the Encoding enum.
- format – A value from the PublicFormat enum. If the encoding is Raw then format must be Raw, otherwise it must be SubjectPublicKeyInfo.

Returns bytes
The public key bytes.
public_bytes_raw()

New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling public_bytes() with Raw encoding and Raw format.

Return bytes

Raw key.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

Ed448 signing

Ed448 is an elliptic curve signing algorithm using EdDSA.

Signing & Verification

```python
>>> from cryptography.hazmat.primitives.asymmetric.ed448 import Ed448PrivateKey
>>> private_key = Ed448PrivateKey.generate()
>>> signature = private_key.sign(b"my authenticated message")
>>> public_key = private_key.public_key()
>>> # Raises InvalidSignature if verification fails
>>> public_key.verify(signature, b"my authenticated message")
```

Key interfaces

class cryptography.hazmat.primitives.asymmetric.ed448.Ed448PrivateKey

New in version 2.6.

classmethod generate()

Generate an Ed448 private key.

Returns

Ed448PrivateKey

classmethod from_private_bytes(data)

Parameters

data (bytes-like) – 57 byte private key.

Returns

Ed448PrivateKey

public_key()

Returns

Ed448PublicKey
**sign(data)**

Parameters

- **data (bytes)** – The data to sign.

Returns bytes

The 114 byte signature.

**private_bytes(encoding, format, encryption_algorithm)**

Allows serialization of the key to bytes. Encoding (PEM, DER, or Raw) and format (PKCS8 or Raw) are chosen to define the exact serialization.

Parameters

- **encoding** – A value from the Encoding enum.
- **format** – A value from the PrivateFormat enum. If the encoding is Raw then format must be Raw, otherwise it must be PKCS8.
- **encryption_algorithm** – An instance of an object conforming to the KeySerializationEncryption interface.

Returns bytes

Serialized key.

**private_bytes_raw()**

New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling private_bytes() with Raw encoding, Raw format, and NoEncryption.

Returns bytes

Raw key.

**class cryptography.hazmat.primitives.asymmetric.ed448.Ed448PublicKey**

New in version 2.6.

**classmethod from_public_bytes(data)**

Parameters

- **data (bytes)** – 57 byte public key.

Returns

Ed448PublicKey

**public_bytes(encoding, format)**

Allows serialization of the key to bytes. Encoding (PEM, DER, or Raw) and format (SubjectPublicKeyInfo or Raw) are chosen to define the exact serialization.

Parameters

- **encoding** – A value from the Encoding enum.
- **format** – A value from the PublicFormat enum. If the encoding is Raw then format must be Raw, otherwise it must be SubjectPublicKeyInfo.

Returns bytes

The public key bytes.

**public_bytes_raw()**

New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling public_bytes() with Raw encoding and Raw format.
Return bytes
Raw key.

\texttt{verify(signature, data)}

Parameters

- \texttt{signature (bytes)} – The signature to verify.
- \texttt{data (bytes)} – The data to verify.

Returns
None

Raises
\texttt{cryptography.exceptions.InvalidSignature} – Raised when the signature cannot be verified.

This is a “Hazardous Materials” module. You should \textbf{ONLY} use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

\section*{X448 key exchange}

X448 is an elliptic curve \textit{Diffie-Hellman key exchange} using \texttt{Curve448}. It allows two parties to jointly agree on a shared secret using an insecure channel.

\subsection*{Exchange Algorithm}

For most applications the \texttt{shared_key} should be passed to a key derivation function. This allows mixing of additional information into the key, derivation of multiple keys, and destroys any structure that may be present.

\begin{verbatim}
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric.x448 import X448PrivateKey
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF

>>> # Generate a private key for use in the exchange.
>>> private_key = X448PrivateKey.generate()

>>> # In a real handshake the peer_public_key will be received from the other party. For this example we'll generate another private key and get a public key from that. Note that in a DH handshake both peers must agree on a common set of parameters.
>>> peer_public_key = X448PrivateKey.generate().public_key()

>>> shared_key = private_key.exchange(peer_public_key)

>>> # Perform key derivation.
>>> derived_key = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
... ).derive(shared_key)

>>> # For the next handshake we MUST generate another private key.
>>> private_key_2 = X448PrivateKey.generate()
\end{verbatim}

(continues on next page)
peer_public_key_2 = X448PrivateKey.generate().public_key()
shared_key_2 = private_key_2.exchange(peer_public_key_2)
derived_key_2 = HKDF(
    algorithm=hashes.SHA256(),
    length=32,
    salt=None,
    info=b'handshake data',
).derive(shared_key_2)

Key interfaces

class cryptography.hazmat.primitives.asymmetric.x448.X448PrivateKey
New in version 2.5.
classmethod generate()
    Generate an X448 private key.
    Returns
        X448PrivateKey
classmethod from_private_bytes(data)
    Parameters
        data (bytes-like) -- 56 byte private key.
    Returns
        X448PrivateKey

from cryptography.hazmat.primitives import serialization
from cryptography.hazmat.primitives.asymmetric import x448

private_key = x448.X448PrivateKey.generate()
private_bytes = private_key.private_bytes(
    encoding=serialization.Encoding.Raw,
    format=serialization.PrivateFormat.Raw,
    encryption_algorithm=serialization.NoEncryption()
)
loaded_private_key = x448.X448PrivateKey.from_private_bytes(private_bytes)

public_key()
    Returns
        X448PublicKey
exchange(peer_public_key)
    Parameters
        peer_public_key (X448PublicKey) -- The public key for the peer.
    Returns
        bytes
        A shared key.
private_bytes(encoding, format, encryption_algorithm)
    Allows serialization of the key to bytes. Encoding ( PEM, DER, or Raw) and format ( PKCS8 or Raw ) are chosen to define the exact serialization.
    Parameters
• **encoding** – A value from the `Encoding` enum.

• **format** – A value from the `PrivateFormat` enum. If the encoding is `Raw` then format must be `Raw`, otherwise it must be `PKCS8`.

• **encryption_algorithm** – An instance of an object conforming to the `KeySerializationEncryption` interface.

    **Return bytes**

    Serialized key.

**private_bytes_raw()**

New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling `private_bytes()` with `Raw` encoding, `Raw` format, and `NoEncryption`.

    **Return bytes**

    Raw key.

class cryptography.hazmat.primitives.asymmetric.x448.X448PublicKey

New in version 2.5.

**classmethod from_public_bytes(data)**

    **Parameters**

    - **data (bytes)** – 56 byte public key.

    **Returns**

    `X448PublicKey`

```python
>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import x448

>>> private_key = x448.X448PrivateKey.generate()

>>> public_key = private_key.public_key()

>>> public_bytes = public_key.public_bytes(...
...    encoding=serialization.Encoding.Raw,
...    format=serialization.PublicFormat.Raw
...)

>>> loaded_public_key = x448.X448PublicKey.from_public_bytes(public_bytes)
```

**public_bytes(encoding, format)**

Allows serialization of the key to bytes. Encoding ( `PEM`, `DER`, or `Raw`) and format ( `SubjectPublicKeyInfo` or `Raw`) are chosen to define the exact serialization.

    **Parameters**

    - **encoding** – A value from the `Encoding` enum.

    - **format** – A value from the `PublicFormat` enum. If the encoding is `Raw` then format must be `Raw`, otherwise it must be `SubjectPublicKeyInfo`.

    **Returns bytes**

    The public key bytes.

**public_bytes_raw()**

New in version 40.

Allows serialization of the key to raw bytes. This method is a convenience shortcut for calling `public_bytes()` with `Raw` encoding and `Raw` format.
This is a “Hazardous Materials” module. You should **ONLY** use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

## Elliptic curve cryptography

cryptography.hazmat.primitives.asymmetric.ec.generate_private_key(curve)

New in version 0.5.

Generate a new private key on curve.

**Parameters**

- **curve** – An instance of `EllipticCurve`.

**Returns**

A new instance of `EllipticCurvePrivateKey`.

cryptography.hazmat.primitives.asymmetric.ec.derive_private_key(private_value, curve)

New in version 1.6.

Derive a private key from private_value on curve.

**Parameters**

- **private_value** (int) – The secret scalar value.
- **curve** – An instance of `EllipticCurve`.

**Returns**

A new instance of `EllipticCurvePrivateKey`.

## Elliptic Curve Signature Algorithms

class cryptography.hazmat.primitives.asymmetric.ec.ECDSA(algorithm)

New in version 0.5.

The ECDSA signature algorithm first standardized in NIST publication FIPS 186-3, and later in FIPS 186-4.

Note that while elliptic curve keys can be used for both signing and key exchange, this is bad cryptographic practice. Instead, users should generate separate signing and ECDH keys.

**Parameters**

- **algorithm** – An instance of `HashAlgorithm`.

```python
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import ec
>>> private_key = ec.generate_private_key(ec.SECP384R1())
... data = b"this is some data I'd like to sign"
>>> signature = private_key.sign(data,
...                            ec.SECP384R1())
```
The signature is a bytes object, whose contents are DER encoded as described in RFC 3279. This can be decoded using `decode_dss_signature()`.

If your data is too large to be passed in a single call, you can hash it separately and pass that value using `Prehashed`.

```python
from cryptography.hazmat.primitives.asymmetric import utils

chosen_hash = hashes.SHA256()
hasher = hashes.Hash(chosen_hash)
hasher.update(b"data & ")
hasher.update(b"more data")
digest = hasher.finalize()
sig = private_key.sign(
    ... digest,
    ... ec.ECDSA(utils.Prehashed(chosen_hash))
)
```

Verification requires the public key, the DER-encoded signature itself, the signed data, and knowledge of the hashing algorithm that was used when producing the signature:

```python
public_key = private_key.public_key()
public_key.verify(signature, data, ec.ECDSA(hashes.SHA256()))
```

As above, the signature is a bytes object whose contents are DER encoded as described in RFC 3279. It can be created from a raw (r,s) pair by using `encode_dss_signature()`.

If the signature is not valid, an `InvalidSignature` exception will be raised.

If your data is too large to be passed in a single call, you can hash it separately and pass that value using `Prehashed`.

```python
chosen_hash = hashes.SHA256()
hasher = hashes.Hash(chosen_hash)
hasher.update(b"data & ")
hasher.update(b"more data")
digest = hasher.finalize()
public_key.verify(
    ... sig,
    ... digest,
    ... ec.ECDSA(utils.Prehashed(chosen_hash))
)
```

**Note:** Although in this case the public key was derived from the private one, in a typical setting you will not possess the private key. The `Key loading` section explains how to load the public key from other sources.
public_numbers

    Type
    EllipticCurvePublicNumbers

    The EllipticCurvePublicNumbers which makes up the EC public key associated with this EC private
    key.

private_value

    Type
    int

    The private value.

private_key()

    Convert a collection of numbers into a private key suitable for doing actual cryptographic operations.

    Returns
    A new instance of EllipticCurvePrivateKey.

class cryptography.hazmat.primitives.asymmetric.ec.EllipticCurvePublicNumbers(x, y, curve)

    Warning: The point represented by this object is not validated in any way until
    EllipticCurvePublicNumbers.public_key() is called and may not represent a valid point on
    the curve. You should not attempt to perform any computations using the values from this class until you
    have either validated it yourself or called public_key() successfully.

New in version 0.5.

The collection of integers that make up an EC public key.

curve

    Type
    EllipticCurve

    The elliptic curve for this key.

x

    Type
    int

    The affine x component of the public point used for verifying.

y

    Type
    int

    The affine y component of the public point used for verifying.

public_key()

    Convert a collection of numbers into a public key suitable for doing actual cryptographic operations.

    Raises
    ValueError – Raised if the point is invalid for the curve.

    Returns
    A new instance of EllipticCurvePublicKey.
classmethod from_encoded_point(curve, data)

New in version 1.1.

Note: This has been deprecated in favor of from_encoded_point().

Decodes a byte string as described in SEC 1 v2.0 section 2.3.3 and returns an EllipticCurvePublicNumbers. This method only supports uncompressed points.

Parameters

- curve – An EllipticCurve instance.
- data (bytes) – The serialized point byte string.

Returns

An EllipticCurvePublicNumbers instance.

Raises

- ValueError – Raised on invalid point type or data length.
- TypeError – Raised when curve is not an EllipticCurve.

Elliptic Curve Key Exchange algorithm

class cryptography.hazmat.primitives.asymmetric.ec.ECDH

New in version 1.1.

The Elliptic Curve Diffie-Hellman Key Exchange algorithm standardized in NIST publication 800-56A.

For most applications the shared_key should be passed to a key derivation function. This allows mixing of additional information into the key, derivation of multiple keys, and destroys any structure that may be present.

Note that while elliptic curve keys can be used for both signing and key exchange, this is bad cryptographic practice. Instead, users should generate separate signing and ECDH keys.

Warning: This example does not give forward secrecy and is only provided as a demonstration of the basic Diffie-Hellman construction. For real world applications always use the ephemeral form described after this example.

```python
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import ec
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF

# Generate a private key for use in the exchange.
>>> server_private_key = ec.generate_private_key(...
...     ec.SECP384R1())
...

# In a real handshake the peer is a remote client. For this example we'll generate another local private key though.
>>> peer_private_key = ec.generate_private_key(...
...     ec.SECP384R1())
...

>>> shared_key = server_private_key.exchange(...
...     ec.ECDH(), peer_private_key.public_key())

(continues on next page)```
# Perform key derivation.

```
>>> derived_key = HKDF(
...    algorithm=hashes.SHA256(),
...    length=32,
...    salt=None,
...    info=b'handshake data',
...    ).derive(shared_key)
``` 

And now we can demonstrate that the handshake performed in the opposite direction gives the same final value.

```
>>> same_shared_key = peer_private_key.exchange(
...    ec.ECDH(), server_private_key.public_key())
``` 

# Perform key derivation.

```
>>> same_derived_key = HKDF(
...    algorithm=hashes.SHA256(),
...    length=32,
...    salt=None,
...    info=b'handshake data',
...    ).derive(same_shared_key)
``` 

```
>>> derived_key == same_derived_key
True
```

ECDHE (or EEC DH), the ephemeral form of this exchange, is strongly preferred over simple ECDH and provides forward secrecy when used. You must generate a new private key using `generate_private_key()` for each `exchange()` when performing an ECDHE key exchange. An example of the ephemeral form:

```
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import ec
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF

>>> # Generate a private key for use in the exchange.
>>> private_key = ec.generate_private_key(
...     ec.SECP384R1()
...     )

>>> # In a real handshake the peer_public_key will be received from the other party. For this example we'll generate another private key and get a public key from that.
>>> peer_public_key = ec.generate_private_key(
...     ec.SECP384R1()
...     ).public_key()

>>> shared_key = private_key.exchange(ec.ECDH(), peer_public_key)

>>> # Perform key derivation.
>>> derived_key = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
...     ).derive(shared_key)

>>> # For the next handshake we MUST generate another private key.
>>> private_key_2 = ec.generate_private_key(
...     ec.SECP384R1()
...     )

>>> peer_public_key_2 = ec.generate_private_key(
...     ec.SECP384R1()
...     )
```
Elliptic Curves

Elliptic curves provide equivalent security at much smaller key sizes than other asymmetric cryptography systems such as RSA or DSA. For many operations elliptic curves are also significantly faster; elliptic curve diffie-hellman is faster than diffie-hellman.

Note: Curves with a size of less than 224 bits should not be used. You should strongly consider using curves of at least 224 bits.

Generally the NIST prime field (“P”) curves are significantly faster than the other types suggested by NIST at both signing and verifying with ECDSA.

Prime fields also minimize the number of security concerns for elliptic-curve cryptography. However, there is some concern that both the prime field and binary field (“B”) NIST curves may have been weakened during their generation.

Currently cryptography only supports NIST curves, none of which are considered “safe” by the SafeCurves project run by Daniel J. Bernstein and Tanja Lange.

All named curves are instances of EllipticCurve.

class cryptography.hazmat.primitives.asymmetric.ec.SECP256R1
  New in version 0.5.
  SECG curve secp256r1. Also called NIST P-256.

class cryptography.hazmat.primitives.asymmetric.ec.SECP384R1
  New in version 0.5.
  SECG curve secp384r1. Also called NIST P-384.

class cryptography.hazmat.primitives.asymmetric.ec.SECP521R1
  New in version 0.5.
  SECG curve secp521r1. Also called NIST P-521.

class cryptography.hazmat.primitives.asymmetric.ec.SECP224R1
  New in version 0.5.
  SECG curve secp224r1. Also called NIST P-224.

class cryptography.hazmat.primitives.asymmetric.ec.SECP192R1
  New in version 0.5.
  SECG curve secp192r1. Also called NIST P-192.
class cryptography.hazmat.primitives.asymmetric.ec.SECP256K1
    New in version 0.9.
    SECG curve secp256k1.

class cryptography.hazmat.primitives.asymmetric.ec.BrainpoolP256R1
    New in version 2.2.
    Brainpool curve specified in RFC 5639. These curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.BrainpoolP384R1
    New in version 2.2.
    Brainpool curve specified in RFC 5639. These curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.BrainpoolP512R1
    New in version 2.2.
    Brainpool curve specified in RFC 5639. These curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT571K1
    New in version 0.5.
    SECG curve sect571k1. Also called NIST K-571. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT409K1
    New in version 0.5.
    SECG curve sect409k1. Also called NIST K-409. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT283K1
    New in version 0.5.
    SECG curve sect283k1. Also called NIST K-283. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT233K1
    New in version 0.5.
    SECG curve sect233k1. Also called NIST K-233. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT163K1
    New in version 0.5.
    SECG curve sect163k1. Also called NIST K-163. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT571R1
    New in version 0.5.
    SECG curve sect571r1. Also called NIST B-571. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT409R1
    New in version 0.5.
    SECG curve sect409r1. Also called NIST B-409. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT283R1
    New in version 0.5.
    SECG curve sect283r1. Also called NIST B-283. These binary curves are discouraged for new systems.
class cryptography.hazmat.primitives.asymmetric.ec.SECT233R1
    New in version 0.5.
    SECG curve sect233r1. Also called NIST B-233. These binary curves are discouraged for new systems.

class cryptography.hazmat.primitives.asymmetric.ec.SECT163R2
    New in version 0.5.
    SECG curve sect163r2. Also called NIST B-163. These binary curves are discouraged for new systems.

**Key Interfaces**

class cryptography.hazmat.primitives.asymmetric.ec.EllipticCurve
    New in version 0.5.
    A named elliptic curve.

    name
        Type
        str
        The name of the curve. Usually the name used for the ASN.1 OID such as secp256k1.

    key_size
        Type
        int
        Size (in bits) of a secret scalar for the curve (as generated by generate_private_key()).

class cryptography.hazmat.primitives.asymmetric.ec.EllipticCurveSignatureAlgorithm
    New in version 0.5.
    Changed in version 1.6: Prehashed can now be used as an algorithm.
    A signature algorithm for use with elliptic curve keys.

    algorithm
        Type
        HashAlgorithm or Prehashed
        The digest algorithm to be used with the signature scheme.

class cryptography.hazmat.primitives.asymmetric.ec.EllipticCurvePrivateKey
    New in version 0.5.
    An elliptic curve private key for use with an algorithm such as ECDSA.

    exchange(algorithm, peer_public_key)
        New in version 1.1.
        Performs a key exchange operation using the provided algorithm with the peer’s public key.
        For most applications the shared_key should be passed to a key derivation function. This allows mixing
        of additional information into the key, derivation of multiple keys, and destroys any structure that may be
        present.

        Parameters
            * algorithm – The key exchange algorithm, currently only ECDH is supported.
• **peer_public_key** *(EllipticCurvePublicKey)* – The public key for the peer.

Returns **bytes**

A shared key.

**public_key()**

Returns

*EllipticCurvePublicKey*

The EllipticCurvePublicKey object for this private key.

**sign(data, signature_algorithm)**

New in version 1.5.

Sign one block of data which can be verified later by others using the public key.

Parameters

• **data (bytes)** – The message string to sign.

• **signature_algorithm** – An instance of *EllipticCurveSignatureAlgorithm*, such as *ECDSA*.

Returns **bytes**

The signature as a bytes object, whose contents are DER encoded as described in RFC 3279. This can be decoded using *decode_dss_signature()*, which returns the decoded tuple *(r, s)*.

**curve**

Type

*EllipticCurve*

The EllipticCurve that this key is on.

**key_size**

New in version 1.9.

Type

int

Size (in bits) of a secret scalar for the curve (as generated by *generate_private_key()*).

**private_numbers()**

Create a *EllipticCurvePrivateNumbers* object.

Returns

An *EllipticCurvePrivateNumbers* instance.

**private_bytes(encoding, format, encryption_algorithm)**

Allows serialization of the key to bytes. Encoding (PEM or DER), format (TraditionalOpenSSL, OpenSSH or PKCS8) and encryption algorithm (such as BestAvailableEncryption or NoEncryption) are chosen to define the exact serialization.

Parameters

• **encoding** – A value from the *Encoding* enum.

• **format** – A value from the *PrivateFormat* enum.

• **encryption_algorithm** – An instance of an object conforming to the *KeySerializationEncryption* interface.
Return bytes
Serialized key.

class cryptography.hazmat.primitives.asymmetric.ec.EllipticCurvePublicKey
New in version 0.5.
An elliptic curve public key.

curve
Type
EllipticCurve
The elliptic curve for this key.

public_numbers()
Create a EllipticCurvePublicNumbers object.

Returns
An EllipticCurvePublicNumbers instance.

public_bytes(encoding, format)
Allows serialization of the key data to bytes. When encoding the public key the encodings (PEM, DER) and format (SubjectPublicKeyInfo) are chosen to define the exact serialization. When encoding the point the encoding X962 should be used with the formats (UncompressedPoint or CompressedPoint).

Parameters
• encoding – A value from the Encoding enum.
• format – A value from the PublicFormat enum.

Returns
bytes
Serialized data.

verify(signature, data, signature_algorithm)
New in version 1.5.
Verify one block of data was signed by the private key associated with this public key.

Parameters
• signature (bytes) – The DER-encoded signature to verify. A raw signature may be DER-encoded by splitting it into the r and s components and passing them into encode_dss_signature().
• data (bytes) – The message string that was signed.
• signature_algorithm – An instance of EllipticCurveSignatureAlgorithm.

Returns
None

Raises

cryptography.exceptions.InvalidSignature – If the signature does not validate.

key_size
New in version 1.9.

Type
int
Size (in bits) of a secret scalar for the curve (as generated by generate_private_key()).
classmethod from_encoded_point(curve, data)

New in version 2.5.

Decodes a byte string as described in SEC 1 v2.0 section 2.3.3 and returns an EllipticCurvePublicKey. This class method supports compressed points.

Parameters

• curve – An EllipticCurve instance.
• data (bytes) – The serialized point byte string.

Returns

An EllipticCurvePublicKey instance.

 Raises

• ValueError – Raised when an invalid point is supplied.
• TypeError – Raised when curve is not an EllipticCurve.

Serialization

This sample demonstrates how to generate a private key and serialize it.

```python
>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import ec

>>> private_key = ec.generate_private_key(ec.SECP384R1())

>>> serialized_private = private_key.private_bytes(...
    encoding=serialization.Encoding.PEM,
    format=serialization.PrivateFormat.PKCS8,
    encryption_algorithm=serialization.BestAvailableEncryption(b'testpassword')

>>> serialized_private.splitlines()[0]
b'-----BEGIN ENCRYPTED PRIVATE KEY-----'
```

You can also serialize the key without a password, by relying on NoEncryption.

The public key is serialized as follows:

```python
>>> public_key = private_key.public_key()

>>> serialized_public = public_key.public_bytes(...
    encoding=serialization.Encoding.PEM,
    format=serialization.PublicFormat.SubjectPublicKeyInfo)

>>> serialized_public.splitlines()[0]
b'-----BEGIN PUBLIC KEY-----'
```

This is the part that you would normally share with the rest of the world.
**Key loading**

This extends the sample in the previous section, assuming that the variables `serialized_private` and `serialized_public` contain the respective keys in PEM format.

```python
>>> loaded_public_key = serialization.load_pem_public_key(...
    serialized_public,
    ...
)
```

```python
>>> loaded_private_key = serialization.load_pem_private_key(...
    serialized_private,
    ...
    # or password=None, if in plain text
    ...
    password=b'testpassword',
    ...
)
```

**Elliptic Curve Object Identifiers**

class cryptography.hazmat.primitives.asymmetric.ec.EllipticCurveOID

New in version 2.4.

**SECP192R1**

Corresponds to the dotted string "1.2.840.10045.3.1.1".

**SECP224R1**

Corresponds to the dotted string "1.3.132.0.33".

**SECP256K1**

Corresponds to the dotted string "1.3.132.0.10".

**SECP256R1**

Corresponds to the dotted string "1.2.840.10045.3.1.7".

**SECP384R1**

Corresponds to the dotted string "1.3.132.0.34".

**SECP521R1**

Corresponds to the dotted string "1.3.132.0.35".

**BRAINPOOLP256R1**

New in version 2.5.

Corresponds to the dotted string "1.3.36.3.3.2.8.1.1.7".

**BRAINPOOLP384R1**

New in version 2.5.

Corresponds to the dotted string "1.3.36.3.3.2.8.1.1.11".

**BRAINPOOLP512R1**

New in version 2.5.

Corresponds to the dotted string "1.3.36.3.3.2.8.1.1.13".

**SECT163K1**

New in version 2.5.

Corresponds to the dotted string "1.3.132.0.1".

SECT163R2
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.15".

SECT233K1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.26".

SECT233R1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.27".

SECT283K1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.16".

SECT283R1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.17".

SECT409K1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.36".

SECT409R1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.37".

SECT571K1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.38".

SECT571R1
New in version 2.5.
Corresponds to the dotted string "1.3.132.0.39".

cryptography.hazmat.primitives.asymmetric.ec.get_curve_for_oid(oid)
New in version 2.6.
A function that takes an ObjectIdentifier and returns the associated elliptic curve class.

Parameters
oid – An instance of ObjectIdentifier.

Returns
The matching elliptic curve class. The returned class conforms to the EllipticCurve interface.

Raises
LookupError – Raised if no elliptic curve is found that matches the provided object identifier.
This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

RSA

RSA is a public-key algorithm for encrypting and signing messages.

Generation

Unlike symmetric cryptography, where the key is typically just a random series of bytes, RSA keys have a complex internal structure with specific mathematical properties.

cryptography.hazmat.primitives.asymmetric.rsa.generate_private_key(public_exponent, key_size)

New in version 0.5.

Changed in version 3.0: Tightened restrictions on public_exponent.

Generates a new RSA private key. key_size describes how many bits long the key should be. Larger keys provide more security; currently 1024 and below are considered breakable while 2048 or 4096 are reasonable default key sizes for new keys. The public_exponent indicates what one mathematical property of the key generation will be. Unless you have a specific reason to do otherwise, you should always use 65537.

```python
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> private_key = rsa.generate_private_key(...
    public_exponent=65537,
    key_size=2048,
    ...)
```

Parameters

- `public_exponent (int)` – The public exponent of the new key. Either 65537 or 3 (for legacy purposes). Almost everyone should use 65537.

- `key_size (int)` – The length of the modulus in bits. For keys generated in 2015 it is strongly recommended to be at least 2048 (See page 41). It must not be less than 512.

Returns

An instance of `RSA_private_key`.

Key loading

If you already have an on-disk key in the PEM format (which are recognizable by the distinctive -----BEGIN {format}----- and -----END {format}----- markers), you can load it:

```python
>>> from cryptography.hazmat.primitives import serialization
>>> with open("path/to/key.pem", "rb") as key_file:
    ...     private_key = serialization.load_pem_private_key(...
        key_file.read(),
        ...     password=None,
        ...)
```
Serialized keys may optionally be encrypted on disk using a password. In this example we loaded an unencrypted key, and therefore we did not provide a password. If the key is encrypted we can pass a bytes object as the password argument.

There is also support for loading public keys in the SSH format.

### Key serialization

If you have a private key that you’ve loaded you can use `private_bytes()` to serialize the key.

```python
>>> from cryptography.hazmat.primitives import serialization
>>> pem = private_key.private_bytes(
...   encoding=serialization.Encoding.PEM,
...   format=serialization.PrivateFormat.PKCS8,
...   encryption_algorithm=serialization.BestAvailableEncryption(b'mypassword')
... )
>>> pem.splitlines()[0]
b'-----BEGIN ENCRYPTED PRIVATE KEY-----'
```

It is also possible to serialize without encryption using `NoEncryption`.

```python
>>> pem = private_key.private_bytes(
...   encoding=serialization.Encoding.PEM,
...   format=serialization.PrivateFormat.TraditionalOpenSSL,
...   encryption_algorithm=serialization.NoEncryption()
... )
>>> pem.splitlines()[0]
b'-----BEGIN RSA PRIVATE KEY-----'
```

For public keys you can use `public_bytes()` to serialize the key.

```python
>>> from cryptography.hazmat.primitives import serialization
>>> public_key = private_key.public_key()
>>> pem = public_key.public_bytes(
...   encoding=serialization.Encoding.PEM,
...   format=serialization.PublicFormat.SubjectPublicKeyInfo
... )
>>> pem.splitlines()[0]
b'-----BEGIN PUBLIC KEY-----'
```

### Signing

A private key can be used to sign a message. This allows anyone with the public key to verify that the message was created by someone who possesses the corresponding private key. RSA signatures require a specific hash function, and padding to be used. Here is an example of signing message using RSA, with a secure hash function and padding:

```python
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import padding
>>> message = b"A message I want to sign"
>>> signature = private_key.sign(
...   message,
...   padding.PSS()
```

(continues on next page)
Valid paddings for signatures are `PSS` and `PKCS1v15`. `PSS` is the recommended choice for any new protocols or applications. `PKCS1v15` should only be used to support legacy protocols.

If your data is too large to be passed in a single call, you can hash it separately and pass that value using `Prehashed`.

```python
>>> from cryptography.hazmat.primitives.asymmetric import utils
tools
>>> chosen_hash = hashes.SHA256()
>>> hasher = hashes.Hash(chosen_hash)
>>> hasher.update(b"data & ")
>>> hasher.update(b"more data")
>>> digest = hasher.finalize()
>>> sig = private_key.sign(
...    digest,
...    padding.PSS(
...        mgf=padding.MGF1(hashes.SHA256()),
...        salt_length=padding.PSS.MAX_LENGTH
...    ),
...    utils.Prehashed(chosen_hash)
...)
```

### Verification

The previous section describes what to do if you have a private key and want to sign something. If you have a public key, a message, a signature, and the signing algorithm that was used you can check that the private key associated with a given public key was used to sign that specific message. You can obtain a public key to use in verification using `load_pem_public_key()`, `load_der_public_key()`, `public_key()`, or `public_key()`.

```python
>>> public_key = private_key.public_key()
>>> public_key.verify(
...    signature,
...    message,
...    padding.PSS(
...        mgf=padding.MGF1(hashes.SHA256()),
...        salt_length=padding.PSS.MAX_LENGTH
...    ),
...    hashes.SHA256()
...)
```

If the signature does not match, `verify()` will raise an `InvalidSignature` exception.

If your data is too large to be passed in a single call, you can hash it separately and pass that value using `Prehashed`.

```python
>>> chosen_hash = hashes.SHA256()
>>> hasher = hashes.Hash(chosen_hash)
>>> hasher.update(b"data & ")
>>> hasher.update(b"more data")
```
Encryption

RSA encryption is interesting because encryption is performed using the public key, meaning anyone can encrypt data. The data is then decrypted using the private key.

Like signatures, RSA supports encryption with several different padding options. Here’s an example using a secure padding and hash function:

```python
>>> message = b"encrypted data"
>>> ciphertext = public_key.encrypt(
...     message,
...     padding.OAEP(
...         mgf=padding.MGF1(algorithm=hashes.SHA256()),
...         algorithm=hashes.SHA256(),
...         label=None
...     )
... )
```

Valid paddings for encryption are **OAEP** and **PKCS1v15**. OAEP is the recommended choice for any new protocols or applications, PKCS1v15 should only be used to support legacy protocols.

Decryption

Once you have an encrypted message, it can be decrypted using the private key:

```python
>>> plaintext = private_key.decrypt(
...     ciphertext,
...     padding.OAEP(
...         mgf=padding.MGF1(algorithm=hashes.SHA256()),
...         algorithm=hashes.SHA256(),
...         label=None
...     )
... )
>>> plaintext == message
True
```
# Padding

class cryptography.hazmat.primitives.asymmetric.padding.AsymmetricPadding

New in version 0.2.

```python
class cryptography.hazmat.primitives.asymmetric.padding.PSS(mgf, salt_length)
```

New in version 0.3.

Changed in version 0.4: Added `salt_length` parameter.

PSS (Probabilistic Signature Scheme) is a signature scheme defined in RFC 3447. It is more complex than PKCS1 but possesses a security proof. This is the recommended padding algorithm for RSA signatures. It cannot be used with RSA encryption.

**Parameters**

- `mgf` – A mask generation function object. At this time the only supported MGF is `MGF1`.
- `salt_length` (`int`) – The length of the salt. It is recommended that this be set to PSS. `DIGEST_LENGTH` or `PSS.MAX_LENGTH`.

**MAX_LENGTH**

Pass this attribute to `salt_length` to get the maximum salt length available.

**DIGEST_LENGTH**

New in version 37.0.0.

Pass this attribute to `salt_length` to set the salt length to the byte length of the digest passed when calling `sign`. Note that this is not the length of the digest passed to `MGF1`.

**AUTO**

New in version 37.0.0.

Pass this attribute to `salt_length` to automatically determine the salt length when verifying. Raises `ValueError` if used when signing.

**mgf**

Type

`MGF`

New in version 42.0.0.

The padding’s mask generation function (MGF).

class cryptography.hazmat.primitives.asymmetric.padding.OAEP(mgf, algorithm, label)

New in version 4.0.

OAEP (Optimal Asymmetric Encryption Padding) is a padding scheme defined in RFC 3447. It provides probabilistic encryption and is proven secure against several attack types. This is the recommended padding algorithm for RSA encryption. It cannot be used with RSA signing.

**Parameters**

- `mgf` – A mask generation function object. At this time the only supported MGF is `MGF1`.
- `algorithm` – An instance of `HashAlgorithm`.
- `label` (`bytes`) – A label to apply. This is a rarely used field and should typically be set to `None` or `b""`, which are equivalent.
algorithm

Type
HashAlgorithm

New in version 42.0.0.
The padding’s hash algorithm.

mgf

Type
MGF

New in version 42.0.0.
The padding’s mask generation function (MGF).

class cryptography.hazmat.primitives.asymmetric.padding.PKCS1v15

New in version 0.3.
PKCS1 v1.5 (also known as simply PKCS1) is a simple padding scheme developed for use with RSA keys. It is defined in RFC 3447. This padding can be used for signing and encryption.

It is not recommended that PKCS1v15 be used for new applications. **OAEP** should be preferred for encryption and **PSS** should be preferred for signatures.

| Warning: | Our implementation of PKCS1 v1.5 decryption is not constant time. See Known security limitations for details. |

cryptography.hazmat.primitives.asymmetric.padding.calculate_max_pss_salt_length(key, hash_algorithm)

New in version 1.5.

Parameters

- **key** – An RSA public or private key.
- **hash_algorithm** – A cryptography.hazmat.primitives.hashes.HashAlgorithm.

Returns int

The computed salt length.

Computes the length of the salt that **PSS** will use if **PSS.MAX_LENGTH** is used.

Mask generation functions

class cryptography.hazmat.primitives.asymmetric.padding.MGF

New in version 37.0.0.

class cryptography.hazmat.primitives.asymmetric.padding.MGF1(algorithm)

New in version 0.3.

Changed in version 0.6: Removed the deprecated salt_length parameter.

MGF1 (Mask Generation Function 1) is used as the mask generation function in **PSS** and **OAEP** padding. It takes a hash algorithm.

Parameters

- **algorithm** – An instance of **HashAlgorithm**.

2.3. Primitives
**Numbers**

These classes hold the constituent components of an RSA key. They are useful only when more traditional Key Serialization is unavailable.

```python
class cryptography.hazmat.primitives.asymmetric.rsa.RSAPublicNumbers(e, n)
    New in version 0.5.
    The collection of integers that make up an RSA public key.
    n
        Type
        int
        The public modulus.
    e
        Type
        int
        The public exponent.

class cryptography.hazmat.primitives.asymmetric.rsa.RSAPrivateNumbers(p, q, d, dmp1, dmq1, iqmp, public_numbers)
    New in version 0.5.
    The collection of integers that make up an RSA private key.

    Warning: With the exception of the integers contained in the RSAPublicNumbers all attributes of this class must be kept secret. Revealing them will compromise the security of any cryptographic operations performed with a key loaded from them.
```

```python
class RSAPublicNumbers
    The RSAPublicNumbers which makes up the RSA public key associated with this RSA private key.
    p
        Type
        int
        p, one of the two primes composing n.
    q
        Type
        int
        q, one of the two primes composing n.
```
d

Type
 int

The private exponent.

dmp1

Type
 int

A Chinese remainder theorem coefficient used to speed up RSA operations. Calculated as: d mod (p-1)

dmq1

Type
 int

A Chinese remainder theorem coefficient used to speed up RSA operations. Calculated as: d mod (q-1)

iqmp

Type
 int

A Chinese remainder theorem coefficient used to speed up RSA operations. Calculated as: q⁻¹ mod p

private_key(*, unsafe_skip_rsa_key_validation=False)

Parameters
 unsafe_skip_rsa_key_validation (bool) – New in version 39.0.0.

A keyword-only argument that defaults to False. If True RSA private keys will not be validated. This significantly speeds up loading the keys, but is unsafe unless you are certain the key is valid. User supplied keys should never be loaded with this parameter set to True. If you do load an invalid key this way and attempt to use it OpenSSL may hang, crash, or otherwise misbehave.

Returns
 An instance of RSAPrivateKey.

Handling partial RSA private keys

If you are trying to load RSA private keys yourself you may find that not all parameters required by RSAPrivateNumbers are available. In particular the Chinese Remainder Theorem (CRT) values dmp1, dmq1, iqmp may be missing or present in a different form. For example, OpenPGP does not include the iqmp, dmp1 or dmq1 parameters.

The following functions are provided for users who want to work with keys like this without having to do the math themselves.

crypto.hazmat.primitives.asymmetric.rsa.rsa_crt_iqmp(p, q)

New in version 0.4.

Computes the iqmp (also known as qInv) parameter from the RSA primes p and q.
crypto.hazmat.primitives.asymmetric.rsa.rsa_crt_dmp1(private_exponent, p)

New in version 0.4.

Computes the dmp1 parameter from the RSA private exponent (d) and prime p.
cryptography.hazmat.primitives.asymmetric.rsa.rsa_crt_dmq1(private_exponent, q)

New in version 0.4.
Computes the dmq1 parameter from the RSA private exponent (d) and prime q.

cryptography.hazmat.primitives.asymmetric.rsa.rsa_recover_prime_factors(n, e, d)

New in version 0.8.
Computes the prime factors (p, q) given the modulus, public exponent, and private exponent.

**Note:** When recovering prime factors this algorithm will always return p and q such that \( p > q \). Note: before 1.5, this function always returned p and q such that \( p < q \). It was changed because libraries commonly require \( p > q \).

**Returns**
A tuple (p, q)

**Key interfaces**

class cryptography.hazmat.primitives.asymmetric.rsa.RSAPrivateKey

New in version 0.2.
An RSA private key.
decrypt(ciphertext, padding)

New in version 0.4.

**Warning:** Our implementation of PKCS1 v1.5 decryption is not constant time. See Known security limitations for details.

Decrypt data that was encrypted with the public key.

**Parameters**

- **ciphertext** (bytes) – The ciphertext to decrypt.
- **padding** – An instance of AsymmetricPadding.

**Return bytes**
Decrypted data.

public_key()

**Returns**
RSAPublicKey
An RSA public key object corresponding to the values of the private key.

**key_size**

**Type**
int

The bit length of the modulus.
\texttt{sign(data, padding, algorithm)}

New in version 1.4.

Changed in version 1.6: \texttt{Prehashed} can now be used as an \texttt{algorithm}.

Sign one block of data which can be verified later by others using the public key.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{data} (\texttt{bytes}) – The message string to sign.
  \item \texttt{padding} – An instance of \texttt{AsymmetricPadding}.
  \item \texttt{algorithm} – An instance of \texttt{HashAlgorithm} or \texttt{Prehashed} if the \texttt{data} you want to sign has already been hashed.
\end{itemize}

\textbf{Return bytes}

Signature.

\texttt{private_numbers()}

Create a \texttt{RSAPrivateNumbers} object.

\textbf{Returns}

An \texttt{RSAPrivateNumbers} instance.

\texttt{private_bytes(encoding, format, encryption_algorithm)}

Allows serialization of the key to bytes. Encoding (\texttt{PEM} or \texttt{DER}), format (\texttt{TraditionalOpenSSL}, \texttt{OpenSSH} or \texttt{PKCS8}) and encryption algorithm (such as \texttt{BestAvailableEncryption} or \texttt{NoEncryption}) are chosen to define the exact serialization.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{encoding} – A value from the \texttt{Encoding} enum.
  \item \texttt{format} – A value from the \texttt{PrivateFormat} enum.
  \item \texttt{encryption_algorithm} – An instance of an object conforming to the \texttt{KeySerializationEncryption} interface.
\end{itemize}

\textbf{Return bytes}

Serialized key.

\textbf{class} \texttt{cryptography.hazmat.primitives.asymmetric.rsa.RSAPublicKey}

New in version 0.2.

An RSA public key.

\texttt{encrypt(plaintext, padding)}

New in version 0.4.

Encrypt data with the public key.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{plaintext} (\texttt{bytes}) – The plaintext to encrypt.
  \item \texttt{padding} – An instance of \texttt{AsymmetricPadding}.
\end{itemize}

\textbf{Return bytes}

Encrypted data.

\textbf{Raises}

\texttt{ValueError} – The data could not be encrypted. One possible cause is if \texttt{data} is too large; RSA keys can only encrypt data that is smaller than the key size.
key_size

Type int

The bit length of the modulus.

public_numbers()

Create a RSAPublicNumbers object.

Returns An RSAPublicNumbers instance.

public_bytes(encoding, format)

Allows serialization of the key to bytes. Encoding (PEM or DER) and format (SubjectPublicKeyInfo or PKCS1) are chosen to define the exact serialization.

Parameters

• encoding – A value from the Encoding enum.
• format – A value from the PublicFormat enum.

Return bytes

Serialized key.

verify(signature, data, padding, algorithm)

New in version 1.4.

Changed in version 1.6: Prehashed can now be used as an algorithm.

Verify one block of data was signed by the private key associated with this public key.

Parameters

• signature (bytes) – The signature to verify.
• data (bytes) – The message string that was signed.
• padding – An instance of AsymmetricPadding.
• algorithm – An instance of HashAlgorithm or Prehashed if the data you want to verify has already been hashed.

Returns None

Raises cryptography.exceptions.InvalidSignature – If the signature does not validate.

recover_data_from_signature(signature, padding, algorithm)

New in version 3.3.

Recovers the signed data from the signature. The data typically contains the digest of the original message string. The padding and algorithm parameters must match the ones used when the signature was created for the recovery to succeed.

The algorithm parameter can also be set to None to recover all the data present in the signature, without regard to its format or the hash algorithm used for its creation.

For PKCS1v15 padding, this method returns the data after removing the padding layer. For standard signatures the data contains the full DigestInfo structure. For non-standard signatures, any data can be returned, including zero-length data.
Normally you should use the `verify()` function to validate the signature. But for some non-standard signature formats you may need to explicitly recover and validate the signed data. The following are some examples:

- Some old Thawte and Verisign timestamp certificates without `DigestInfo`.
- Signed MD5/SHA1 hashes in TLS 1.1 or earlier (RFC 4346, section 4.7).
- IKE version 1 signatures without `DigestInfo` (RFC 2409, section 5.1).

**Parameters**

- `signature (bytes)` – The signature.
- `padding` – An instance of `AsymmetricPadding`. Recovery is only supported with some of the padding types. (Currently only with `PKCS1v15`).
- `algorithm` – An instance of `HashAlgorithm`. Can be `None` to return the all the data present in the signature.

**Return bytes**
The signed data.

**Raises**

- `cryptography.exceptions.InvalidSignature` – If the signature is invalid.
- `cryptography.exceptions.UnsupportedAlgorithm` – If signature data recovery is not supported with the provided padding type.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

### Diffie-Hellman key exchange

**Note:** For security and performance reasons we suggest using `ECDH` instead of DH where possible.

**Diffie-Hellman key exchange** (D–H) is a method that allows two parties to jointly agree on a shared secret using an insecure channel.

**Exchange Algorithm**

For most applications the `shared_key` should be passed to a key derivation function. This allows mixing of additional information into the key, derivation of multiple keys, and destroys any structure that may be present.

**Warning:** This example does not give forward secrecy and is only provided as a demonstration of the basic Diffie-Hellman construction. For real world applications always use the ephemeral form described after this example.
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import dh
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF

# Generate some parameters. These can be reused.
>>> parameters = dh.generate_parameters(generator=2, key_size=2048)
# Generate a private key for use in the exchange.
>>> server_private_key = parameters.generate_private_key()
# In a real handshake the peer is a remote client. For this
# example we'll generate another local private key though. Note that in
# a DH handshake both peers must agree on a common set of parameters.
>>> peer_private_key = parameters.generate_private_key()
>>> shared_key = server_private_key.exchange(peer_private_key.public_key())

# Perform key derivation.
>>> derived_key = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
... ).derive(shared_key)
# And now we can demonstrate that the handshake performed in the
# opposite direction gives the same final value
>>> same_shared_key = peer_private_key.exchange(server_private_key.public_key())
>>> same_derived_key = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
... ).derive(same_shared_key)

>>> derived_key == same_derived_key

DHE (or EDH), the ephemeral form of this exchange, is strongly preferred over simple DH and provides forward secrecy when used. You must generate a new private key using `generate_private_key()` for each `exchange()` when performing an DHE key exchange. An example of the ephemeral form:

>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import dh
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF

# Generate some parameters. These can be reused.
>>> parameters = dh.generate_parameters(generator=2, key_size=2048)
# Generate a private key for use in the exchange.
>>> private_key = parameters.generate_private_key()
# In a real handshake the peer_public_key will be received from the
# other party. For this example we'll generate another private key and
# get a public key from that. Note that in a DH handshake both peers
# must agree on a common set of parameters.
>>> peer_public_key = parameters.generate_private_key().public_key()
>>> shared_key = private_key.exchange(peer_public_key)
# Perform key derivation.
>>> derived_key = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
... ).derive(shared_key)
... salt=None,
... info=b'handshake data',
... ).derive(shared_key)

>>> # For the next handshake we MUST generate another private key, but
>>> # we can reuse the parameters.
>>> private_key_2 = parameters.generate_private_key()
>>> peer_public_key_2 = parameters.generate_private_key().public_key()
>>> shared_key_2 = private_key_2.exchange(peer_public_key_2)
>>> derived_key_2 = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=None,
...     info=b'handshake data',
... ).derive(shared_key_2)

To assemble a `DHParameters` and a `DHPublicKey` from primitive integers, you must first create the `DHPublicNumbers` and `DHParameterNumbers` objects. For example, if `p`, `g`, and `y` are `int` objects received from a peer:

```python
pn = dh.DHPublicNumbers(y, pn)
peer_public_key = peer_public_numbers.public_key()
```

**Group parameters**

cryptography.hazmat.primitives.asymmetric.dh.generate_parameters(generator, key_size)

Generate a new DH parameter group.

**Parameters**

- generator: The `int` to use as a generator. Must be 2 or 5.
- key_size: The bit length of the prime modulus to generate.

**Returns**

DH parameters as a new instance of `DHParameters`.

**Raises**

- `ValueError`: If `key_size` is not at least 512.

```python
class cryptography.hazmat.primitives.asymmetric.dh.DHParameters
```

New in version 1.7.

`generate_private_key()`

Generate a DH private key. This method can be used to generate many new private keys from a single set of parameters.

**Returns**

An instance of `DHPrivateKey`.

`parameter_numbers()`

Return the numbers that make up this set of parameters.
Returns
A **DHPublicKey**.

**parameters()**
New in version 1.7.

Parameters

- **peer_public_key** (DHPublicKey) – The public key for the peer.

Returns

- **DHPublicKey**.

**private_numbers()**
Return the numbers that make up this private key.

Returns

- **DHPrivateNumbers**.

**private_bytes(encoding, format, encryption_algorithm)**
New in version 1.8.

Allows serialization of the key to bytes. Encoding (PEM or DER), format (PKCS8) and encryption algorithm (such as **BestAvailableEncryption** or **NoEncryption**) are chosen to define the exact serialization.

Parameters

- **encoding** – A value from the **Encoding** enum.

- **format** – A value from the **ParameterFormat** enum. At the moment only PKCS3 is supported.
• **encoding** – A value from the `Encoding` enum.
• **format** – A value from the `PrivateFormat` enum.
• **encryption_algorithm** – An instance of an object conforming to the `KeySerializationEncryption` interface.

Return bytes
Serialized key.

class cryptography.hazmat.primitives.asymmetric.dh.DHPublicKey
New in version 1.7.

key_size
The bit length of the prime modulus.

parameters()
Return the parameters associated with this private key.

Returns
A `DHParameters`.

class cryptography.hazmat.primitives.asymmetric.dh.DHPublicNumbers
New in version 0.8.
The collection of integers that define a Diffie-Hellman group.

p
Type
`int`
The prime modulus value.

g
Type
`int`
The generator value. Must be 2 or greater.

q

New in version 1.8.

Type

int

The subgroup order value.

parameters()

New in version 1.7.

Returns

A new instance of \texttt{DHParameters}.

class cryptography.hazmat.primitives.asymmetric.dh.DHPublicNumbers\( (x, \text{public\_numbers}) \)

New in version 0.8.

The collection of integers that make up a Diffie-Hellman private key.

\textbf{public\_numbers}

Type

\texttt{DHPublicNumbers}

The \texttt{DHPublicNumbers} which makes up the DH public key associated with this DH private key.

x

Type

\texttt{int}

The private value.

private\_key()

New in version 1.7.

Returns

A new instance of \texttt{DHPublicKey}.

class cryptography.hazmat.primitives.asymmetric.dh.DHPublicNumbers\( (y, \text{parameter\_numbers}) \)

New in version 0.8.

The collection of integers that make up a Diffie-Hellman public key.

\textbf{parameter\_numbers}

Type

\texttt{DHPublicNumbers}

The parameters for this DH group.

y

Type

\texttt{int}

The public value.

public\_key()

New in version 1.7.

Returns

A new instance of \texttt{DHPublicKey}.
This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

## DSA

**Note:** DSA is a legacy algorithm and should generally be avoided in favor of choices like EdDSA using curve25519 or ECDSA.

DSA is a public-key algorithm for signing messages.

### Generation

cryptography.hazmat.primitives.asymmetric.dsa.generate_private_key(key_size)

    New in version 0.5.

    Changed in version 3.0: Added support for 4096-bit keys for some legacy applications that continue to use DSA despite the wider cryptographic community’s ongoing protestations.

    Generate a DSA private key from the given key size. This function will generate a new set of parameters and key in one step.

    **Parameters**
    - **key_size** *(int)* – The length of the modulus in bits. It should be either 1024, 2048, 3072, or 4096. For keys generated in 2015 this should be at least 2048 (See page 41).

    **Returns**
    An instance of DSAPrivateKey.

cryptography.hazmat.primitives.asymmetric.dsa.generate_parameters(key_size)

    New in version 0.5.

    Changed in version 3.0: Added support for 4096-bit keys for some legacy applications that continue to use DSA despite the wider cryptographic community’s ongoing protestations.

    Generate DSA parameters.

    **Parameters**
    - **key_size** *(int)* – The length of $p$. It should be either 1024, 2048, 3072, or 4096. For keys generated in 2015 this should be at least 2048 (See page 41).

    **Returns**
    An instance of DSAParameters.
Signing

Using a `DSAPrivateKey` instance.

```python
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import dsa
>>> private_key = dsa.generate_private_key(
    ...   key_size=1024,
    ...)
>>> data = b"this is some data I'd like to sign"
>>> signature = private_key.sign(
    ...   data,
    ...   hashes.SHA256()
    ...)
```

The signature is a bytes object, whose contents is DER encoded as described in RFC 3279. This can be decoded using `decode_dss_signature()`.

If your data is too large to be passed in a single call, you can hash it separately and pass that value using `Prehashed`.

```python
>>> from cryptography.hazmat.primitives.asymmetric import utils
>>> chosen_hash = hashes.SHA256()
>>> hasher = hashes.Hash(chosen_hash)
>>> hasher.update(b"data & ")
>>> hasher.update(b"more data")
>>> digest = hasher.finalize()
>>> sig = private_key.sign(
    ...   digest,
    ...   utils.Prehashed(chosen_hash)
    ...
)
```

Verification

Verification is performed using a `DSAPublicKey` instance. You can get a public key object with `load_pem_public_key()`, `load_der_public_key()`, `public_key()`, or `public_key()`.

```python
>>> public_key = private_key.public_key()
>>> public_key.verify(
    ...   signature,
    ...   data,
    ...   hashes.SHA256()
    ...
)
```

`verify()` takes the signature in the same format as is returned by `sign()`.

`verify()` will raise an `InvalidSignature` exception if the signature isn't valid.

If your data is too large to be passed in a single call, you can hash it separately and pass that value using `Prehashed`.

```python
>>> chosen_hash = hashes.SHA256()
>>> hasher = hashes.Hash(chosen_hash)
>>> hasher.update(b"data & ")
>>> hasher.update(b"more data")
>>> digest = hasher.finalize()
```
```python
>>> public_key.verify(
...    sig,
...    digest,
...    utils.Prehashed(chosen_hash)
... )
```

**Numbers**

class cryptography.hazmat.primitives.asymmetric.dsa.DSAPrimitivesNumbers(p, q, g)

New in version 0.5.
The collection of integers that make up a set of DSA parameters.

**p**

Type int

The public modulus.

**q**

Type int

The sub-group order.

**g**

Type int

The generator.

**Parameters**

Returns

A new instance of DSAPrimitivesNumbers.

class cryptography.hazmat.primitives.asymmetric.dsa.DSPublicNumbers(y, parameter_numbers)

New in version 0.5.
The collection of integers that make up a DSA public key.

**y**

Type int

The public value y.

**parameter_numbers**

Type DSAPrimitivesNumbers

The DSAPrimitivesNumbers associated with the public key.
public_key()

Returns
A new instance of DSAPublicKey.

class cryptography.hazmat.primitives.asymmetric.dsa.DSAPublicNumbers(x, public_numbers)
New in version 0.5.
The collection of integers that make up a DSA private key.

Warning: Revealing the value of x will compromise the security of any cryptographic operations performed.

x

Type
int
The private value x.

public_numbers

Type
DSAPublicNumbers
The DSAPublicNumbers associated with the private key.

private_key()

Returns
A new instance of DSAPrivateKey.

Key interfaces

class cryptography.hazmat.primitives.asymmetric.dsa.DSAPrivateNumbers
New in version 0.5.
Generate a DSA private key. This method can be used to generate many new private keys from a single set of parameters.

Returns
An instance of DSAPrivateKey.

parameter_numbers()

Create a DSAPrincipalNumbers object.

Returns
A DSAPrincipalNumbers instance.

class cryptography.hazmat.primitives.asymmetric.dsa.DSAPrivateKey
New in version 0.3.
A DSA private key.
public_key()

    Returns
    DSAPublicKey

    An DSA public key object corresponding to the values of the private key.

parameters()

    Returns
    DSAPublicParameters

    The DSAPublicParameters object associated with this private key.

key_size

    Type
    int

    The bit length of \( q \).

sign(data, algorithm)

    New in version 1.5.

    Changed in version 1.6: Prehashed can now be used as an algorithm.

    Sign one block of data which can be verified later by others using the public key.

    Parameters

    • data (bytes) – The message string to sign.

    • algorithm – An instance of HashAlgorithm or Prehashed if the data you want to sign has already been hashed.

    Return bytes
    Signature.

private_numbers()

    Create a DSAPrivateNumbers object.

    Returns
    A DSAPrivateNumbers instance.

private_bytes(encoding, format, encryption_algorithm)

    Allows serialization of the key to bytes. Encoding (PEM or DER), format (TraditionalOpenSSL or PKCS8) and encryption algorithm (such as BestAvailableEncryption or NoEncryption) are chosen to define the exact serialization.

    Parameters

    • encoding – A value from the Encoding enum.

    • format – A value from the PrivateFormat enum.

    • encryption_algorithm – An instance of an object conforming to the KeySerializationEncryption interface.

    Return bytes
    Serialized key.

class cryptography.hazmat.primitives.asymmetric.dsa.DSAPublicKey

    New in version 0.3.

    A DSA public key.
**key_size**

Type

int

The bit length of \( q \).

**parameters()**

Returns

\( \text{DSAParameters} \)

The DSAParameters object associated with this public key.

**public_numbers()**

Create a \( \text{DSAPublicNumbers} \) object.

Returns

A \( \text{DSAPublicNumbers} \) instance.

**public_bytes(encoding, format)**

Allows serialization of the key to bytes. Encoding (PEM or DER) and format (SubjectPublicKeyInfo) are chosen to define the exact serialization.

Parameters

- **encoding** – A value from the Encoding enum.
- **format** – A value from the PublicFormat enum.

Returns bytes

Serialized key.

**verify(signature, data, algorithm)**

New in version 1.5.

Changed in version 1.6: **Prehashed** can now be used as an algorithm.

Verify one block of data was signed by the private key associated with this public key.

Parameters

- **signature** (bytes) – The signature to verify.
- **data** (bytes) – The message string that was signed.
- **algorithm** – An instance of HashAlgorithm or Prehashed if the data you want to sign has already been hashed.

Returns

None

Raises

\( \text{cryptography.exceptions.InvalidSignature} \) – If the signature does not validate.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.
Key Serialization

There are several common schemes for serializing asymmetric private and public keys to bytes. They generally support encryption of private keys and additional key metadata.

Many serialization formats support multiple different types of asymmetric keys and will return an instance of the appropriate type. You should check that the returned key matches the type your application expects when using these methods.

```python
>>> from cryptography.hazmat.primitives.asymmetric import dsa, rsa
>>> from cryptography.hazmat.primitives.serialization import load_pem_private_key
>>> key = load_pem_private_key(pem_data, password=None)
>>> if isinstance(key, rsa.RSAPrivateKey):
...    signature = sign_with_rsa_key(key, message)
... elif isinstance(key, dsa.DSAPrivateKey):
...    signature = sign_with_dsa_key(key, message)
... else:
...    raise TypeError
```

Key dumping

The serialization module contains functions for loading keys from bytes. To dump a key object to bytes, you must call the appropriate method on the key object. Documentation for these methods in found in the `rsa`, `dsa`, and `ec` module documentation.

PEM

PEM is an encapsulation format, meaning keys in it can actually be any of several different key types. However these are all self-identifying, so you don’t need to worry about this detail. PEM keys are recognizable because they all begin with `-----BEGIN {format}-----` and end with `-----END {format}-----`.

**Note:** A PEM block which starts with `-----BEGIN CERTIFICATE-----` is not a public or private key, it’s an X.509 Certificate. You can load it using `load_pem_x509_certificate()` and extract the public key with `Certificate.public_key`.

```python
cryptography.hazmat.primitives.serialization.load_pem_private_key(data, password, *, unsafe_skip_rsa_key_validation=False)
```

New in version 0.6.

**Note:** SSH private keys are a different format and must be loaded with `load_ssh_private_key()`.

Deserialize a private key from PEM encoded data to one of the supported asymmetric private key types.

**Parameters**

- **data (bytes-like)** – The PEM encoded key data.
- **password (bytes-like)** – The password to use to decrypt the data. Should be `None` if the private key is not encrypted.
• **unsafe_skip_rsa_key_validation** *(bool)* – New in version 39.0.0.

A keyword-only argument that defaults to False. If True RSA private keys will not be validated. This significantly speeds up loading the keys, but is unsafe unless you are certain the key is valid. User supplied keys should never be loaded with this parameter set to True. If you do load an invalid key this way and attempt to use it OpenSSL may hang, crash, or otherwise misbehave.

**Returns**

One of `Ed25519PrivateKey`, `X25519PrivateKey`, `Ed448PrivateKey`, `X448PrivateKey`, `RSAPrivateKey`, `DSAPrivateKey`, `DHPublicKey`, or `EllipticCurvePrivateKey` depending on the contents of data.

**Raises**

- **ValueError** – If the PEM data could not be decrypted or if its structure could not be decoded successfully.
- **TypeError** – If a password was given and the private key was not encrypted. Or if the key was encrypted but no password was supplied.
- **cryptography.exceptions.UnsupportedAlgorithm** – If the serialized key type is not supported by the OpenSSL version cryptography is using.

cryptography.hazmat.primitives.serialization.load_pem_public_key *(data)*

New in version 0.6.

Deserialize a public key from PEM encoded data to one of the supported asymmetric public key types. The PEM encoded data is typically a `subjectPublicKeyInfo` payload as specified in RFC 5280.

```python
>>> from cryptography.hazmat.primitives.serialization import load_pem_public_key
>>> key = load_pem_public_key(public_pem_data)
>>> isinstance(key, rsa.RSAPublicKey)
True
```

**Parameters**

- **data** *(bytes)* – The PEM encoded key data.

**Returns**

One of `Ed25519PublicKey`, `X25519PublicKey`, `Ed448PublicKey`, `X448PublicKey`, `RSAPublicKey`, `DSAPublicKey`, `DHPublicKey`, or `EllipticCurvePublicKey` depending on the contents of data.

**Raises**

- **ValueError** – If the PEM data’s structure could not be decoded successfully.
- **cryptography.exceptions.UnsupportedAlgorithm** – If the serialized key type is not supported by the OpenSSL version cryptography is using.

cryptography.hazmat.primitives.serialization.load_pem_parameters *(data)*

.. versionadded:: 2.0

Deserialize parameters from PEM encoded data to one of the supported asymmetric parameters types.

```python
>>> from cryptography.hazmat.primitives.serialization import load_pem_parameters
>>> from cryptography.hazmat.primitives.asymmetric import dh
>>> parameters = load_pem_parameters(parameters_pem_data)
>>> isinstance(parameters, dh.DHParameters)
True
```
Parameters

`data (bytes)` – The PEM encoded parameters data.

Returns

Currently only `DHParameters` supported.

Raises

- `ValueError` – If the PEM data’s structure could not be decoded successfully.
- `cryptography.exceptions.UnsupportedAlgorithm` – If the serialized key type is not supported by the OpenSSL version `cryptography` is using.

**DER**

DER is an ASN.1 encoding type. There are no encapsulation boundaries and the data is binary. DER keys may be in a variety of formats, but as long as you know whether it is a public or private key the loading functions will handle the rest.

`cryptography.hazmat.primitives.serialization.load_der_private_key(data, password, *, unsafe_skip_rsa_key_validation=False)`

New in version 0.8.

Deserialize a private key from DER encoded data to one of the supported asymmetric private key types.

Parameters

- `data (bytes-like)` – The DER encoded key data.
- `password (bytes-like)` – The password to use to decrypt the data. Should be `None` if the private key is not encrypted.
- `unsafe_skip_rsa_key_validation (bool)` – New in version 39.0.0.

A keyword-only argument that defaults to `False`. If `True` RSA private keys will not be validated. This significantly speeds up loading the keys, but is `unsafe` unless you are certain the key is valid. User supplied keys should never be loaded with this parameter set to `True`. If you do load an invalid key this way and attempt to use it OpenSSL may hang, crash, or otherwise misbehave.

Returns

One of `Ed25519PrivateKey`, `X25519PrivateKey`, `Ed448PrivateKey`, `X448PrivateKey`, `RSAPrivateKey`, `DSAPrivateKey`, `DHPrivateKey`, or `EllipticCurvePrivateKey` depending on the contents of data.

Raises

- `ValueError` – If the DER data could not be decrypted or if its structure could not be decoded successfully.
- `TypeError` – If a `password` was given and the private key was not encrypted. Or if the key was encrypted but no password was supplied.
- `cryptography.exceptions.UnsupportedAlgorithm` – If the serialized key type is not supported by the OpenSSL version `cryptography` is using.

```python
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> from cryptography.hazmat.primitives.serialization import load_der_private_key
>>> key = load_der_private_key(der_data, password=None)
```
cryptography.hazmat.primitives.serialization.load_der_public_key(data)

New in version 0.8.

Deserialize a public key from DER encoded data to one of the supported asymmetric public key types. The DER encoded data is typically a subjectPublicKeyInfo payload as specified in RFC 5280.

Parameters

- **data** *(bytes)* – The DER encoded key data.

Returns

One of `Ed25519PublicKey`, `X25519PublicKey`, `Ed448PublicKey`, `X448PublicKey`, `RSAPublicKey`, `DSAPublicKey`, `DHPublicKey`, or `EllipticCurvePublicKey` depending on the contents of data.

Raises

- `ValueError` – If the DER data’s structure could not be decoded successfully.
- `cryptography.exceptions.UnsupportedAlgorithm` – If the serialized key type is not supported by the OpenSSL version `cryptography` is using.

```python
from cryptography.hazmat.primitives.asymmetric import rsa
from cryptography.hazmat.primitives.serialization import load_der_public_key
key = load_der_public_key(public_der_data)
isinstance(key, rsa.RSAPublicKey)
```

---

cryptography.hazmat.primitives.serialization.load_der_parameters(data)

New in version 2.0.

Deserialize parameters from DER encoded data to one of the supported asymmetric parameters types.

Parameters

- **data** *(bytes)* – The DER encoded parameters data.

Returns

Currently only `DHParameters` supported.

Raises

- `ValueError` – If the DER data’s structure could not be decoded successfully.
- `cryptography.exceptions.UnsupportedAlgorithm` – If the serialized key type is not supported by the OpenSSL version `cryptography` is using.

```python
from cryptography.hazmat.primitives.asymmetric import dh
from cryptography.hazmat.primitives.serialization import load_der_parameters
parameters = load_der_parameters(parameters_der_data)
isinstance(parameters, dh.DHParameters)
```
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**OpenSSH Public Key**

The format used by OpenSSH to store public keys, as specified in [RFC 4253].

An example RSA key in OpenSSH format (line breaks added for formatting purposes):

```plaintext
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQDDu/XRP1kyK6Gt36gts9XAkFiuiLW6RU0j3KKVZSs1I7ZUmU9/9aVh/rZV43WQG8jaR6kkcp4stOR0DEt1lPDA7ZRBnrifHpsQY0B74A2aOjgkv7DBfsE6gcDQlub0PfjWyrYQlUhtOLQEKvY/C0vtziRL3juawWnCd7K3W3xwJvAdgGk7i61fHd+de0NPENP2H58E4odr22f
sxn/adpDqfb2sM0kPwQs0awvrrKGvUaustkivQ44WiiSFnB0oJB/1K/CKVuy///ImSCGHQRvhwariN2tvZ6CBNSLh3iQgeB0AkyjJnlg7MXB2qYq/Ci2FUoryCXZMzHvnv testkey@localhost
```

DSA keys look almost identical but begin with `ssh-dss` rather than `ssh-rsa`. ECDSA keys have a slightly different format, they begin with `ecdsa-sha2-{curve}`.

```plaintext
cryptography.hazmat.primitives.serialization.SSHPublicKeyTypes
New in version 40.0.0.

Type alias: A union of public key types accepted for SSH: `RSAPublicKey`, `DSAPublicKey`, `EllipticCurvePublicKey`, or `Ed25519PublicKey`.
```

```plaintext
cryptography.hazmat.primitives.serialization.load_ssh_public_key(data)
New in version 0.7.
```

**Note:** SSH DSA key support is deprecated and will be removed in a future release.

Deserialize a public key from OpenSSH ([RFC 4253](https://tools.ietf.org/html/rfc4253) and PROTOCOL.certkeys) encoded data to an instance of the public key type.

**Parameters**
- `data` ([bytes-like](https://docs.python.org/3/glossary.html#term-byte-like)) – The OpenSSH encoded key data.

**Returns**
- One of `SSHPublicKeyTypes` depending on the contents of `data`.

** Raises **
- `ValueError` – If the OpenSSH data could not be properly decoded or if the key is not in the proper format.
- `cryptography.exceptions.UnsupportedAlgorithm` – If the serialized key is of a type that is not supported.

**OpenSSH Private Key**

The format used by OpenSSH to store private keys, as approximately specified in PROTOCOL.certkeys.

An example ECDSA key in OpenSSH format:

```
-----BEGIN OPENSSH PRIVATE KEY-----
b3BlbnNzaC1cI1ZXxtdjeAAAABAG5vbmuAAAAAEbem9uZQAAAABAAAAAaAAAABNLY2RzYS1zaGeYlW5pc3WmJju2AAAACG5pc3WmJju2AAACQRI0fWhI1C27XyQpq6ih6bxjhGmUrZE/h3kBhuxQcZjJAAAqKpZvaoj81WjAAAAE2VjZHNhLXNoYTItbmllzdHAyNTYAAAIBmlzdHAyNTYAAAABBBBiejR9acjULFupiq
(continues on next page)
```

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nSKHpvGOEaZStkr8DF/y+EzwNvegsIVH410vvXmVR27hcJa9BkpV/rT+HeQEWG7FALbdemo
MAAAAga/VGV2asRlL3kXXao0aochQ59nXHA2xEGeAoQd952r0AAAJbWFya29AdmZmAQID
BAUGBw==
-----END OPENSSH PRIVATE KEY-----

cryptography.hazmat.primitives.serialization.SSHPrivateKeyTypes
New in version 40.0.0.

Type alias: A union of private key types accepted for SSH: RSAPrivateKey, DSAPrivateKey, EllipticCurvePrivateKey or Ed25519PrivateKey.

cryptography.hazmat.primitives.serialization.load_ssh_private_key(data, password)
New in version 3.0.

Note: SSH DSA key support is deprecated and will be removed in a future release.

Deserialize a private key from OpenSSH encoded data to an instance of the private key type.

Parameters
• data (bytes-like) – The PEM encoded OpenSSH private key data.
• password (bytes) – Password bytes to use to decrypt password-protected key. Or None if not needed.

Returns
One of SSHPrivateKeyTypes depending on the contents of data.

Raises
• ValueError – If the OpenSSH data could not be properly decoded, if the key is not in the proper format or the incorrect password was provided.
• cryptography.exceptions.UnsupportedAlgorithm – If the serialized key is of a type that is not supported.

OpenSSH Certificate

The format used by OpenSSH for certificates, as specified in PROTOCOL.certkeys.

cryptography.hazmat.primitives.serialization.SSHCertPublicKeyTypes
New in version 40.0.0.

Type alias: A union of public key types supported for SSH certificates: RSAPublicKey, EllipticCurvePublicKey or Ed25519PublicKey

cryptography.hazmat.primitives.serialization.SSHCertPrivateKeyTypes
New in version 40.0.0.

Type alias: A union of private key types supported for SSH certificates: RSAPrivateKey, EllipticCurvePrivateKey or Ed25519PrivateKey

cryptography.hazmat.primitives.serialization.load_ssh_public_identity(data)
New in version 40.0.0.
Note: This function does not support parsing certificates with DSA public keys or signatures from DSA certificate authorities. DSA is a deprecated algorithm and should not be used.

Deserializes an OpenSSH encoded identity to an instance of `SSHCertificate` or the appropriate public key type. Parsing a certificate does not verify anything. It is up to the caller to perform any necessary verification.

**Parameters**
- `data` *(bytes)* – The OpenSSH encoded data.

**Returns**
- `SSHCertificate` or one of `SSHCertPublicKeyTypes`.

**Raises**
- `ValueError` – If the OpenSSH data could not be properly decoded.
- `cryptography.exceptions.UnsupportedAlgorithm` – If the data contains a public key type that is not supported.

```python
class cryptography.hazmat.primitives.serialization.SSHCertificate

New in version 40.0.0.

nonce

Type
```
bytes
```

The nonce field is a CA-provided random value of arbitrary length (but typically 16 or 32 bytes) included to make attacks that depend on inducing collisions in the signature hash infeasible.

**public_key()**

The public key contained in the certificate, one of `SSHCertPublicKeyTypes`.

**serial**

Type
```
int
```

Serial is an optional certificate serial number set by the CA to provide an abbreviated way to refer to certificates from that CA. If a CA does not wish to number its certificates, it must set this field to zero.

**type**

Type
```
SSHCertificateType
```

Type specifies whether this certificate is for identification of a user or a host.

**key_id**

Type
```
bytes
```

This is a free-form text field that is filled in by the CA at the time of signing; the intention is that the contents of this field are used to identify the identity principal in log messages.

**valid_principals**

Type
```
list[bytes]
```

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“valid principals” is a list containing one or more principals as byte strings. These principals list the names for which this certificate is valid; hostnames for host certificates and usernames for user certificates. As a special case, an empty list means the certificate is valid for any principal of the specified type.

**valid_after**

Type int

An integer representing the Unix timestamp (in UTC) after which the certificate is valid. **This time is inclusive.**

**valid_before**

Type int

An integer representing the Unix timestamp (in UTC) before which the certificate is valid. **This time is not inclusive.**

**critical_options**

Type dict[bytes, bytes]

Critical options is a dict of zero or more options that are critical for the certificate to be considered valid. If any of these options are not supported by the implementation, the certificate must be rejected.

**extensions**

Type dict[bytes, bytes]

Extensions is a dict of zero or more options that are non-critical for the certificate to be considered valid. If any of these options are not supported by the implementation, the implementation may safely ignore them.

**signature_key()**

The public key used to sign the certificate, one of **SSHCertPublicKeyTypes**.

**verify_cert_signature()**

**Warning:** This method does not validate anything about whether the signing key is trusted! Callers are responsible for validating trust in the signer.

Validates that the signature on the certificate was created by the private key associated with the certificate’s signature key and that the certificate has not been changed since signing.

**Returns**

None

**Raises**

**InvalidSignature** if the signature is invalid.

**public_bytes()**

**Returns**

The serialized certificate in OpenSSH format.

**Return type**

bytes
**class** cryptography.hazmat.primitives.serialization.SSHCertificateType

New in version 40.0.0.

An enumeration of the types of SSH certificates.

**USER**

The cert is intended for identification of a user. Corresponds to the value 1.

**HOST**

The cert is intended for identification of a host. Corresponds to the value 2.

**SSH Certificate Builder**

**class** cryptography.hazmat.primitives.serialization.SSHCertificateBuilder

New in version 40.0.0.

**Note:** This builder does not support generating certificates with DSA public keys or creating signatures with DSA certificate authorities. DSA is a deprecated algorithm and should not be used.

```python
>>> import datetime
>>> from cryptography.hazmat.primitives.asymmetric import ec
>>> from cryptography.hazmat.primitives.serialization import (...
... SSHCertificateType, SSHCertificateBuilder
... )
>>> signing_key = ec.generate_private_key(ec.SECP256R1())
>>> public_key = ec.generate_private_key(ec.SECP256R1()).public_key()
>>> valid_after = datetime.datetime(2023, 1, 1, 1, tzinfo=datetime.timezone.utc).timestamp()
>>> valid_before = datetime.datetime(2023, 7, 1, 1, tzinfo=datetime.timezone.utc).timestamp()
>>> key_id = b"a_key_id"
>>> valid_principals = [b"eve", b"alice"]
>>> builder = (...
... SSHCertificateBuilder()
... .public_key(public_key)
... .type(SSHCertificateType.USER)
... .valid_before(valid_before)
... .valid_after(valid_after)
... .key_id(b"a_key_id")
... .valid_principals(valid_principals)
... .add_extension(b"no-touch-required", b"")
... )
>>> builder.sign(signing_key).public_bytes()

b'...

**public_key** *(public_key)*

**Parameters**

**public_key** *(SSHCertPublicKeyTypes)* – The public key to be included in the certificate. This value is required.
serial

Parameters
  serial (int) – The serial number to be included in the certificate. This is not a required value and will be set to zero if not provided. Value must be between 0 and 2^{64} - 1, inclusive.

type
type

Parameters
  type (SSHCertificateType) – The type of the certificate. There are two options, user or host.

key_id

Parameters
  key_id (bytes) – The key ID to be included in the certificate. This is not a required value.

valid_principals

Parameters
  valid_principals (list[bytes]) – A list of principals that the certificate is valid for. This is a required value unless valid_for_all_principals() has been called.

valid_for_all_principals()

Marks the certificate as valid for all principals. This cannot be set if principals have been added via valid_principals().

valid_after

Parameters
  valid_after (int) – The Unix timestamp (in UTC) that marks the activation time for the certificate. This is a required value.

valid_before

Parameters
  valid_before (int) – The Unix timestamp (in UTC) that marks the expiration time for the certificate. This is a required value.

add_critical_option

Parameters
  • name (bytes) – The name of the critical option to add. No duplicates are allowed.
  • value (bytes) – The value of the critical option to add. This is commonly an empty byte string.

add_extension

Parameters
  • name (bytes) – The name of the extension to add. No duplicates are allowed.
  • value (bytes) – The value of the extension to add.

sign

Parameters
  private_key (SSHCertPrivateKeyTypes) – The private key that will be used to sign the certificate.
Returns
The signed certificate.

Return type
SSHCertificate

PKCS12

PKCS12 is a binary format described in RFC 7292. It can contain certificates, keys, and more. PKCS12 files commonly have a pfx or p12 file suffix.

Note: cryptography only supports a single private key and associated certificates when parsing PKCS12 files at this time.
New in version 3.0.

**Note:** With OpenSSL 3.0.0+ the defaults for encryption when serializing PKCS12 have changed and some versions of Windows and macOS will not be able to read the new format. Maximum compatibility can be achieved by using SHA1 for MAC algorithm and `PBESv1SHA1And3KeyTripleDESCBC` for encryption algorithm as seen in the example below. However, users should avoid this unless required for compatibility.

**Warning:** PKCS12 encryption is typically not secure and should not be used as a security mechanism. Wrap a PKCS12 blob in a more secure envelope if you need to store or send it safely.

Serialize a PKCS12 blob.

**Note:** Due to a bug in Firefox it’s not possible to load unencrypted PKCS12 blobs in Firefox.

**Parameters**

- **name** *(bytes)* – The friendly name to use for the supplied certificate and key.
- **key** *(PKCS12PrivateKeyTypes)* – The private key to include in the structure.
- **cert** *(Certificate or None)* – The certificate associated with the private key.
- **cas** *(None, or list of Certificate or PKCS12Certificate)* – An optional set of certificates to also include in the structure. If a `PKCS12Certificate` is given, its friendly name will be serialized.
- **encryption_algorithm** – The encryption algorithm that should be used for the key and certificate. An instance of an object conforming to the `KeySerializationEncryption` interface. PKCS12 encryption is typically **very weak** and should not be used as a security boundary.

**Return bytes**

Serialized PKCS12.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives.serialization import BestAvailableEncryption, load_pem_private_key, pkcs12

>>> cert = x509.load_pem_x509_certificate(ca_cert)
>>> key = load_pem_private_key(ca_key, None)
>>> p12 = pkcs12.serialize_key_and_certificates(...
    b"friendlyname", key, cert, None, BestAvailableEncryption(b"password")
...)
```

This example uses an `encryption_builder()` to create a PKCS12 with more compatible, but substantially less secure, encryption.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.serialization import PrivateFormat, load_pem_private_key, pkcs12

>>> encryption = (
```

(continues on next page)
class cryptography.hazmat.primitives.serialization.pkcs12.PKCS12Certificate

New in version 36.0.0.

Represents additional data provided for a certificate in a PKCS12 file.

certificate
A Certificate instance.

friendly_name

Type
bytes or None

An optional byte string containing the friendly name of the certificate.

class cryptography.hazmat.primitives.serialization.pkcs12.PKCS12KeyAndCertificates

New in version 36.0.0.

A simplified representation of a PKCS12 file.

key
An optional private key belonging to cert (see PKCS12PrivateKeyTypes).

cert
An optional PKCS12Certificate instance belonging to the private key key.

additional_certs
A list of PKCS12Certificate instances.

class cryptography.hazmat.primitives.serialization.pkcs12.PBES

New in version 38.0.0.

An enumeration of password-based encryption schemes used in PKCS12. These values are used with KeySerializationEncryptionBuilder.

PBESv1SHA1And3KeyTripleDESCBC
PBESv1 using SHA1 as the KDF PRF and 3-key triple DES-CBC as the cipher.

PBESv2SHA256AndAES256CBC
PBESv2 using SHA256 as the KDF PRF and AES256-CBC as the cipher. This is only supported on OpenSSL 3.0.0 or newer.

2.3. Primitives
PKCS7

PKCS7 is a format described in RFC 2315, among other specifications. It can contain certificates, CRLs, and much more. PKCS7 files commonly have a p7b, p7m, or p7s file suffix but other suffixes are also seen in the wild.

**Note:** cryptography only supports parsing certificates from PKCS7 files at this time.

cryptography.hazmat.primitives.serialization.pkcs7.PKCS7HashTypes
New in version 40.0.0.
Type alias: A union of hash types supported for PKCS7 serialization: SHA1, SHA224, SHA256, SHA384, or SHA512.

cryptography.hazmat.primitives.serialization.pkcs7.PKCS7PrivateKeyTypes
New in version 40.0.0.
Type alias: A union of private key types supported for PKCS7 serialization: RSAPrivateKey or EllipticCurvePrivateKey

cryptography.hazmat.primitives.serialization.pkcs7.load_pem_pkcs7_certificates(data)
New in version 3.1.
Deserializes a PEM encoded PKCS7 blob to a list of certificates. PKCS7 can contain many other types of data, including CRLs, but this function will ignore everything except certificates.

Parameters
- data (bytes) – The data.

Returns
- A list of Certificate.

Raises
- ValueError – If the PKCS7 data could not be loaded.
- cryptography.exceptions.UnsupportedAlgorithm – If the PKCS7 data is of a type that is not supported.

cryptography.hazmat.primitives.serialization.pkcs7.load_der_pkcs7_certificates(data)
New in version 3.1.
Deserializes a DER encoded PKCS7 blob to a list of certificates. PKCS7 can contain many other types of data, including CRLs, but this function will ignore everything except certificates.

Parameters
- data (bytes) – The data.

Returns
- A list of Certificate.

Raises
- ValueError – If the PKCS7 data could not be loaded.
- cryptography.exceptions.UnsupportedAlgorithm – If the PKCS7 data is of a type that is not supported.

cryptography.hazmat.primitives.serialization.pkcs7.serialize_certificates(certs, encoding)
New in version 37.0.0.
Serialize a list of certificates to a PKCS7 structure.
Parameters

- **certs** – A list of *Certificate*.
- **encoding** – *PEM* or *DER*.

Returns bytes

The serialized PKCS7 data.

class cryptography.hazmat.primitives.serialization.pkcs7.PKCS7SignatureBuilder

The PKCS7 signature builder can create both basic PKCS7 signed messages as well as S/MIME messages, which are commonly used in email. S/MIME has multiple versions, but this implements a subset of *RFC 2632*, also known as S/MIME Version 3.

New in version 3.2.

```python
>>> from cryptography import x509
>>> from cryptography.hazmat.primitives import hashes, serialization
>>> from cryptography.hazmat.primitives.serialization import pkcs7

>>> cert = x509.load_pem_x509_certificate(ca_cert)
>>> key = serialization.load_pem_private_key(ca_key, None)
>>> options = [pkcs7.PKCS7Options.DetachedSignature]
>>> pkcs7.PKCS7SignatureBuilder().set_data(...
   b"data to sign"
... ).add_signer(...
   cert, key, hashes.SHA256()
... ).sign(...
   serialization.Encoding.SMIME, options
... )
b'...'"'

set_data(*data*)

Parameters

- **data** (*bytes-like*) – The data to be hashed and signed.

add_signer(*certificate, private_key, hash_algorithm*, *, rsa_padding=\*None*)

Parameters

- **certificate** – The *Certificate*.
- **private_key** – The *RSAPrivateKey* or *EllipticCurvePrivateKey* associated with the certificate provided (matches *PKCS7PrivateKeyTypes*).
- **hash_algorithm** – The *HashAlgorithm* that will be used to generate the signature. This must be one of the types in *PKCS7HashTypes*.
- **rsa_padding** – New in version 42.0.0.

This is a keyword-only argument. If **private_key** is an *RSAPrivateKey* then this can be set to either *PKCS1v15* or *PSS* to sign with those respective paddings. If this is *None* then RSA keys will default to PKCS1v15 padding. All other key types **must** not pass a value other than *None*.

add_certificate(*certificate*)

Add an additional certificate (typically used to help build a verification chain) to the PKCS7 structure. This method may be called multiple times to add as many certificates as desired.

Parameters

- **certificate** – The *Certificate* to add.
sign(encoding, options)

Parameters

• encoding – PEM, DER, or SMIME.
• options – A list of PKCS7Options.

Returns bytes
The signed PKCS7 message.

class cryptography.hazmat.primitives.serialization.pkcs7.PKCS7Options
New in version 3.2.
An enumeration of options for PKCS7 signature creation.

Text
The text option adds text/plain headers to an S/MIME message when serializing to SMIME. This option is disallowed with DER serialization.

Binary
Signing normally converts line endings (LF to CRLF). When passing this option the data will not be converted.

DetachedSignature
Don’t embed the signed data within the ASN.1. When signing with SMIME this also results in the data being added as clear text before the PEM encoded structure.

NoCapabilities
PKCS7 structures contain a MIMECapabilities section inside the authenticatedAttributes. Passing this as an option removes MIMECapabilities.

NoAttributes
PKCS7 structures contain an authenticatedAttributes section. Passing this as an option removes that section. Note that if you pass NoAttributes you can’t pass NoCapabilities since NoAttributes removes MIMECapabilities and more.

NoCerts
Don’t include the signer’s certificate in the PKCS7 structure. This can reduce the size of the signature but requires that the recipient can obtain the signer’s certificate by other means (for example from a previously signed message).

Serialization Formats

class cryptography.hazmat.primitives.serialization.PrivateFormat
New in version 0.8.
An enumeration for private key formats. Used with the private_bytes method available on RSAKey, EllipticCurvePrivateKey, DHPrivateKey and DSAPrivateKey.

TraditionalOpenSSL
Frequently known as PKCS#1 format. Still a widely used format, but generally considered legacy.

A PEM encoded RSA key will look like:

```
-----BEGIN RSA PRIVATE KEY-----
...
-----END RSA PRIVATE KEY-----
```
PKCS8

A more modern format for serializing keys which allows for better encryption. Choose this unless you have explicit legacy compatibility requirements.

A PEM encoded key will look like:

```
-----BEGIN PRIVATE KEY-----
...
-----END PRIVATE KEY-----
```

Raw

New in version 2.5.

A raw format used by X448 key exchange. It is a binary format and is invalid for other key types.

OpenSSH

New in version 3.0.

Custom private key format for OpenSSH, internals are based on SSH protocol and not ASN1. Requires PEM encoding.

A PEM encoded OpenSSH key will look like:

```
-----BEGIN OPENSSH PRIVATE KEY-----
...
-----END OPENSSH PRIVATE KEY-----
```

PKCS12

New in version 38.0.0.

The PKCS#12 format is a binary format used to store private keys and certificates. This attribute is used in conjunction with encryption_builder() to allow control of the encryption algorithm and parameters.

```python
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.serialization import PrivateFormat,
...    pkcs12
>>> encryption = (
...    PrivateFormat.PKCS12.encryption_builder().
...    kdf_rounds(50000).
...    key_cert_algorithm(pkcs12.PBES.PBESv2SHA256AndAES256CBC).
...    hmac_hash(hashes.SHA256()).build(b"my password")
... )
>>> p12 = pkcs12.serialize_key_and_certificates(
...    b"friendlyname", key, None, None, encryption
... )
```

**encryption_builder()**

New in version 38.0.0.

Returns a builder for configuring how values are encrypted with this format. You must call this method on an element of the enumeration. For example, PrivateFormat.OpenSSH.encryption_builder().

For most use cases, BestAvailableEncryption is preferred.

Returns

A new instance of KeySerializationEncryptionBuilder
>>> from cryptography.hazmat.primitives import serialization
>>> encryption = (...
...    serialization.PrivateFormat.OpenSSH.encryption_builder().kdf_rounds(30).
...    build(b"my password")
...)
>>> key.private_bytes(...
...    encoding=serialization.Encoding.PEM,
...    format=serialization.PrivateFormat.OpenSSH,
...    encryption_algorithm=encryption
...)
b'-----BEGIN OPENSSH PRIVATE KEY-----
...
-----END OPENSSH PRIVATE KEY-----

class cryptography.hazmat.primitives.serialization.PublicFormat
New in version 0.8.

An enumeration for public key formats. Used with the public_bytes method available on RSAPublicKey, EllipticCurvePublicKey, DHPublicKey, and DSAPublicKey.

SubjectPublicKeyInfo
This is the typical public key format. It consists of an algorithm identifier and the public key as a bit string. Choose this unless you have specific needs.

A PEM encoded key will look like:

```
-----BEGIN PUBLIC KEY-----
...
-----END PUBLIC KEY-----
```

PKCS1
Just the public key elements (without the algorithm identifier). This format is RSA only, but is used by some older systems.

A PEM encoded key will look like:

```
-----BEGIN RSA PUBLIC KEY-----
...
-----END RSA PUBLIC KEY-----
```

OpenSSH
New in version 1.4.

The public key format used by OpenSSH (e.g. as found in ~/.ssh/id_rsa.pub or ~/.ssh/authorized_keys).

Raw
New in version 2.5.

A raw format used by X448 key exchange. It is a binary format and is invalid for other key types.

CompressedPoint
New in version 2.5.

A compressed elliptic curve public key as defined in ANSI X9.62 section 4.3.6 (as well as SEC 1 v2.0).

UncompressedPoint
New in version 2.5.

An uncompressed elliptic curve public key as defined in ANSI X9.62 section 4.3.6 (as well as SEC 1 v2.0).
class cryptography.hazmat.primitives.serialization.ParameterFormat

New in version 2.0.

An enumeration for parameters formats. Used with the parameter_bytes method available on DHParameters.

PKCS3

ASN1 DH parameters sequence as defined in PKCS3.

Serialization Encodings

class cryptography.hazmat.primitives.serialization.Encoding

An enumeration for encoding types. Used with the private_bytes method available on RSAPrivateKey, EllipticCurvePrivateKey, DHPrivateKey, DSAPrivateKey, and X448PrivateKey as well as public_bytes on RSAPublicKey, DHPublicKey, EllipticCurvePublicKey, and X448PublicKey.

PEM

New in version 0.8.

For PEM format. This is a base64 format with delimiters.

DER

New in version 0.9.

For DER format. This is a binary format.

OpenSSH

New in version 1.4.

The format used by OpenSSH public keys. This is a text format.

Raw

New in version 2.5.

A raw format used by X448 key exchange. It is a binary format and is invalid for other key types.

X962

New in version 2.5.

The format used by elliptic curve point encodings. This is a binary format.

SMIME

New in version 3.2.

An output format used for PKCS7. This is a text format.

Serialization Encryption Types

class cryptography.hazmat.primitives.serialization.KeySerializationEncryption

Objects with this interface are usable as encryption types with methods like private_bytes available on RSAPrivateKey, EllipticCurvePrivateKey, DHPrivateKey, DSAPrivateKey and DSAPrivateKey. All other classes in this section represent the available choices for encryption and have this interface.

class cryptography.hazmat.primitives.serialization.BestAvailableEncryption(password)

Encrypt using the best available encryption for a given key. This is a curated encryption choice and the algorithm may change over time. The encryption algorithm may vary based on which version of OpenSSL the library is compiled against.
Parameters

password (bytes) – The password to use for encryption.

class cryptography.hazmat.primitives.serialization.NoEncryption

Do not encrypt.

class cryptography.hazmat.primitives.serialization.KeySerializationEncryptionBuilder

New in version 38.0.0.

A builder that can be used to configure how data is encrypted. To create one, call PrivateFormat.

encryption_builder(). Different serialization types will support different options on this builder.

kdf_rounds (rounds)

Set the number of rounds the Key Derivation Function should use. The meaning of the number of rounds
varies on the KDF being used.

Parameters

rounds (int) – Number of rounds.

key_cert_algorithm (algorithm)

Set the encryption algorithm to use when encrypting the key and certificate in a PKCS12 structure.

Parameters

algorithm – A value from the PBES enumeration.

hmac_hash (algorithm)

Set the hash algorithm to use within the MAC for a PKCS12 structure.

Parameters

algorithm – An instance of a HashAlgorithm.

build (password)

Turns the builder into an instance of KeySerializationEncryption with a given password.

Parameters

password (bytes) – The password.

Returns

A KeySerializationEncryption encryption object that can be passed to methods like

private_bytes or serialize_key_and_certificates().

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what
you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

Asymmetric Utilities

cryptography.hazmat.primitives.asymmetric.utils.decode_dss_signature (signature)

Takes in signatures generated by the DSA/ECDSA signers and returns a tuple \((r, s)\). These signatures are
ASN.1 encoded Dss–Sig–Value sequences (as defined in RFC 3279).

Parameters

signature (bytes) – The signature to decode.

Returns

The decoded tuple \((r, s)\).
**Raises**

`ValueError` – Raised if the signature is malformed.

cryptography.hazmat.primitives.asymmetric.utils.encode_dss_signature(r, s)

Creates an ASN.1 encoded Dss-Sig-Value (as defined in RFC 3279) from raw r and s values.

**Parameters**

- `r (int)` – The raw signature value r.
- `s (int)` – The raw signature value s.

**Return bytes**

The encoded signature.

class cryptography.hazmat.primitives.asymmetric.utils.Prehashed(algorithm)

New in version 1.6.

Prehashed can be passed as the `algorithm` in the RSA `sign()` and `verify()` as well as DSA `sign()` and `verify()` methods.

For elliptic curves it can be passed as the `algorithm` in ECDSA and then used with `sign()` and `verify()`.

**Parameters**

- `algorithm` – An instance of `HashAlgorithm`.

```python
>>> import hashlib
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.asymmetric import ... padding, rsa, utils ...
>>> 
>>> private_key = rsa.generate_private_key(...
...     public_exponent=65537,
...     key_size=2048,
... )
>>> prehashed_msg = hashlib.sha256(b"A message I want to sign").digest()
>>> signature = private_key.sign(...
...     prehashed_msg,
...     padding.PSS(...
...         mgf=padding.MGF1(hashes.SHA256()),
...         salt_length=padding.PSS.MAX_LENGTH ...
...     ),
...     utils.Prehashed(hashes.SHA256()) ...
... )
>>> public_key = private_key.public_key()
>>> public_key.verify(...
...     signature,
...     prehashed_msg,
...     padding.PSS(...
...         mgf=padding.MGF1(hashes.SHA256()),
...         salt_length=padding.PSS.MAX_LENGTH ...
...     ),
...     utils.Prehashed(hashes.SHA256()) ...
... )
```
Common types

Asymmetric key types do not inherit from a common base class. The following union type aliases can be used instead to reference a multitude of key types.

cryptography.hazmat.primitives.asymmetric.types.PublicKeyTypes

New in version 40.0.0.

Type alias: A union of all public key types supported: DHPublicKey, RSAPublicKey, DSAPublicKey, EllipticCurvePublicKey, Ed25519PublicKey, Ed448PublicKey, X25519PublicKey, X448PublicKey.

cryptography.hazmat.primitives.asymmetric.types.PrivateKeyTypes

New in version 40.0.0.

Type alias: A union of all private key types supported: DHPublicKey, RSAPrivateKey, DSAPrivateKey, EllipticCurvePrivateKey, Ed25519PrivateKey, Ed448PrivateKey, X25519PrivateKey, X448PrivateKey.

cryptography.hazmat.primitives.asymmetric.types.CertificatePublicKeyTypes

New in version 40.0.0.

Type alias: A union of all public key types supported for X.509 certificates: RSAPublicKey, DSAPublicKey, EllipticCurvePublicKey, Ed25519PublicKey, Ed448PublicKey, X25519PublicKey, X448PublicKey.

cryptography.hazmat.primitives.asymmetric.types.CertificateIssuerPublicKeyTypes

New in version 40.0.0.

Type alias: A union of all public key types that can sign other X.509 certificates as an issuer. x448/x25519 can be a public key, but cannot be used in signing, so they are not allowed in these contexts.

Allowed: RSAPublicKey, DSAPublicKey, EllipticCurvePublicKey, Ed25519PublicKey, Ed448PublicKey.

cryptography.hazmat.primitives.asymmetric.types.CertificateIssuerPrivateKeyTypes

New in version 40.0.0.

Type alias: A union of all private key types that can sign other X.509 certificates as an issuer. x448/x25519 can be a public key, but cannot be used in signing, so they are not allowed in these contexts.

Allowed: RSAPrivateKey, DSAPrivateKey, EllipticCurvePrivateKey, Ed25519PrivateKey, Ed448PrivateKey.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

2.3.3 Constant time functions

This module contains functions for operating with secret data in a way that does not leak information about that data through how long it takes to perform the operation. These functions should be used whenever operating on secret data along with data that is user supplied.

An example would be comparing a HMAC signature received from a client to the one generated by the server code for authentication purposes.

For more information about this sort of issue, see Coda Hale’s blog post about the timing attacks on KeyCzar and Java’s MessageDigest.isEqual().
cryptography.hazmat.primitives.constant_time.bytes_eq(a, b)

Compares a and b with one another. If a and b have different lengths, this returns False immediately. Otherwise it compares them in a way that takes the same amount of time, regardless of how many characters are the same between the two.

>>> from cryptography.hazmat.primitives import constant_time
>>> constant_time.bytes_eq(b"foo", b"foo")
True
>>> constant_time.bytes_eq(b"foo", b"bar")
False

Parameters
• a (bytes) – The left-hand side.
• b (bytes) – The right-hand side.

Returns bool
True if a has the same bytes as b, otherwise False.

Raises
TypeError – This exception is raised if a or b is not bytes.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

2.3.4 Key derivation functions

Key derivation functions derive bytes suitable for cryptographic operations from passwords or other data sources using a pseudo-random function (PRF). Different KDFs are suitable for different tasks such as:

• Cryptographic key derivation

  Deriving a key suitable for use as input to an encryption algorithm. Typically this means taking a password and running it through an algorithm such as PBKDF2HMAC or HKDF. This process is typically known as key stretching.

• Password storage

  When storing passwords you want to use an algorithm that is computationally intensive. Legitimate users will only need to compute it once (for example, taking the user’s password, running it through the KDF, then comparing it to the stored value), while attackers will need to do it billions of times. Ideal password storage KDFs will be demanding on both computational and memory resources.

2.3. Primitives
Variable cost algorithms

PBKDF2

class cryptography.hazmat.primitives.kdf.pbkdf2.PBKDF2HMAC(algorithm, length, salt, iterations)
    New in version 0.2.

PBKDF2 (Password Based Key Derivation Function 2) is typically used for deriving a cryptographic key from a password. It may also be used for key storage, but an alternate key storage KDF such as Scrypt is generally considered a better solution.

This class conforms to the KeyDerivationFunction interface.

```python
>>> import os
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.pbkdf2 import PBKDF2HMAC
>>> # Salts should be randomly generated
>>> salt = os.urandom(16)
>>> # derive
>>> kdf = PBKDF2HMAC(...
...    algorithm=hashes.SHA256(), ...
...    length=32, ...
...    salt=salt, ...
...    iterations=480000,
...    )
>>> key = kdf.derive(b"my great password")
>>> # verify
>>> kdf = PBKDF2HMAC(...
...    algorithm=hashes.SHA256(), ...
...    length=32, ...
...    salt=salt, ...
...    iterations=480000,
...    )
>>> kdf.verify(b"my great password", key)
```

Parameters

- **algorithm** – An instance of HashAlgorithm.
- **length (int)** – The desired length of the derived key in bytes. Maximum is \((2^{32} - 1) \times algorithm.digest_size\).
- **salt (bytes)** – A salt. Secure values\(^1\) are 128-bits (16 bytes) or longer and randomly generated.
- **iterations (int)** – The number of iterations to perform of the hash function. This can be used to control the length of time the operation takes. Higher numbers help mitigate brute force attacks against derived keys. A more detailed description can be consulted for additional information.

Raises

- **TypeError** – This exception is raised if salt is not bytes.

\(^1\) See NIST SP 800-132.
**derive(key_material)**

**Parameters**
- `key_material (bytes-like)`: The input key material. For PBKDF2 this should be a password.

**Return** bytes
- the derived key.

**Raises**
- `cryptography.exceptions.AlreadyFinalized`: This is raised when `derive()` or `verify()` is called more than once.
- `TypeError`: This exception is raised if `key_material` is not `bytes`.

This generates and returns a new key from the supplied password.

**verify(key_material, expected_key)**

**Parameters**
- `key_material (bytes)`: The input key material. This is the same as `key_material` in `derive()`.
- `expected_key (bytes)`: The expected result of deriving a new key, this is the same as the return value of `derive()`.

**Raises**
- `cryptography.exceptions.InvalidKey`: This is raised when the derived key does not match the expected key.
- `cryptography.exceptions.AlreadyFinalized`: This is raised when `derive()` or `verify()` is called more than once.

This checks whether deriving a new key from the supplied `key_material` generates the same key as the `expected_key`, and raises an exception if they do not match. This can be used for checking whether the password a user provides matches the stored derived key.

**Scrypt**

**class cryptography.hazmat.primitives.kdf.scrypt.Scrypt(salt, length, n, r, p)**

New in version 1.6.

Scrypt is a KDF designed for password storage by Colin Percival to be resistant against hardware-assisted attackers by having a tunable memory cost. It is described in **RFC 7914**.

This class conforms to the `KeyDerivationFunction` interface.

```python
>>> import os
>>> from cryptography.hazmat.primitives.kdf.scrypt import Scrypt
>>> salt = os.urandom(16)
>>> # derive
>>> kdf = Scrypt(...  ...  salt=salt,
...  ...  length=32,
...  ...  n=2**14,
...  ...  r=8,
...  ...  p=1,
...  ... )
```

(continues on next page)
>>> key = kdf.derive(b"my great password")
>>> # verify
>>> kdf = Scrypt(
...     salt=salt,
...     length=32,
...     n=2**14,
...     r=8,
...     p=1,
... )
>>> kdf.verify(b"my great password", key)

Parameters

- **salt** *(bytes)* – A salt.
- **length** *(int)* – The desired length of the derived key in bytes.
- **n** *(int)* – CPU/Memory cost parameter. It must be larger than 1 and be a power of 2.
- **r** *(int)* – Block size parameter.
- **p** *(int)* – Parallelization parameter.

The computational and memory cost of Scrypt can be adjusted by manipulating the 3 parameters: \(n\), \(r\), and \(p\). In general, the memory cost of Scrypt is affected by the values of both \(n\) and \(r\), while \(n\) also determines the number of iterations performed. \(p\) increases the computational cost without affecting memory usage. A more in-depth explanation of the 3 parameters can be found here.

**RFC 7914** recommends values of \(r=8\) and \(p=1\) while scaling \(n\) to a number appropriate for your system. The *scrypt paper* suggests a minimum value of \(n=2^{14}\) for interactive logins (\(t < 100\text{ms}\)), or \(n=2^{20}\) for more sensitive files (\(t < 5\text{s}\)).

**Raises**

- *cryptography.exceptions.UnsupportedAlgorithm* – If Scrypt is not supported by the OpenSSL version *cryptography* is using.
- *TypeError* – This exception is raised if *salt* is not bytes.
- *ValueError* – This exception is raised if *n* is less than 2, if *n* is not a power of 2, if *r* is less than 1 or if *p* is less than 1.

**derive**(key\_material)

Parameters

- **key\_material** *(bytes-like)* – The input key material.

Return bytes

the derived key.

**Raises**

- *TypeError* – This exception is raised if *key\_material* is not bytes.
- *cryptography.exceptions.AlreadyFinalized* – This is raised when *derive()* or *verify()* is called more than once.

This generates and returns a new key from the supplied password.
verify(key_material, expected_key)

Parameters

- **key_material** (bytes) – The input key material. This is the same as key_material in derive().

- **expected_key** (bytes) – The expected result of deriving a new key, this is the same as the return value of derive().

Raises

- **cryptography.exceptions.InvalidKey** – This is raised when the derived key does not match the expected key.

- **cryptography.exceptions.AlreadyFinalized** – This is raised when derive() or verify() is called more than once.

This checks whether deriving a new key from the supplied key_material generates the same key as the expected_key, and raises an exception if they do not match. This can be used for checking whether the password a user provides matches the stored derived key.

Fixed cost algorithms

ConcatKDF

class cryptography.hazmat.primitives.kdf.concatkdf.ConcatKDFHash(algorithm, length, otherinfo)

New in version 1.0.

ConcatKDFHash (Concated Key Derivation Function) is defined by the NIST Special Publication NIST SP 800-56Ar3 document, to be used to derive keys for use after a Key Exchange negotiation operation.

Warning: ConcatKDFHash should not be used for password storage.

```python
>>> import os
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.concatkdf import ConcatKDFHash
>>> otherinfo = b"concatkdf-example"
>>> ckdf = ConcatKDFHash(...
...   algorithm=hashes.SHA256(),
...   length=32,
...   otherinfo=otherinfo,
... )
>>> key = ckdf.derive(b"input key")
>>> ckdf = ConcatKDFHash(...
...   algorithm=hashes.SHA256(),
...   length=32,
...   otherinfo=otherinfo,
... )
>>> ckdf.verify(b"input key", key)
```

Parameters

- **algorithm** – An instance of HashAlgorithm.
• **length** *(int)* – The desired length of the derived key in bytes. Maximum is `hashlen * (2^32 - 1)`.

• **otherinfo** *(bytes)* – Application specific context information. If `None` is explicitly passed an empty byte string will be used.

**Raises**

- **TypeError** – This exception is raised if `otherinfo` is not `bytes`.

**derive** *(key_material)*

**Parameters**

- **key_material** *(bytes-like)* – The input key material.

**Return bytes**

- The derived key.

**Raises**

- **TypeError** – This exception is raised if `key_material` is not `bytes`.

- **cryptography.exceptions.AlreadyFinalized** – This is raised when `derive()` or `verify()` is called more than once.

Derives a new key from the input key material.

**verify** *(key_material, expected_key)*

**Parameters**

- **key_material** *(bytes)* – The input key material. This is the same as `key_material` in `derive()`.

- **expected_key** *(bytes)* – The expected result of deriving a new key, this is the same as the return value of `derive()`.

**Raises**

- **cryptography.exceptions.InvalidKey** – This is raised when the derived key does not match the expected key.

- **cryptography.exceptions.AlreadyFinalized** – This is raised when `derive()` or `verify()` is called more than once.

This checks whether deriving a new key from the supplied `key_material` generates the same key as the `expected_key`, and raises an exception if they do not match.

class cryptography.hazmat.primitives.kdf.concatkdf.ConcatKDFHMAC(algorithm, length, salt, otherinfo)

*New in version 1.0.*

Similar to ConcatKDFHash but uses an HMAC function instead.

**Warning:** ConcatKDFHMAC should not be used for password storage.
>>> ckdf = ConcatKDFHMAC(
...    algorithm=hashes.SHA256(),
...    length=32,
...    salt=salt,
...    otherinfo=otherinfo,
...    )
>>> key = ckdf.derive(b"input key")
>>> ckdf = ConcatKDFHMAC(
...    algorithm=hashes.SHA256(),
...    length=32,
...    salt=salt,
...    otherinfo=otherinfo,
...    )
>>> ckdf.verify(b"input key", key)

Parameters

- **algorithm** – An instance of HashAlgorithm.
- **length** (int) – The desired length of the derived key in bytes. Maximum is hashlen * \((2^32 - 1)\).
- **salt** (bytes) – A salt. Randomizes the KDF’s output. Optional, but highly recommended. Ideally as many bits of entropy as the security level of the hash: often that means cryptographically random and as long as the hash output. Does not have to be secret, but may cause stronger security guarantees if secret; If None is explicitly passed a default salt of algorithm.block_size null bytes will be used.
- **otherinfo** (bytes) – Application specific context information. If None is explicitly passed an empty byte string will be used.

Raises

- **TypeError** – This exception is raised if salt or otherinfo is not bytes.

**derive(key_material)**

Parameters

- **key_material** (bytes) – The input key material.

Return bytes

The derived key.

Raises

- **TypeError** – This exception is raised if key_material is not bytes.
- **cryptography.exceptions.AlreadyFinalized** – This is raised when derive() or verify() is called more than once.

Derives a new key from the input key material.

**verify(key_material, expected_key)**

Parameters

- **key_material** (bytes) – The input key material. This is the same as key_material in derive().

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• **expected_key** *(bytes)* – The expected result of deriving a new key, this is the same as the return value of `derive()`.

**Raises**

• [*cryptography.exceptions.InvalidKey*] – This is raised when the derived key does not match the expected key.

• [*cryptography.exceptions.AlreadyFinalized*] – This is raised when `derive()` or `verify()` is called more than once.

This checks whether deriving a new key from the supplied `key_material` generates the same key as the `expected_key`, and raises an exception if they do not match.

**HKDF**

class cryptography.hazmat.primitives.kdf.hkdf.HKDF(*algorithm*, *length*, *salt*, *info*)

New in version 0.2.

HKDF (HMAC-based Extract-and-Expand Key Derivation Function) is suitable for deriving keys of a fixed size used for other cryptographic operations.

**Warning:** HKDF should not be used for password storage.

```python
>>> import os
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDF
>>> salt = os.urandom(16)
>>> info = b"hkdf-example"
>>> hkdf = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=salt,
...     info=info,
... )
>>> key = hkdf.derive(b"input key")
>>> hkdf = HKDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     salt=salt,
...     info=info,
... )
>>> hkdf.verify(b"input key", key)
```

**Parameters**

• **algorithm** – An instance of `HashAlgorithm`.

• **length** *(int)* – The desired length of the derived key in bytes. Maximum is 255 * `(algorithm.digest_size // 8)`.

• **salt** *(bytes)* – A salt. Randomizes the KDF’s output. Optional, but highly recommended. Ideally as many bits of entropy as the security level of the hash: often that means cryptographically random and as long as the hash output. Worse (shorter, less entropy) salt values can still meaningfully contribute to security. May be reused. Does not have to be secret, but
may cause stronger security guarantees if secret; see RFC 5869 and the HKDF paper for more details. If None is explicitly passed a default salt of algorithm.digest_size // 8 null bytes will be used. See understanding HKDF for additional detail about the salt and info parameters.

- **info (bytes)** – Application specific context information. If None is explicitly passed an empty byte string will be used.

**Raises**

- **TypeError** – This exception is raised if salt or info is not bytes.

**derive(key_material)**

**Parameters**

- **key_material (bytes-like)** – The input key material.

**Return bytes**

The derived key.

**Raises**

- **TypeError** – This exception is raised if key_material is not bytes.
- **cryptography.exceptions.AlreadyFinalized** – This is raised when derive() or verify() is called more than once.

Dervies a new key from the input key material by performing both the extract and expand operations.

**verify(key_material, expected_key)**

**Parameters**

- **key_material (bytes)** – The input key material. This is the same as key_material in derive().
- **expected_key (bytes)** – The expected result of deriving a new key, this is the same as the return value of derive().

**Raises**

- **cryptography.exceptions.InvalidKey** – This is raised when the derived key does not match the expected key.
- **cryptography.exceptions.AlreadyFinalized** – This is raised when derive() or verify() is called more than once.

This checks whether deriving a new key from the supplied key_material generates the same key as the expected_key, and raises an exception if they do not match.

**class cryptography.hazmat.primitives.kdf.hkdf.HKDFExpand(algorithm, length, info)**

New in version 0.5.

HKDF consists of two stages, extract and expand. This class exposes an expand only version of HKDF that is suitable when the key material is already cryptographically strong.

**Warning:** HKDFExpand should only be used if the key material is cryptographically strong. You should use HKDF if you are unsure.
>>> import os
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.hkdf import HKDFExpand

>>> info = b"hkdf-example"
>>> key_material = os.urandom(16)
>>> hkdf = HKDFExpand(
...     algorithm=hashes.SHA256(),
...     length=32,
...     info=info,
...     )

>>> key = hkdf.derive(key_material)
>>> hkdf = HKDFExpand(
...     algorithm=hashes.SHA256(),
...     length=32,
...     info=info,
...     )

>>> hkdf.verify(key_material, key)

Parameters

- **algorithm** – An instance of HashAlgorithm.
- **length** (*int*) – The desired length of the derived key in bytes. Maximum is 255 * (algorithm.digest_size // 8).
- **info** (*bytes*) – Application specific context information. If None is explicitly passed an empty byte string will be used.

Raises

- **TypeError** – This exception is raised if info is not bytes.

**derive**(key_material)

Parameters

- **key_material** (*bytes*) – The input key material.

Return *bytes*

The derived key.

Raises

- **TypeError** – This exception is raised if key_material is not bytes.

- **cryptography.exceptions.AlreadyFinalized** – This is raised when derive() or verify() is called more than once.

Derives a new key from the input key material by performing both the extract and expand operations.

**verify**(key_material, expected_key)

Parameters

- **key_material** (*bytes*) – The input key material. This is the same as key_material in derive().
- **expected_key** (*bytes*) – The expected result of deriving a new key, this is the same as the return value of derive().

Raises
• `cryptography.exceptions.InvalidKey` – This is raised when the derived key does not match the expected key.

• `cryptography.exceptions.AlreadyFinalized` – This is raised when `derive()` or `verify()` is called more than once.

• `TypeError` – This is raised if the provided `key_material` is a `unicode` object

This checks whether deriving a new key from the supplied `key_material` generates the same key as the `expected_key`, and raises an exception if they do not match.

**KBKDF**

class `cryptography.hazmat.primitives.kdf.kbkdf.KBKDFHMAC(algorithm, mode, length, rlen, llen, location, label, context, fixed)`

New in version 1.4.

KBKDF (Key Based Key Derivation Function) is defined by the NIST SP 800-108 document, to be used to derive additional keys from a key that has been established through an automated key-establishment scheme.

**Warning:** KBKDFHMAC should not be used for password storage.

```
>>> import os
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.kbkdf import KBKDFHMAC

>>> label = b"KBKDF HMAC Label"
>>> context = b"KBKDF HMAC Context"

>>> kdf = KBKDFHMAC(
...     algorithm=hashes.SHA256(),
...     mode=Mode.CounterMode,
...     length=32,
...     rlen=4,
...     llen=4,
...     location=CounterLocation.BeforeFixed,
...     label=label,
...     context=context,
...     fixed=None,
... )

>>> key = kdf.derive(b"input key")

>>> kdf = KBKDFHMAC(
...     algorithm=hashes.SHA256(),
...     mode=Mode.CounterMode,
...     length=32,
...     rlen=4,
...     llen=4,
...     location=CounterLocation.BeforeFixed,
...     label=label,
...     context=context,
...     fixed=None,
... )

>>> kdf.verify(b"input key", key)
```
Parameters

- **algorithm** – An instance of `HashAlgorithm`.
- **mode** – The desired mode of the PRF. A value from the `Mode` enum.
- **length** (int) – The desired length of the derived key in bytes.
- **rlen** (int) – An integer that indicates the length of the binary representation of the counter in bytes.
- **llen** (int) – An integer that indicates the binary representation of the `length` in bytes.
- **location** – The desired location of the counter. A value from the `CounterLocation` enum.
- **label** (bytes) – Application specific label information. If `None` is explicitly passed an empty byte string will be used.
- **context** (bytes) – Application specific context information. If `None` is explicitly passed an empty byte string will be used.
- **fixed** (bytes) – Instead of specifying `label` and `context` you may supply your own fixed data. If `fixed` is specified, `label` and `context` is ignored.
- **break_location** (int) – A keyword-only argument. An integer that indicates the bytes offset where counter bytes are to be located. Required when `location` is `MiddleFixed`.

Raises

- **TypeError** – This exception is raised if `label` or `context` is not bytes. Also raised if `rlen`, `llen`, or `break_location` is not int.
- **ValueError** – This exception is raised if `rlen` or `llen` is greater than 4 or less than 1. This exception is also raised if you specify a `label` or `context` and `fixed`. This exception is also raised if you specify `break_location` and `location` is not `MiddleFixed`.

**derive(key_material)**

Parameters

- **key_material** (bytes-like) – The input key material.

Return bytes

The derived key.

Raises

- **TypeError** – This exception is raised if `key_material` is not bytes.
- **cryptography.exceptions.AlreadyFinalized** – This is raised when `derive()` or `verify()` is called more than once.

Derives a new key from the input key material.

**verify(key_material, expected_key)**

Parameters

- **key_material** (bytes) – The input key material. This is the same as `key_material` in `derive()`.
- **expected_key** (bytes) – The expected result of deriving a new key, this is the same as the return value of `derive()`.

Raises
• \texttt{cryptography.exceptions.InvalidKey} – This is raised when the derived key does not match the expected key.

• \texttt{cryptography.exceptions.AlreadyFinalized} – This is raised when \texttt{derive()} or \texttt{verify()} is called more than once.

This checks whether deriving a new key from the supplied \texttt{key\_material} generates the same key as the \texttt{expected\_key}, and raises an exception if they do not match.

\begin{verbatim}
class cryptography.hazmat.primitives.kdf.kbkdf.KBKDFCMAC(algorithm, mode, length, rlen, llen, location, label, context, fixed)

New in version 35.0.0.

KBKDF (Key Based Key Derivation Function) is defined by the NIST SP 800-108 document, to be used to derive additional keys from a key that has been established through an automated key-establishment scheme.

\begin{verbatim}
>>> from cryptography.hazmat.primitives.ciphers import algorithms
>>> from cryptography.hazmat.primitives.kdf.kbkdf import ( ...
...   CounterLocation, KBKDFCMAC, Mode ...
... )
>>> label = b"KBKDF CMAC Label"
>>> context = b"KBKDF CMAC Context"
>>> kdf = KBKDFCMAC( ...
...   algorithm=algorithms.AES, ...
...   mode=Mode.CounterMode, ...
...   length=32, ...
...   rlen=4, ...
...   llen=4, ...
...   location=CounterLocation.BeforeFixed, ...
...   label=label, ...
...   context=context, ...
...   fixed=None, ...
... )
>>> key = kdf.derive(b"32 bytes long input key material")
>>> kdf = KBKDFCMAC( ...
...   algorithm=algorithms.AES, ...
...   mode=Mode.CounterMode, ...
...   length=32, ...
...   rlen=4, ...
...   llen=4, ...
...   location=CounterLocation.BeforeFixed, ...
...   label=label, ...
...   context=context, ...
...   fixed=None, ...
... )
>>> kdf.verify(b"32 bytes long input key material", key)
\end{verbatim}

Parameters

• \texttt{algorithm} – A class implementing a block cipher algorithm being a subclass of \texttt{CipherAlgorithm} and \texttt{BlockCipherAlgorithm}.

• \texttt{mode} – The desired mode of the PRF. A value from the \texttt{Mode} enum.
• **length (int)** – The desired length of the derived key in bytes.
• **rlen (int)** – An integer that indicates the length of the binary representation of the counter in bytes.
• **llen (int)** – An integer that indicates the binary representation of the length in bytes.
• **location** – The desired location of the counter. A value from the `CounterLocation` enum.
• **label (bytes)** – Application specific label information. If `None` is explicitly passed an empty byte string will be used.
• **context (bytes)** – Application specific context information. If `None` is explicitly passed an empty byte string will be used.
• **fixed (bytes)** – Instead of specifying label and context you may supply your own fixed data. If `fixed` is specified, `label` and `context` is ignored.
• **break_location (int)** – A keyword-only argument. An integer that indicates the bytes offset where counter bytes are to be located. Required when `location` is `MiddleFixed`.

Raises

• `cryptography.exceptions.UnsupportedAlgorithm` – This is raised if `algorithm` is not a subclass of `CipherAlgorithm` and `BlockCipherAlgorithm`.
• `TypeError` – This exception is raised if `label` or `context` is not bytes, `rlen`, `llen`, or `break_location` is not int, `mode` is not `Mode` or `location` is not `CounterLocation`.
• `ValueError` – This exception is raised if `rlen` or `llen` is greater than 4 or less than 1. This exception is also raised if you specify a `label` or `context` and `fixed`. This exception is also raised if you specify `break_location` and `location` is not `MiddleFixed`.

**derive(key_material)**

Parameters

  • **key_material (bytes-like)** – The input key material.

Return bytes

  The derived key.

Raises

• `TypeError` – This exception is raised if `key_material` is not bytes.
• `ValueError` – This exception is raised if `key_material` is not a valid key for `algorithm` passed to `KRBDFMAC` constructor.

• `cryptography.exceptions.AlreadyFinalized` – This is raised when `derive()` or `verify()` is called more than once.

Derives a new key from the input key material.

**verify(key_material, expected_key)**

Parameters

• **key_material (bytes)** – The input key material. This is the same as `key_material` in `derive()`.
• **expected_key (bytes)** – The expected result of deriving a new key, this is the same as the return value of `derive()`.
Raises

cryptography.exceptions.InvalidKey – This is raised when the derived key does not match the expected key.

Raises

Exceptions raised by `derive()`.

This checks whether deriving a new key from the supplied `key_material` generates the same key as the `expected_key`, and raises an exception if they do not match.

class cryptography.hazmat.primitives.kdf.kbkdf.Mode

An enumeration for the key based key derivative modes.

CounterMode

The output of the PRF is computed with a counter as the iteration variable.

class cryptography.hazmat.primitives.kdf.kbkdf.CounterLocation

An enumeration for the key based key derivative counter location.

BeforeFixed

The counter iteration variable will be concatenated before the fixed input data.

AfterFixed

The counter iteration variable will be concatenated after the fixed input data.

MiddleFixed

New in version 38.0.0.

The counter iteration variable will be concatenated in the middle of the fixed input data.

X963KDF

class cryptography.hazmat.primitives.kdf.x963kdf.X963KDF(algorithm, length, otherinfo)

New in version 1.1.

X963KDF (ANSI X9.63 Key Derivation Function) is defined by ANSI in the ANSI X9.63:2001 document, to be used to derive keys for use after a Key Exchange negotiation operation.

SECG in SEC 1 v2.0 recommends that ConcatKDFHash be used for new projects. This KDF should only be used for backwards compatibility with pre-existing protocols.

Warning: X963KDF should not be used for password storage.

```python
>>> import os
>>> from cryptography.hazmat.primitives import hashes
>>> from cryptography.hazmat.primitives.kdf.x963kdf import X963KDF
>>> sharedinfo = b"ANSI X9.63 Example"
>>> xkdf = X963KDF(
...     algorithm=hashes.SHA256(),
...     length=32,
...     sharedinfo=sharedinfo,
...     )
>>> key = xkdf.derive(b"input key")
>>> xkdf = X963KDF(
```
algorithm=hashes.SHA256(),
... length=32,
... sharedinfo=sharedinfo,
...

```python
>>> xkdf.verify(b"input key", key)
```

**Parameters**

- **algorithm** – An instance of `HashAlgorithm`.
- **length** *(int)* – The desired length of the derived key in bytes. Maximum is *hashlen* \((2^{32} - 1)\).
- **sharedinfo** *(bytes)* – Application specific context information. If `None` is explicitly passed an empty byte string will be used.

**Raises**

- **`TypeError`** – This exception is raised if `sharedinfo` is not `bytes`.

**derive**(key_material)

**Parameters**

- **key_material** *(bytes-like)* – The input key material.

**Return**

- bytes

  The derived key.

**Raises**

- **`TypeError`** – This exception is raised if `key_material` is not `bytes`.
- **`cryptography.exceptions.AlreadyFinalized`** – This is raised when `derive()` or `verify()` is called more than once.

Derives a new key from the input key material.

**verify**(key_material, expected_key)

**Parameters**

- **key_material** *(bytes)* – The input key material. This is the same as `key_material` in `derive()`.
- **expected_key** *(bytes)* – The expected result of deriving a new key, this is the same as the return value of `derive()`.

**Raises**

- **`cryptography.exceptions.InvalidKey`** – This is raised when the derived key does not match the expected key.
- **`cryptography.exceptions.AlreadyFinalized`** – This is raised when `derive()` or `verify()` is called more than once.

This checks whether deriving a new key from the supplied `key_material` generates the same key as the `expected_key`, and raises an exception if they do not match.
Interface

class cryptography.hazmat.primitives.kdf.KeyDerivationFunction

New in version 0.2.

derive(key_material)

Parameters

key_material (bytes) – The input key material. Depending on what key derivation function you are using this could be either random bytes, or a user supplied password.

Returns

The new key.

Raises

cryptography.exceptions.AlreadyFinalized – This is raised when derive() or verify() is called more than once.

This generates and returns a new key from the supplied key material.

verify(key_material, expected_key)

Parameters

• key_material (bytes) – The input key material. This is the same as key_material in derive().

• expected_key (bytes) – The expected result of deriving a new key, this is the same as the return value of derive().

Raises

• cryptography.exceptions.InvalidKey – This is raised when the derived key does not match the expected key.

• cryptography.exceptions.AlreadyFinalized – This is raised when derive() or verify() is called more than once.

This checks whether deriving a new key from the supplied key_material generates the same key as the expected_key, and raises an exception if they do not match. This can be used for something like checking whether a user’s password attempt matches the stored derived key.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

2.3.5 Key wrapping

Key wrapping is a cryptographic construct that uses symmetric encryption to encapsulate key material. Key wrapping algorithms are occasionally utilized to protect keys at rest or transmit them over insecure networks. Many of the protections offered by key wrapping are also offered by using authenticated symmetric encryption.

cryptography.hazmat.primitives.keywrap.aes_key_wrap(wrapping_key, key_to_wrap)

New in version 1.1.

This function performs AES key wrap (without padding) as specified in RFC 3394.

Parameters
• **wrapping_key** *(bytes)* – The wrapping key.
• **key_to_wrap** *(bytes)* – The key to wrap.

**Return bytes**
The wrapped key as bytes.

cryptography.hazmat.primitives.keywrap.aes_key_unwrap*(wrapping_key, wrapped_key)*

New in version 1.1.

This function performs AES key unwrap (without padding) as specified in RFC 3394.

**Parameters**
• **wrapping_key** *(bytes)* – The wrapping key.
• **wrapped_key** *(bytes)* – The wrapped key.

**Return bytes**
The unwrapped key as bytes.

**Raises**
  - `cryptography.hazmat.primitives.keywrap.InvalidUnwrap` – This is raised if the key is not successfully unwrapped.

cryptography.hazmat.primitives.keywrap.aes_key_wrap_with_padding*(wrapping_key, key_to_wrap)*

New in version 2.2.

This function performs AES key wrap with padding as specified in RFC 5649.

**Parameters**
• **wrapping_key** *(bytes)* – The wrapping key.
• **key_to_wrap** *(bytes)* – The key to wrap.

**Return bytes**
The wrapped key as bytes.

cryptography.hazmat.primitives.keywrap.aes_key_unwrap_with_padding*(wrapping_key, wrapped_key)*

New in version 2.2.

This function performs AES key unwrap with padding as specified in RFC 5649.

**Parameters**
• **wrapping_key** *(bytes)* – The wrapping key.
• **wrapped_key** *(bytes)* – The wrapped key.

**Return bytes**
The unwrapped key as bytes.

**Raises**
  - `cryptography.hazmat.primitives.keywrap.InvalidUnwrap` – This is raised if the key is not successfully unwrapped.
Exceptions

class cryptography.hazmat.primitives.keywrap.InvalidUnwrap

This is raised when a wrapped key fails to unwrap. It can be caused by a corrupted or invalid wrapped key or an invalid wrapping key.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

2.3.6 Message authentication codes

While cryptography supports multiple MAC algorithms, we strongly recommend that HMAC should be used unless you have a very specific need.

For more information on why HMAC is preferred, see Use cases for CMAC vs. HMAC?

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

Cipher-based message authentication code (CMAC)

Cipher-based message authentication codes (or CMACs) are a tool for calculating message authentication codes using a block cipher coupled with a secret key. You can use an CMAC to verify both the integrity and authenticity of a message.

A subset of CMAC with the AES-128 algorithm is described in RFC 4493.

class cryptography.hazmat.primitives.cmac.CMAC(algorithm)

New in version 0.4.

CMAC objects take a BlockCipherAlgorithm instance.

```python
>>> from cryptography.hazmat.primitives import cmac
>>> from cryptography.hazmat.primitives.ciphers import algorithms
>>> c = cmac.CMAC(algorithms.AES(key))
>>> c.update(b"message to authenticate")
>>> c.finalize()
b'CT\xd1\xc8\xe15\xbe4e\xdb\x86\x84\xca\xd9Xk'
```

If algorithm isn’t a BlockCipherAlgorithm instance then TypeError will be raised.

To check that a given signature is correct use the verify() method. You will receive an exception if the signature is wrong:

```python
>>> c = cmac.CMAC(algorithms.AES(key))
>>> c.update(b"message to authenticate")
>>> c.verify(b"an incorrect signature")
Traceback (most recent call last):
```

(continues on next page)
cryptography.exceptions.InvalidSignature: Signature did not match digest.

Parameters
algorithm – An instance of BlockCipherAlgorithm.

Raises
• TypeError – This is raised if the provided algorithm is not an instance of BlockCipherAlgorithm
• cryptography.exceptions.UnsupportedAlgorithm – This is raised if the provided algorithm is unsupported.

update(data)

Parameters
data (bytes) – The bytes to hash and authenticate.

Raises
• cryptography.exceptions.AlreadyFinalized – See finalize()
• TypeError – This exception is raised if data is not bytes.

copy()

Copy this CMAC instance, usually so that we may call finalize() to get an intermediate value while we continue to call update() on the original instance.

Returns
A new instance of CMAC that can be updated and finalized independently of the original instance.

Raises
• cryptography.exceptions.AlreadyFinalized – See finalize()

verify(signature)

Finalize the current context and securely compare the MAC to signature.

Parameters
signature (bytes) – The bytes to compare the current CMAC against.

Raises
• cryptography.exceptions.AlreadyFinalized – See finalize()
• cryptography.exceptions.InvalidSignature – If signature does not match digest
• TypeError – This exception is raised if signature is not bytes.

finalize()

Finalize the current context and return the message authentication code as bytes.

After finalize has been called this object can no longer be used and update(), copy(), verify() and finalize() will raise an AlreadyFinalized exception.

Return bytes
The message authentication code as bytes.

Raises
• cryptography.exceptions.AlreadyFinalized –
This is a “Hazardous Materials” module. You should **ONLY** use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

## Hash-based message authentication codes (HMAC)

Hash-based message authentication codes (or HMACs) are a tool for calculating message authentication codes using a cryptographic hash function coupled with a secret key. You can use an HMAC to verify both the integrity and authenticity of a message.

```python
from cryptography.hazmat.primitives import hashes, hmac

key = b'test key. Beware! A real key should use os.urandom or TRNG to generate'
h = hmac.HMAC(key, hashes.SHA256())
h.update(b'message to hash')
signature = h.finalize()
```

If `algorithm` isn’t a `HashAlgorithm` instance then `TypeError` will be raised.

To check that a given signature is correct use the `verify()` method. You will receive an exception if the signature is wrong:

```python
h = hmac.HMAC(key, hashes.SHA256())
h.update(b'message to hash')
h_copy = h.copy()  # get a copy of `h` to be reused
h.verify(signature)

h_copy.verify(b'an incorrect signature')
```

**Parameters**

- `key` (*bytes-like*) – The secret key.
- `algorithm` – An `HashAlgorithm` instance such as those described in Cryptographic Hashes.

**Raises**

- `cryptography.exceptions.UnsupportedAlgorithm` – This is raised if the provided `algorithm` isn’t supported.
update\(msg\)

Parameters
msg \((bytes-like)\) – The bytes to hash and authenticate.

Raises

- cryptography.exceptions.AlreadyFinalized – See finalize()
- TypeError – This exception is raised if msg is not bytes.

copy()

Copy this HMAC instance, usually so that we may call finalize() to get an intermediate digest value while we continue to call update() on the original instance.

Returns
A new instance of HMAC that can be updated and finalized independently of the original instance.

Raises

- cryptography.exceptions.AlreadyFinalized – See finalize()

verify\((signature)\)

Finalize the current context and securely compare digest to signature.

Parameters
signature \((bytes)\) – The bytes to compare the current digest against.

Raises

- cryptography.exceptions.AlreadyFinalized – See finalize()
- cryptography.exceptions.InvalidSignature – If signature does not match digest
- TypeError – This exception is raised if signature is not bytes.

finalize()

Finalize the current context and return the message digest as bytes.

After finalize has been called this object can no longer be used and update(), copy(), verify() and finalize() will raise an AlreadyFinalized exception.

Return bytes
The message digest as bytes.

Raises

- cryptography.exceptions.AlreadyFinalized –

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.
Poly1305

Poly1305 is an authenticator that takes a 32-byte key and a message and produces a 16-byte tag. This tag is used to authenticate the message. Each key must only be used once. Using the same key to generate tags for multiple messages allows an attacker to forge tags. Poly1305 is described in RFC 7539.

class cryptography.hazmat.primitives.poly1305.Poly1305(key)

New in version 2.7.

Warning: Using the same key to generate tags for multiple messages allows an attacker to forge tags. Always generate a new key per message you want to authenticate. If you are using this as a MAC for symmetric encryption please use ChaCha20Poly1305 instead.

```python
>>> from cryptography.hazmat.primitives import poly1305
>>> p = poly1305.Poly1305(key)
>>> p.update(b"message to authenticate")
>>> p.finalize()
```

To check that a given tag is correct use the `verify()` method. You will receive an exception if the tag is wrong:

```python
>>> p = poly1305.Poly1305(key)
>>> p.update(b"message to authenticate")
>>> p.verify(b"an incorrect tag")
Traceback (most recent call last):
... cryptography.exceptions.InvalidSignature: Value did not match computed tag.
```

Parameters

- **key** *(bytes-like)* – The secret key.

Raises

- `cryptography.exceptions.UnsupportedAlgorithm` – This is raised if the version of OpenSSL cryptography is compiled against does not support this algorithm.

`update(data)`

Parameters

- **data** *(bytes-like)* – The bytes to hash and authenticate.

Raises

- `cryptography.exceptions.AlreadyFinalized` – See `finalize()`
- `TypeError` – This exception is raised if `data` is not bytes.

`verify(tag)`

Finalize the current context and securely compare the MAC to `tag`.

Parameters

- **tag** *(bytes)* – The bytes to compare against.

Raises

- `cryptography.exceptions.AlreadyFinalized` – See `finalize()`
- `cryptography.exceptions.InvalidSignature` – If `tag` does not match.
• **TypeError** – This exception is raised if `tag` is not bytes.

**finalize()**

Finalize the current context and return the message authentication code as bytes.

After **finalize** has been called this object can no longer be used and `update()`, `verify()`, and `finalize()` will raise an `AlreadyFinalized` exception.

**Return bytes**

The message authentication code as bytes.

**Raises**

cryptography.exceptions.AlreadyFinalized –

**classmethod generate_tag(key, data)**

A single step alternative to do sign operations. Returns the message authentication code as bytes for the given `key` and `data`.

**Parameters**

- **key** *(bytes-like)* – Secret key as bytes.
- **data** *(bytes-like)* – The bytes to hash and authenticate.

**Return bytes**

The message authentication code as bytes.

**Raises**

- cryptography.exceptions.UnsupportedAlgorithm – This is raised if the version of OpenSSL cryptography is compiled against does not support this algorithm.
- **TypeError** – This exception is raised if `key` or `data` are not bytes.

```python
>>> poly1305.Poly1305.generate_tag(key, b"message to authenticate")
b'T\xae\xff3\xbdf\xef\xd5r\xe01\xe2n=\xb7\xfdh'
```

**classmethod verify_tag(key, data, tag)**

A single step alternative to do verify operations. Securely compares the MAC to `tag`, using the given `key` and `data`.

**Parameters**

- **key** *(bytes-like)* – Secret key as bytes.
- **data** *(bytes-like)* – The bytes to hash and authenticate.
- **tag** *(bytes)* – The bytes to compare against.

**Raises**

- cryptography.exceptions.UnsupportedAlgorithm – This is raised if the version of OpenSSL cryptography is compiled against does not support this algorithm.
- **TypeError** – This exception is raised if `key`, `data` or `tag` are not bytes.
- cryptography.exceptions.InvalidSignature – If tag does not match.

```python
>>> poly1305.Poly1305.verify_tag(key, b"message to authenticate", b"an→→incorrect tag")
Traceback (most recent call last):
...
cryptography.exceptions.InvalidSignature: Value did not match computed tag.
```
This is a “Hazardous Materials” module. You should **ONLY** use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

### 2.3.7 Message digests (Hashing)

```python
from cryptography.hazmat.primitives.hashes import hashes

digest = hashes.Hash(hashes.SHA256())
digest.update(b"abc")
digest.update(b"123")
digest.finalize()
```

Keep in mind that attacks against cryptographic hashes only get stronger with time, and that often algorithms that were once thought to be strong, become broken. Because of this it’s important to include a plan for upgrading the hash algorithm you use over time. For more information, see Lifetimes of cryptographic hash functions.

**Parameters**
- **algorithm** – A `HashAlgorithm` instance such as those described in below.

**Raises**
- `cryptography.exceptions.UnsupportedAlgorithm` – This is raised if the provided algorithm is unsupported.

**update**(data)

**Parameters**
- **data** *(bytes)* – The bytes to be hashed.

**Raises**
- `TypeError` – This exception is raised if `data` is not bytes.

**copy**()

Copy this `Hash` instance, usually so that you may call `finalize()` to get an intermediate digest value while we continue to call `update()` on the original instance.

**Returns**
- A new instance of `Hash` that can be updated and finalized independently of the original instance.

**Raises**
**finalize()**

Finalize the current context and return the message digest as bytes.

After `finalize` has been called this object can no longer be used and `update()`, `copy()`, and `finalize()` will raise an `AlreadyFinalized` exception.

**Return bytes**

The message digest as bytes.

---

**SHA-2 family**

**class** cryptography.hazmat.primitives.hashes.SHA224

SHA-224 is a cryptographic hash function from the SHA-2 family and is standardized by NIST. It produces a 224-bit message digest.

**class** cryptography.hazmat.primitives.hashes.SHA256

SHA-256 is a cryptographic hash function from the SHA-2 family and is standardized by NIST. It produces a 256-bit message digest.

**class** cryptography.hazmat.primitives.hashes.SHA384

SHA-384 is a cryptographic hash function from the SHA-2 family and is standardized by NIST. It produces a 384-bit message digest.

**class** cryptography.hazmat.primitives.hashes.SHA512

SHA-512 is a cryptographic hash function from the SHA-2 family and is standardized by NIST. It produces a 512-bit message digest.

**class** cryptography.hazmat.primitives.hashes.SHA512_224

New in version 2.5.

SHA-512/224 is a cryptographic hash function from the SHA-2 family and is standardized by NIST. It produces a 224-bit message digest.

**class** cryptography.hazmat.primitives.hashes.SHA512_256

New in version 2.5.

SHA-512/256 is a cryptographic hash function from the SHA-2 family and is standardized by NIST. It produces a 256-bit message digest.

---

**BLAKE2**

BLAKE2 is a cryptographic hash function specified in [RFC 7693](https://tools.ietf.org/html/rfc7693). BLAKE2’s design makes it immune to length-extension attacks, an advantage over the SHA-family of hashes.

---

**Note:** While the RFC specifies keying, personalization, and salting features, these are not supported at this time due to limitations in OpenSSL.

**class** cryptography.hazmat.primitives.hashes.BLAKE2b(digest_size)

BLAKE2b is optimized for 64-bit platforms and produces an 1 to 64-byte message digest.

**Parameters**

`digest_size (int)` – The desired size of the hash output in bytes. Only 64 is supported at this time.
Raises

\texttt{ValueError} – If the \texttt{digest\_size} is invalid.

class cryptography.hazmat.primitives.hashes.BLAKE2s(digest\_size)

BLAKE2s is optimized for 8 to 32-bit platforms and produces a 1 to 32-byte message digest.

Parameters

\texttt{digest\_size (int)} – The desired size of the hash output in bytes. Only 32 is supported at this time.

Raises

\texttt{ValueError} – If the \texttt{digest\_size} is invalid.

SHA-3 family

SHA-3 is the most recent NIST secure hash algorithm standard. Despite the larger number SHA-3 is not considered to be better than SHA-2. Instead, it uses a significantly different internal structure so that if an attack appears against SHA-2 it is unlikely to apply to SHA-3. SHA-3 is significantly slower than SHA-2 so at this time most users should choose SHA-2.

class cryptography.hazmat.primitives.hashes.SHA3_224

New in version 2.5.

SHA3/224 is a cryptographic hash function from the SHA-3 family and is standardized by NIST. It produces a 224-bit message digest.

class cryptography.hazmat.primitives.hashes.SHA3_256

New in version 2.5.

SHA3/256 is a cryptographic hash function from the SHA-3 family and is standardized by NIST. It produces a 256-bit message digest.

class cryptography.hazmat.primitives.hashes.SHA3_384

New in version 2.5.

SHA3/384 is a cryptographic hash function from the SHA-3 family and is standardized by NIST. It produces a 384-bit message digest.

class cryptography.hazmat.primitives.hashes.SHA3_512

New in version 2.5.

SHA3/512 is a cryptographic hash function from the SHA-3 family and is standardized by NIST. It produces a 512-bit message digest.

class cryptography.hazmat.primitives.hashes.SHAKE128(digest\_size)

New in version 2.5.

SHAKE128 is an extendable output function (XOF) based on the same core permutations as SHA3. It allows the caller to obtain an arbitrarily long digest length. Longer lengths, however, do not increase security or collision resistance and lengths shorter than 128 bit (16 bytes) will decrease it.

Parameters

\texttt{digest\_size (int)} – The length of output desired. Must be greater than zero.

Raises

\texttt{ValueError} – If the \texttt{digest\_size} is invalid.
class cryptography.hazmat.primitives.hashes.SHAKE256(digest_size)
    New in version 2.5.

    SHAKE256 is an extendable output function (XOF) based on the same core permutations as SHA3. It allows
the caller to obtain an arbitrarily long digest length. Longer lengths, however, do not increase security or collision
resistance and lengths shorter than 256 bit (32 bytes) will decrease it.

    Parameters
        digest_size (int) – The length of output desired. Must be greater than zero.

    Raises
        ValueError – If the digest_size is invalid.

SHA-1

Warning: SHA-1 is a deprecated hash algorithm that has practical known collision attacks. You are strongly
discouraged from using it. Existing applications should strongly consider moving away.

class cryptography.hazmat.primitives.hashes.SHA1

SHA-1 is a cryptographic hash function standardized by NIST. It produces an 160-bit message digest. Crypt-
analysis of SHA-1 has demonstrated that it is vulnerable to practical collision attacks, and collisions have been
demonstrated.

MD5

Warning: MD5 is a deprecated hash algorithm that has practical known collision attacks. You are strongly
discouraged from using it. Existing applications should strongly consider moving away.

class cryptography.hazmat.primitives.hashes.MD5

MD5 is a deprecated cryptographic hash function. It produces a 128-bit message digest and has practical known
collision attacks.

SM3

class cryptography.hazmat.primitives.hashes.SM3
    New in version 35.0.0.

    SM3 is a cryptographic hash function standardized by the Chinese National Cryptography Administration in
GM/T 0004-2012. It produces 256-bit message digests. (An English description is available at draft-sca-cfrg-
sm3.) This hash should be used for compatibility purposes where required and is not otherwise recommended
for use.
Interfaces

```python
class cryptography.hazmat.primitives.hashes.HashAlgorithm
    name
        Type
            str
        The standard name for the hash algorithm, for example: "sha256" or "blake2b".

digest_size
        Type
            int
        The size of the resulting digest in bytes.
```

```python
class cryptography.hazmat.primitives.hashes.HashContext
    algorithm
        A HashAlgorithm that will be used by this context.

    update(data)
        Parameters
            data(bytes) – The data you want to hash.

    finalize()
        Returns
            The final digest as bytes.

copy()
        Returns
            A HashContext that is a copy of the current context.
```

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

You may instead be interested in Fernet (symmetric encryption).

### 2.3.8 Symmetric encryption

Symmetric encryption is a way to encrypt or hide the contents of material where the sender and receiver both use the same secret key. Note that symmetric encryption is not sufficient for most applications because it only provides secrecy but not authenticity. That means an attacker can’t see the message but an attacker can create bogus messages and force the application to decrypt them. In many contexts, a lack of authentication on encrypted messages can result in a loss of secrecy as well.

For this reason in nearly all contexts it is necessary to combine encryption with a message authentication code, such as HMAC, in an “encrypt-then-MAC” formulation as described by Colin Percival. cryptography includes a recipe named Fernet (symmetric encryption) that does this for you. To minimize the risk of security issues you should evaluate Fernet to see if it fits your needs before implementing anything using this module. If Fernet (symmetric encryption) is not appropriate for your use-case then you may still benefit from Authenticated encryption which combines encryption and authentication securely.
Cryptography Documentation, Release 42.0.0.dev1

```python
>>> import os
>>> from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes
>>> key = os.urandom(32)
>>> iv = os.urandom(16)
>>> cipher = Cipher(algorithms.AES(key), modes.CBC(iv))
>>> encryptor = cipher.encryptor()
>>> ct = encryptor.update(b'a secret message') + encryptor.finalize()
>>> decryptor = cipher.decryptor()
>>> decryptor.update(ct) + decryptor.finalize()
b'a secret message'
```

Parameters

- **algorithm** – A `CipherAlgorithm` instance such as those described below.
- **mode** – A `Mode` instance such as those described below.

Raises

- `cryptography.exceptions.UnsupportedAlgorithm` – This is raised if the provided algorithm is unsupported.

encryptor()

Returns

An encrypting `CipherContext` instance.

If the requested combination of algorithm and mode is unsupported an `UnsupportedAlgorithm` exception will be raised.

decryptor()

Returns

A decrypting `CipherContext` instance.

If the requested combination of algorithm and mode is unsupported an `UnsupportedAlgorithm` exception will be raised.

Algorithms

class cryptography.hazmat.primitives.ciphers.algorithms.AES(key)

AES (Advanced Encryption Standard) is a block cipher standardized by NIST. AES is both fast, and cryptographically strong. It is a good default choice for encryption.

Parameters

- **key** (`bytes-like`) – The secret key. This must be kept secret. Either 128, 192, or 256 bits long.

class cryptography.hazmat.primitives.ciphers.algorithms.AES128(key)

New in version 38.0.0.

An AES class that only accepts 128 bit keys. This is identical to the standard AES class except that it will only accept a single key length.

Parameters

- **key** (`bytes-like`) – The secret key. This must be kept secret. 128 bits long.
class cryptography.hazmat.primitives.ciphers.algorithms.AES256(key)

New in version 38.0.0.

An AES class that only accepts 256 bit keys. This is identical to the standard AES class except that it will only accept a single key length.

Parameters

key (bytes-like) – The secret key. This must be kept secret. 256 bits long.

class cryptography.hazmat.primitives.ciphers.algorithms.Camellia(key)

Camellia is a block cipher approved for use by CRYPTREC and ISO/IEC. It is considered to have comparable security and performance to AES but is not as widely studied or deployed.

Parameters

key (bytes-like) – The secret key. This must be kept secret. Either 128, 192, or 256 bits long.

class cryptography.hazmat.primitives.ciphers.algorithms.ChaCha20(key, nonce)

New in version 2.1.

Note: In most cases users should use ChaCha20Poly1305 instead of this class. ChaCha20 alone does not provide integrity so it must be combined with a MAC to be secure. ChaCha20Poly1305 does this for you.

ChaCha20 is a stream cipher used in several IETF protocols. While it is standardized in RFC 7539, this implementation is not RFC-compliant. This implementation uses a 64 bits counter and a 64 bits nonce as defined in the original algorithm, rather than the 32/96 counter/nonce split defined in RFC 7539.

Parameters

• key (bytes-like) – The secret key. This must be kept secret. 256 bits (32 bytes) in length.

• nonce (bytes-like) – Should be unique, a nonce. It is critical to never reuse a nonce with a given key. Any reuse of a nonce with the same key compromises the security of every message encrypted with that key. The nonce does not need to be kept secret and may be included with the ciphertext. This must be 128 bits in length. The 128-bit value is a concatenation of the 8-byte little-endian counter and the 8-byte nonce.

Note: In the original version of the algorithm the nonce is defined as a 64-bit value that is later concatenated with a block counter (encoded as a 64-bit little-endian). If you have a separate nonce and block counter you will need to concatenate it yourself before passing it. For example, if you have an initial block counter of 2 and a 64-bit nonce the concatenated nonce would be \texttt{struct.pack(\textquotesingle\textless Q\textquotesingle, 2) + nonce}.

>>> import struct, os
>>> from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes
>>> nonce = os.urandom(8)
>>> counter = 0
>>> full_nonce = struct.pack(\textquotesingle\textless Q\textquotesingle, counter) + nonce
>>> algorithm = algorithms.ChaCha20(key, full_nonce)
>>> cipher = Cipher(algorithm, mode=None)
>>> encryptor = cipher.encryptor()
>>> ct = encryptor.update(b\textquotesingle\textapos a secret message\textapos )
>>> decryptor = cipher.decryptor()
>>> decryptor.update(ct)
>>> b\textapos a secret message\textapos
Triple DES (Data Encryption Standard), sometimes referred to as 3DES, is a block cipher standardized by NIST. Triple DES has known crypto-analytic flaws, however none of them currently enable a practical attack. Nonetheless, Triple DES is not recommended for new applications because it is incredibly slow; old applications should consider moving away from it.

Parameters

- key (bytes-like) – The secret key. This must be kept secret. Either 64, 128, or 192 bits long. DES only uses 56, 112, or 168 bits of the key as there is a parity byte in each component of the key. Some writing refers to there being up to three separate keys that are each 56 bits long, they can simply be concatenated to produce the full key.

CAST5 (also known as CAST-128) is a block cipher approved for use in the Canadian government by the Communications Security Establishment. It is a variable key length cipher and supports keys from 40-128 bits in length.

Parameters

- key (bytes-like) – The secret key. This must be kept secret. 40 to 128 bits in length in increments of 8 bits.

SEED is a block cipher developed by the Korea Information Security Agency (KISA). It is defined in RFC4269 and is used broadly throughout South Korean industry, but rarely found elsewhere.

Parameters

- key (bytes-like) – The secret key. This must be kept secret. 128 bits in length.

SM4 is a block cipher developed by the Chinese Government and standardized in the GB/T 32907-2016. It is used in the Chinese WAPI (Wired Authentication and Privacy Infrastructure) standard. (An English description is available at draft-ribose-cfrg-sm4-10.) This block cipher should be used for compatibility purposes where required and is not otherwise recommended for use.

Parameters

- key (bytes-like) – The secret key. This must be kept secret. 128 bits in length.

Warning: These ciphers are considered weak for a variety of reasons. New applications should avoid their use and existing applications should strongly consider migrating away.

Blowfish is a block cipher developed by Bruce Schneier. It is known to be susceptible to attacks when using weak keys. The author has recommended that users of Blowfish move to newer algorithms such as AES.

Parameters

- key (bytes-like) – The secret key. This must be kept secret. 32 to 448 bits in length in increments of 8 bits.
The `cryptography` library provides various primitives for cryptographic operations. Here are some important components:

### ARC4

**class cryptography.hazmat.primitives.ciphers.algorithms.ARC4(key)**

ARC4 (Alleged RC4) is a stream cipher with serious weaknesses in its initial stream output. Its use is strongly discouraged. ARC4 does not use mode constructions.

**Parameters**

- `key (bytes-like)` – The secret key. This must be kept secret. Either 40, 56, 64, 80, 128, 192, or 256 bits in length.

```python
>>> from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes

>>> algorithm = algorithms.ARC4(key)
>>> cipher = Cipher(algorithm, mode=None)
>>> encryptor = cipher.encryptor()
>>> ct = encryptor.update(b"a secret message")
>>> decryptor = cipher.decryptor()
>>> decryptor.update(ct)
```

### IDEA

**class cryptography.hazmat.primitives.ciphers.algorithms.IDEA(key)**

IDEA (International Data Encryption Algorithm) is a block cipher created in 1991. It is an optional component of the OpenPGP standard. This cipher is susceptible to attacks when using weak keys. It is recommended that you do not use this cipher for new applications.

**Parameters**

- `key (bytes-like)` – The secret key. This must be kept secret. 128 bits in length.

### Modes

**class cryptography.hazmat.primitives.ciphers.modes.CBC(initialization_vector)**

CBC (Cipher Block Chaining) is a mode of operation for block ciphers. It is considered cryptographically strong.

Padding is required when using this mode.

**Parameters**

- `initialization_vector (bytes-like)` – Must be random bytes. They do not need to be kept secret and they can be included in a transmitted message. Must be the same number of bytes as the block_size of the cipher. Each time something is encrypted a new initialization_vector should be generated. Do not reuse an initialization_vector with a given key, and particularly do not use a constant initialization_vector.

A good construction looks like:

```python
>>> import os

>>> from cryptography.hazmat.primitives.ciphers.modes import CBC

>>> iv = os.urandom(16)
>>> mode = CBC(iv)
```

While the following is bad and will leak information:

```python
>>> from cryptography.hazmat.primitives.ciphers.modes import CBC

>>> iv = b"a" * 16
>>> mode = CBC(iv)
```

**class cryptography.hazmat.primitives.ciphers.modes.CTR(nonce)**

This mode uses a counter instead of a chaining vector. It is often used in a streaming application like the TLS protocol. Because it is a streaming cipher, it does not require padding.

```python
>>> from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes

>>> nonce = os.urandom(32)
>>> algorithm = algorithms.AES(nonce)
>>> cipher = Cipher(algorithm, mode=None)
>>> encryptor = cipher.encryptor()
>>> ct = encryptor.update(b"a secret message")
>>> decryptor = cipher.decryptor()
>>> decryptor.update(ct)
```
CTR (Counter) is a mode of operation for block ciphers. It is considered cryptographically strong. It transforms a block cipher into a stream cipher.

This mode does not require padding.

Parameters

nonce (bytes-like) – Should be unique, a nonce. It is critical to never reuse a nonce with a given key. Any reuse of a nonce with the same key compromises the security of every message encrypted with that key. Must be the same number of bytes as the block_size of the cipher with a given key. The nonce does not need to be kept secret and may be included with the ciphertext.

class cryptography.hazmat.primitives.ciphers.modes.OFB(initialization_vector)

OFB (Output Feedback) is a mode of operation for block ciphers. It transforms a block cipher into a stream cipher.

This mode does not require padding.

Parameters

initialization_vector (bytes-like) – Must be random bytes. They do not need to be kept secret and they can be included in a transmitted message. Must be the same number of bytes as the block_size of the cipher. Do not reuse an initialization_vector with a given key.

class cryptography.hazmat.primitives.ciphers.modes.CFB(initialization_vector)

CFB (Cipher Feedback) is a mode of operation for block ciphers. It transforms a block cipher into a stream cipher.

This mode does not require padding.

Parameters

initialization_vector (bytes-like) – Must be random bytes. They do not need to be kept secret and they can be included in a transmitted message. Must be the same number of bytes as the block_size of the cipher. Do not reuse an initialization_vector with a given key.

class cryptography.hazmat.primitives.ciphers.modes.CFB8(initialization_vector)

CFB (Cipher Feedback) is a mode of operation for block ciphers. The CFB8 variant uses an 8-bit shift register.

This mode does not require padding.

Parameters

initialization_vector (bytes-like) – Must be random bytes. They do not need to be kept secret and they can be included in a transmitted message. Must be the same number of bytes as the block_size of the cipher. Do not reuse an initialization_vector with a given key.

class cryptography.hazmat.primitives.ciphers.modes.GCM(initialization_vector, tag=None, min_tag_length=16)

Danger: If you are encrypting data that can fit into memory you should strongly consider using AESGCM instead of this.

When using this mode you must not use the decrypted data until the appropriate finalization method (finalize() or finalize_with_tag()) has been called. GCM provides no guarantees of ciphertext integrity until decryption is complete.
GCM (Galois Counter Mode) is a mode of operation for block ciphers. An AEAD (authenticated encryption with additional data) mode is a type of block cipher mode that simultaneously encrypts the message as well as authenticating it. Additional unencrypted data may also be authenticated. Additional means of verifying integrity such as HMAC are not necessary.

**This mode does not require padding.**

**Parameters**

- **initialization_vector** *(bytes-like)* – Must be unique, a nonce. They do not need to be kept secret and they can be included in a transmitted message. NIST recommends a 96-bit IV length for performance critical situations but it can be up to $2^{64} - 1$ bits. Do not reuse an initialization_vector with a given key.

**Note:** Cryptography will generate a 128-bit tag when finalizing encryption. You can shorten a tag by truncating it to the desired length but this is not recommended as it makes it easier to forge messages, and also potentially leaks the key (NIST SP-800-38D recommends 96-bits or greater). Applications wishing to allow truncation can pass the min_tag_length parameter.

Changed in version 0.5: The min_tag_length parameter was added in 0.5, previously truncation down to 4 bytes was always allowed.

**Parameters**

- **tag** *(bytes)* – The tag bytes to verify during decryption. When encrypting this must be None. When decrypting, it may be None if the tag is supplied on finalization using finalize_with_tag(). Otherwise, the tag is mandatory.

- **min_tag_length** *(int)* – The minimum length tag must be. By default this is 16, meaning tag truncation is not allowed. Allowing tag truncation is strongly discouraged for most applications.

**Raises**

- `ValueError` – This is raised if len(tag) < min_tag_length or the initialization_vector is too short.

An example of securely encrypting and decrypting data with AES in the GCM mode looks like:

```python
import os
from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes

def encrypt(key, plaintext, associated_data):
    # Generate a random 96-bit IV.
    iv = os.urandom(12)

    # Construct an AES-GCM Cipher object with the given key and a
    # randomly generated IV.
    encryptor = Cipher(
        algorithms.AES(key),
        modes.GCM(iv),
    ).encryptor()

    # associated_data will be authenticated but not encrypted,
```
# it must also be passed in on decryption.
encryptor.authenticate_additional_data(associated_data)

# Encrypt the plaintext and get the associated ciphertext.
# GCM does not require padding.
ciphertext = encryptor.update(plaintext) + encryptor.finalize()

return (iv, ciphertext, encryptor.tag)

def decrypt(key, associated_data, iv, ciphertext, tag):
    # Construct a Cipher object, with the key, iv, and additionally the
    # GCM tag used for authenticating the message.
    decryptor = Cipher(
        algorithms.AES(key),
        modes.GCM(iv, tag),
    ).decryptor()

    # We put associated_data back in or the tag will fail to verify
    # when we finalize the decryptor.
    decryptor.authenticate_additional_data(associated_data)

    # Decryption gets us the authenticated plaintext.
    # If the tag does not match an InvalidTag exception will be raised.
    return decryptor.update(ciphertext) + decryptor.finalize()

iv, ciphertext, tag = encrypt(
    key,
    b"a secret message!",
    b"authenticated but not encrypted payload"
)

print(decrypt(
    key,
    b"authenticated but not encrypted payload",
    iv,
    ciphertext,
    tag
))

b'a secret message!'
XTS (XEX-based tweaked-codebook mode with ciphertext stealing) is a mode of operation for the AES block cipher that is used for disk encryption.

**This mode does not require padding.**

**Parameters**

- **tweak (bytes-like)** – The tweak is a 16 byte value typically derived from something like the disk sector number. A given (tweak, key) pair should not be reused, although doing so is less catastrophic than in CTR mode.

**Insecure modes**

| Warning: These modes are insecure. New applications should never make use of them, and existing applications should strongly consider migrating away. |

**class cryptography.hazmat.primitives.ciphers.modes.ECB**

ECB (Electronic Code Book) is the simplest mode of operation for block ciphers. Each block of data is encrypted in the same way. This means identical plaintext blocks will always result in identical ciphertext blocks, which can leave significant patterns in the output.

**Padding is required when using this mode.**

**Interfaces**

**class cryptography.hazmat.primitives.ciphersCipherContext**

When calling encryptor() or decryptor() on a Cipher object the result will conform to the CipherContext interface. You can then call update(data) with data until you have fed everything into the context. Once that is done call finalize() to finish the operation and obtain the remainder of the data.

Block ciphers require that the plaintext or ciphertext always be a multiple of their block size. Because of that **padding** is sometimes required to make a message the correct size. CipherContext will not automatically apply any padding; you’ll need to add your own. For block ciphers the recommended padding is **PKCS7**. If you are using a stream cipher mode (such as **CTR**) you don’t have to worry about this.

**update(data)**

**Parameters**

- **data (bytes-like)** – The data you wish to pass into the context.

**Return bytes**

Returns the data that was encrypted or decrypted.

**Raises**

`cryptography.exceptions.AlreadyFinalized` – See **finalize()**

When the Cipher was constructed in a mode that turns it into a stream cipher (e.g. **CTR**), this will return bytes immediately, however in other modes it will return chunks whose size is determined by the cipher’s block size.

**update_into(data, buf)**

New in version 1.8.
Warning: This method allows you to avoid a memory copy by passing a writable buffer and reading the resulting data. You are responsible for correctly sizing the buffer and properly handling the data. This method should only be used when extremely high performance is a requirement and you will be making many small calls to `update_into`.

Parameters

- **data** *(bytes-like)* – The data you wish to pass into the context.
- **buf** – A writable Python buffer that the data will be written into. This buffer should be `len(data) + n - 1` bytes where `n` is the block size (in bytes) of the cipher and mode combination.

Return int

Number of bytes written.

Raises

- **ValueError** – This is raised if the supplied buffer is too small.

```python
>>> import os
>>> from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes
>>> key = os.urandom(32)
>>> iv = os.urandom(16)
>>> cipher = Cipher(algorithms.AES(key), modes.CBC(iv))
>>> encryptor = cipher.encryptor()
>>> # the buffer needs to be at least len(data) + n - 1 where n is cipher/mode_
>>> # block size in bytes
>>> buf = bytearray(31)
>>> len_encrypted = encryptor.update_into(b"a secret message", buf)
>>> # get the ciphertext from the buffer reading only the bytes written to it_
>>> # (len_encrypted)
>>> ct = bytes(buf[:len_encrypted]) + encryptor.finalize()
>>> decryptor = cipher.decryptor()
>>> len_decrypted = decryptor.update_into(ct, buf)
>>> # get the plaintext from the buffer reading only the bytes written (len_
>>> # decrypted)
>>> bytes(buf[:len_decrypted]) + decryptor.finalize()
```

finalize()

Return bytes

Returns the remainder of the data.

Raises

- **ValueError** – This is raised when the data provided isn’t a multiple of the algorithm’s block size.

Once `finalize` is called this object can no longer be used and `update()` and `finalize()` will raise an `AlreadyFinalized` exception.

```python
class cryptography.hazmat.primitives.ciphers.AEADCipherContext
```

When calling encryptor or decryptor on a Cipher object with an AEAD mode (e.g. `GCM`) the result will conform to the AEADCipherContext and CipherContext interfaces. If it is an encryption or decryption context it will additionally be an AEADEncryptionContext or AEADDecryptionContext instance, respectively.
AEADCipherContext contains an additional method authenticate_additional_data() for adding additional authenticated but unencrypted data (see note below). You should call this before calls to update. When you are done call finalize to finish the operation.

**Note:** In AEAD modes all data passed to update() will be both encrypted and authenticated. Do not pass encrypted data to the authenticate_additional_data() method. It is meant solely for additional data you may want to authenticate but leave unencrypted.

authenticate_additional_data(data)

**Parameters**

- data (bytes-like) – Any data you wish to authenticate but not encrypt.

**Raises**

- AlreadyFinalized

**class cryptography.hazmat.primitives.ciphers.AEADEncryptionContext**

When creating an encryption context using encryptor on a Cipher object with an AEAD mode such as GCM an object conforming to both the AEADEncryptionContext and AEADCipherContext interfaces will be returned. This interface provides one additional attribute tag. tag can only be obtained after finalize has been called.

tag

**Return bytes**

- Returns the tag value as bytes.

**Raises**

- NotYetFinalized if called before the context is finalized.

**class cryptography.hazmat.primitives.ciphers.AEADDecryptionContext**

New in version 1.9.

When creating an encryption context using decryptor on a Cipher object with an AEAD mode such as GCM an object conforming to both the AEADDecryptionContext and AEADCipherContext interfaces will be returned. This interface provides one additional method finalize_with_tag() that allows passing the authentication tag for validation after the ciphertext has been decrypted.

finalize_with_tag(tag)

**Parameters**

- tag (bytes) – The tag bytes to verify after decryption.

**Return bytes**

- Returns the remainder of the data.

**Raises**

- ValueError – This is raised when the data provided isn’t a multiple of the algorithm’s block size, if min_tag_length is less than 4, or if len(tag) < min_tag_length. min_tag_length is an argument to the GCM constructor.

If the authentication tag was not already supplied to the constructor of the GCM mode object, this method must be used instead of finalize().

**class cryptography.hazmat.primitives.ciphers.CipherAlgorithm**

A named symmetric encryption algorithm.

name
**Type**

*str*

The standard name for the mode, for example, “AES”, “Camellia”, or “Blowfish”.

**key_size**

*Type*

*int*

The number of *bits* in the key being used.

class cryptography.hazmat.primitives.ciphers.BlockCipherAlgorithm

A block cipher algorithm.

**block_size**

*Type*

*int*

The number of *bits* in a block.

Interfaces used by the symmetric cipher modes described in *Symmetric Encryption Modes*.  

class cryptography.hazmat.primitives.ciphers.modes.Mode

A named cipher mode.

**name**

*Type*

*str*

This should be the standard shorthand name for the mode, for example Cipher-Block Chaining mode is “CBC”.

**validate_for_algorithm**(algorithm)

*Parameters*

algorithm (cryptography.hazmat.primitives.ciphers.CipherAlgorithm) –

Checks that the combination of this mode with the provided algorithm meets any necessary invariants. This should raise an exception if they are not met.

For example, the CBC mode uses this method to check that the provided initialization vector’s length matches the block size of the algorithm.

class cryptography.hazmat.primitives.ciphers.modes.ModeWithInitializationVector

A cipher mode with an initialization vector.

**initialization_vector**

*Type*

*bytes-like*

Exact requirements of the initialization are described by the documentation of individual modes.

class cryptography.hazmat.primitives.ciphers.modes.ModeWithNonce

A cipher mode with a nonce.

**nonce**

*Type*

*bytes-like*
Exact requirements of the nonce are described by the documentation of individual modes.

class cryptography.hazmat.primitives.ciphers.modes.ModeWithAuthenticationTag
A cipher mode with an authentication tag.

tag

Type
bytes-like

Exact requirements of the tag are described by the documentation of individual modes.

class cryptography.hazmat.primitives.ciphers.modes.ModeWithTweak
New in version 2.1.
A cipher mode with a tweak.
tweak

Type
bytes-like

Exact requirements of the tweak are described by the documentation of individual modes.

Exceptions

class cryptography.exceptions.InvalidTag
This is raised if an authenticated encryption tag fails to verify during decryption.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

2.3.9 Symmetric Padding

Padding is a way to take data that may or may not be a multiple of the block size for a cipher and extend it out so that it is. This is required for many block cipher modes as they require the data to be encrypted to be an exact multiple of the block size.

class cryptography.hazmat.primitives.padding.PKCS7(block_size)

PKCS7 padding is a generalization of PKCS5 padding (also known as standard padding). PKCS7 padding works by appending \( N \) bytes with the value of \( \text{chr}(N) \), where \( N \) is the number of bytes required to make the final block of data the same size as the block size. A simple example of padding is:

```python
>>> from cryptography.hazmat.primitives import padding
>>> padder = padding.PKCS7(128).padder()
>>> padded_data = padder.update(b"11111111111111122222222222")
>>> padded_data
b'11111111111111122222222222'
>>> padded_data += padder.finalize()
>>> padded_data
b'11111111111111122222222222\x06\x06\x06\x06\x06\x06'
>>> unpadder = padding.PKCS7(128).unpadder()
```
Parameters

- `block_size` – The size of the block in \textit{bits} that the data is being padded to.

Raises

- \textbf{ValueError} – Raised if block size is not a multiple of 8 or is not between 0 and 2040 inclusive.

\begin{verbatim}
>>> data = unpadder.update(padded_data)
>>> data
b'1111111111111111'
>>> data + unpadder.finalize()
b'1111111111111222222222'
\end{verbatim}

\begin{verbatim}
Parameters

- `block_size` – The size of the block in \textit{bits} that the data is being padded to.

Raises

- \textbf{ValueError} – Raised if block size is not a multiple of 8 or is not between 0 and 2040 inclusive.

\begin{verbatim}
>>> padder = padding.ANSIX923(128).padder()
>>> padded_data = padder.update(b"11111111111111112222222222")
>>> padded_data
b'1111111111111111'
>>> padded_data += padder.finalize()
>>> padded_data
b'11111111111111112222222222\x06'
>>> unpadder = padding.ANSIX923(128).unpadder()
>>> data = unpadder.update(padded_data)
>>> data
b'1111111111111111'
>>> data + unpadder.finalize()
b'1111111111111222222222'
\end{verbatim}

\begin{verbatim}
Parameters

- `block_size` – The size of the block in \textit{bits} that the data is being padded to.

\end{verbatim}
unpadder()

Returns
An unpadding PaddingContext instance.

class cryptography.hazmat.primitives.padding.PaddingContext
When calling padder() or unpadder() the result will conform to the PaddingContext interface. You can then call update(data) with data until you have fed everything into the context. Once that is done call finalize() to finish the operation and obtain the remainder of the data.

update(data)

Parameters
data (bytes-like) – The data you wish to pass into the context.

Return bytes
Returns the data that was padded or unpadded.

Raises
• TypeError – Raised if data is not bytes.
• cryptography.exceptions.AlreadyFinalized – See finalize().
• TypeError – This exception is raised if data is not bytes.

finalize()
Finalize the current context and return the rest of the data.
After finalize has been called this object can no longer be used; update() and finalize() will raise an AlreadyFinalized exception.

Return bytes
Returns the remainder of the data.

Raises
• TypeError – Raised if data is not bytes.
• ValueError – When trying to remove padding from incorrectly padded data.

This is a “Hazardous Materials” module. You should ONLY use it if you’re 100% absolutely sure that you know what you’re doing because this module is full of land mines, dragons, and dinosaurs with laser guns.

2.3.10 Two-factor authentication

This module contains algorithms related to two-factor authentication.
Currently, it contains an algorithm for generating and verifying one time password values based on Hash-based message authentication codes (HMAC).

class cryptography.hazmat.primitives.twofactor.InvalidToken
This is raised when the verify method of a one time password function’s computed token does not match the expected token.
cryptography.hazmat.primitives.twofactor.hotp.

**HOTPHashTypes**
New in version 40.0.0.

Type alias: A union of supported hash algorithm types: *SHA1, SHA256* or *SHA512*.

class cryptography.hazmat.primitives.twofactor.hotp.

**HOTP** *(key, length, algorithm, *,

  enforce_key_length=True)*
New in version 0.3.

HOTP objects take a key, length and algorithm parameter. The key should be *randomly generated bytes* and is recommended to be 160 *bits* in length. The length parameter controls the length of the generated one time password and must be >= 6 and <= 8.

This is an implementation of *RFC 4226*.

```python
>>> import os
>>> from cryptography.hazmat.primitives.twofactor.hotp import HOTP
>>> from cryptography.hazmat.primitives.hashes import SHA1

>>> key = os.urandom(20)
>>> hotp = HOTP(key, 6, SHA1())
>>> hotp_value = hotp.generate(0)
>>> hotp.verify(hotp_value, 0)
```

**Parameters**

- **key** *(bytes-like)* – Per-user secret key. This value must be kept secret and be at least 128 *bits*. It is recommended that the key be 160 bits.

- **length** *(int)* – Length of generated one time password as int.

- **algorithm** *(cryptography.hazmat.primitives.hashes.HashAlgorithm)* – A hashes instance (must match *HOTPHashTypes*).

- **enforce_key_length** – A boolean flag defaulting to True that toggles whether a minimum key length of 128 *bits* is enforced. This exists to work around the fact that as documented in *Issue #2915*, the Google Authenticator PAM module by default generates 80 bit keys. If this flag is set to False, the application developer should implement additional checks of the key length before passing it into *HOTP*.

  New in version 1.5.

**Raises**

- **ValueError** – This is raised if the provided key is shorter than 128 *bits* or if the length parameter is not 6, 7 or 8.

- **TypeError** – This is raised if the provided algorithm is not *SHA1(), SHA256() or SHA512()* or if the length parameter is not an integer.

**generate**(counter)

*Parameters*

- **counter** *(int)* – The counter value used to generate the one time password.

*Return bytes*

A one time password value.

**verify**(hotp, counter)

*Parameters*
- **hotp** (*bytes*) – The one time password value to validate.
- **counter** (*int*) – The counter value to validate against.

**Raises**

cryptography.hazmat.primitives.twofactor.InvalidToken – This is raised when the supplied HOTP does not match the expected HOTP.

**get_provisioning_uri**(*account_name, counter, issuer*)

New in version 1.0.

**Parameters**

- **account_name** (*str*) – The display name of account, such as 'Alice Smith' or 'alice@example.com'.
- **issuer** (*str* or *None*) – The optional display name of issuer. This is typically the provider or service the user wants to access using the OTP token.
- **counter** (*int*) – The current value of counter.

**Returns**

A URI string.

### Throttling

Due to the fact that the HOTP algorithm generates rather short tokens that are 6 - 8 digits long, brute force attacks are possible. It is highly recommended that the server that validates the token implement a throttling scheme that locks out the account for a period of time after a number of failed attempts. The number of allowed attempts should be as low as possible while still ensuring that usability is not significantly impacted.

### Re-synchronization of the counter

The server’s counter value should only be incremented on a successful HOTP authentication. However, the counter on the client is incremented every time a new HOTP value is requested. This can lead to the counter value being out of synchronization between the client and server.

Due to this, it is highly recommended that the server sets a look-ahead window that allows the server to calculate the next $x$ HOTP values and check them against the supplied HOTP value. This can be accomplished with something similar to the following code.

```python
def verify(hotp, counter, look_ahead):
    assert look_ahead >= 0
    correct_counter = None

    otp = HOTP(key, 6)
    for count in range(counter, counter + look_ahead):
        try:
            otp.verify(hotp, count)
            correct_counter = count
        except InvalidToken:
            pass

    return correct_counter
```

2.3. Primitives
class cryptography.hazmat.primitives.twofactor.totp.TOTP(key, length, algorithm, time_step, *, enforce_key_length=True)

TOTP objects take a key, length, algorithm and time_step parameter. The key should be *randomly generated bytes* and is recommended to be as long as your hash function's output (e.g 256-bit for SHA256). The length parameter controls the length of the generated one time password and must be >= 6 and <= 8.

This is an implementation of [RFC 6238](https://tools.ietf.org/html/rfc6238).

```python
>>> import os
>>> import time
>>> from cryptography.hazmat.primitives.twofactor.totp import TOTP
>>> from cryptography.hazmat.primitives.hashes import SHA1

>>> key = os.urandom(20)
>>> totp = TOTP(key, 8, SHA1(), 30)
>>> time_value = time.time()
>>> totp_value = totp.generate(time_value)
>>> totp.verify(totp_value, time_value)
```

Parameters

- **key** (*bytes-like*) – Per-user secret key. This value must be kept secret and be at least 128 *bits*. It is recommended that the key be 160 bits.

- **length** (*int*) – Length of generated one time password as *int*.


- **time_step** (*int*) – The time step size. The recommended size is 30.

- **enforce_key_length** – A boolean flag defaulting to True that toggles whether a minimum key length of 128 *bits* is enforced. This exists to work around the fact that as documented in [Issue #2915](https://github.com/pyca/cryptography/issues/2915), the Google Authenticator PAM module by default generates 80 bit keys. If this flag is set to False, the application develop should implement additional checks of the key length before passing it into *TOTP*.

New in version 1.5.

Raises

- **ValueError** – This is raised if the provided *key* is shorter than 128 *bits* or if the *length* parameter is not 6, 7 or 8.

- **TypeError** – This is raised if the provided *algorithm* is not *SHA1*, *SHA256* or *SHA512* or if the *length* parameter is not an integer.

**generate** (*time*)

Parameters

- **time** (*int*) – The time value used to generate the one time password.

Return *bytes*

A one time password value.

**verify** (*totp, time*)

Parameters

- **totp** (*bytes*) – The one time password value to validate.

- **time** (*int*) – The time value to validate against.
Raises

cryptography.hazmat.primitives.twofactor.InvalidToken – This is raised when the supplied TOTP does not match the expected TOTP.

**get_provisioning_uri**(*account_name*, *issuer*)

New in version 1.0.

**Parameters**

- *account_name* (*str*) – The display name of account, such as 'Alice Smith' or 'alice@example.com'.

- *issuer* (*str* or *None*) – The optional display name of issuer. This is typically the provider or service the user wants to access using the OTP token.

**Returns**

A URI string.

**Provisioning URI**

The provisioning URI of HOTP and TOTP is a feature of Google Authenticator and not actually part of the HOTP or TOTP RFCs. However, it is widely supported by web sites and mobile applications which are using Two-Factor authentication.

For generating a provisioning URI you can use the get_provisioning_uri method of HOTP/TOTP instances.

```python
counter = 5
account_name = 'alice@example.com'
issuer_name = 'Example Inc'

hotp_uri = hotp.get_provisioning_uri(account_name, counter, issuer_name)
totp_uri = totp.get_provisioning_uri(account_name, issuer_name)
```

A common usage is encoding the provisioning URI into QR code and guiding users to scan it with Two-Factor authentication applications in their mobile devices.

**2.4 Exceptions**

**class cryptography.exceptions.UnsupportedAlgorithm**

Raised when the requested algorithm, or combination of algorithms is not supported.

**class cryptography.exceptions.AlreadyFinalized**

This is raised when a context is used after being finalized.

**class cryptography.exceptions.InvalidSignature**

This is raised when signature verification fails. This can occur with HMAC or asymmetric key signature validation.

**class cryptography.exceptions.NotYetFinalized**

This is raised when the AEAD tag property is accessed on a context before it is finalized.

**class cryptography.exceptions.AlreadyUpdated**

This is raised when additional data is added to a context after update has already been called.
class cryptography.exceptions.InvalidKey

This is raised when the verify method of a key derivation function’s computed key does not match the expected key.

2.5 Random number generation

When generating random data for use in cryptographic operations, such as an initialization vector for encryption in CBC mode, you do not want to use the standard random module APIs. This is because they do not provide a cryptographically secure random number generator, which can result in major security issues depending on the algorithms in use.

Therefore, it is our recommendation to always use your operating system’s provided random number generator, which is available as os.urandom(). For example, if you need 16 bytes of random data for an initialization vector, you can obtain them with:

```python
>>> import os
>>> iv = os.urandom(16)
```

If you need your random number as an big integer, you can use int.from_bytes to convert the result of os.urandom:

```python
>>> serial = int.from_bytes(os.urandom(16), byteorder="big")
```

In addition, the Python standard library includes the secrets module, which can be used for generating cryptographically secure random numbers, with specific helpers for text-based formats.

2.6 Installation

You can install cryptography with pip:

```
$ pip install cryptography
```

If this does not work please upgrade your pip first, as that is the single most common cause of installation problems.

2.6.1 Supported platforms

Currently we test cryptography on Python 3.7+ and PyPy3 7.3.11+ on these operating systems.

- x86-64 RHEL 8.x
- x86-64 CentOS 9 Stream
- x86-64 Fedora (latest)
- x86-64 macOS 13 Ventura and ARM64 macOS 14 Sonoma
- x86-64 Ubuntu 20.04, 22.04, rolling
- ARM64 Ubuntu 22.04
- x86-64 Debian Buster (10.x), Bullseye (11.x), Bookworm (12.x), Trixie (13.x), and Sid (unstable)
- x86-64 and ARM64 Alpine (latest)
- 32-bit and 64-bit Python on 64-bit Windows Server 2022

We test compiling with clang as well as gcc and use the following OpenSSL releases in addition to distribution provided releases from the above supported platforms:
• OpenSSL 1.1.1-latest
• OpenSSL 3.0-latest
• OpenSSL 3.1-latest

We also test against the latest commit of BoringSSL as well as versions of LibreSSL that are receiving security support at the time of a given cryptography release.

2.6.2 Building cryptography on Windows

The wheel package on Windows is a statically linked build (as of 0.5) so all dependencies are included. To install cryptography, you will typically just run

```bash
$ pip install cryptography
```

If you prefer to compile it yourself you’ll need to have OpenSSL installed. You can compile OpenSSL yourself as well or use a binary distribution. Be sure to download the proper version for your architecture and Python (VC2015 is required for 3.7 and above). Wherever you place your copy of OpenSSL you’ll need to set the `OPENSSL_DIR` environment variable to include the proper location. For example:

```
C:\> \path\to\vcvarsall.bat x86_amd64
C:\> set OPENSSL_DIR=C:\OpenSSL-win64
C:\> pip install cryptography
```

You will also need to have Rust installed and available.

If you need to rebuild cryptography for any reason be sure to clear the local wheel cache.

2.6.3 Building cryptography on Linux

**Note:** You should upgrade pip and attempt to install cryptography again before following the instructions to compile it below. Most Linux platforms will receive a binary wheel and require no compiler if you have an updated pip!

cryptography ships manylinux wheels (as of 2.0) so all dependencies are included. For users on pip 19.3 or above running on a manylinux2014 (or greater) compatible distribution (or pip 21.2.4 for musllinux) all you should need to do is:

```
$ pip install cryptography
```

If you want to compile cryptography yourself you’ll need a C compiler, a Rust compiler, headers for Python (if you’re not using pypy), and headers for the OpenSSL and libffi libraries available on your system.

On all Linux distributions you will need to have Rust installed and available.
Alpine

**Warning:** The Rust available by default in Alpine < 3.17 is older than the minimum supported version. See the [Rust installation instructions](#) for information about installing a newer Rust.

```bash
$ sudo apk add gcc musl-dev python3-dev libffi-dev openssl-dev cargo pkgconfig
```

If you get an error with `openssl-dev` you may have to use `libressl-dev`.

Debian/Ubuntu

**Warning:** The Rust available in Debian versions prior to Bookworm are older than the minimum supported version. See the [Rust installation instructions](#) for information about installing a newer Rust.

```bash
$ sudo apt-get install build-essential libssl-dev libffi-dev \ 
   python3-dev cargo pkg-config
```

Fedora/RHEL/CentOS

**Warning:** For RHEL and CentOS you must be on version 8.8 or newer for the command below to install a sufficiently new Rust. If your Rust is less than 1.63.0 please see the [Rust installation instructions](#) for information about installing a newer Rust.

```bash
$ sudo dnf install redhat-rpm-config gcc libffi-devel python3-devel \ 
   openssl-devel cargo pkg-config
```

Building

You should now be able to build and install cryptography. To avoid getting the pre-built wheel on manylinux compatible distributions you'll need to use `--no-binary`.

```bash
$ pip install cryptography --no-binary cryptography
```

Using your own OpenSSL on Linux

Python links to OpenSSL for its own purposes and this can sometimes cause problems when you wish to use a different version of OpenSSL with cryptography. If you want to use cryptography with your own build of OpenSSL you will need to make sure that the build is configured correctly so that your version of OpenSSL doesn’t conflict with Python’s.

The options you need to add allow the linker to identify every symbol correctly even when multiple versions of the library are linked into the same program. If you are using your distribution’s source packages these will probably be patched in for you already, otherwise you’ll need to use options something like this when configuring OpenSSL:
Static Wheels

Cryptography ships statically-linked wheels for macOS, Windows, and Linux (via manylinux and musllinux). This allows compatible environments to use the most recent OpenSSL, regardless of what is shipped by default on those platforms.

If you are using a platform not covered by our wheels, you can build your own statically-linked wheels that will work on your own systems. This will allow you to continue to use relatively old Linux distributions (such as LTS releases), while making sure you have the most recent OpenSSL available to your Python programs.

To do so, you should find yourself a machine that is as similar as possible to your target environment (e.g. your production environment): for example, spin up a new cloud server running your target Linux distribution. On this machine, install the Cryptography dependencies as mentioned in Building cryptography on Linux. Please also make sure you have virtualenv installed: this should be available from your system package manager.

Then, paste the following into a shell script. You’ll need to populate the OPENSSL_VERSION variable. To do that, visit openssl.org and find the latest non-FIPS release version number, then set the string appropriately. For example, for OpenSSL 1.1.1k, use OPENSSL_VERSION="1.1.1k".

When this shell script is complete, you’ll find a collection of wheel files in a directory called wheelhouse. These wheels can be installed by a sufficiently-recent version of pip. The Cryptography wheel in this directory contains a statically-linked OpenSSL binding, which ensures that you have access to the most-recent OpenSSL releases without corrupting your system dependencies.
2.6.4 Building cryptography on macOS

Note: If installation gives a fatal error: 'openssl/aes.h' file not found see the FAQ for information about how to fix this issue.

The wheel package on macOS is a statically linked build (as of 1.0.1) so for users with pip 8 or above you only need one step:

```
$ pip install cryptography
```

If you want to build cryptography yourself or are on an older macOS version, cryptography requires the presence of a C compiler, development headers, and the proper libraries. On macOS much of this is provided by Apple’s Xcode development tools. To install the Xcode command line tools (on macOS 10.10+) open a terminal window and run:

```
$ xcode-select --install
```

This will install a compiler (clang) along with (most of) the required development headers.

You will also need to have Rust installed and available, which can be obtained from Homebrew, MacPorts, or directly from the Rust website. If you are linking against a universal2 archive of OpenSSL, the minimum supported Rust version is 1.66.0.

Finally you need OpenSSL, which you can obtain from Homebrew or MacPorts. Cryptography does not support the OpenSSL/LibreSSL libraries Apple ships in its base operating system.

To build cryptography and dynamically link it:

Homebrew

```
$ brew install openssl@3 rust
$ env OPENSSL_DIR="$(brew --prefix openssl@3)" pip install cryptography
```

MacPorts:

```
$ sudo port install openssl rust
$ env OPENSSL_DIR="-L/opt/local" pip install cryptography
```

You can also build cryptography statically:

Homebrew

```
$ brew install openssl@3 rust
$ env OPENSSL_STATIC=1 OPENSSL_DIR="$(brew --prefix openssl@3)" pip install cryptography
```

MacPorts:

```
$ sudo port install openssl rust
$ env OPENSSL_STATIC=1 OPENSSL_DIR="/opt/local" pip install cryptography
```

If you need to rebuild cryptography for any reason be sure to clear the local wheel cache.
2.6.5 Rust

**Note:** If you are using Linux, then you should **upgrade pip** (in a virtual environment!) and attempt to install cryptography again before trying to install the Rust toolchain. On most Linux distributions, the latest version of pip will be able to install a binary wheel, so you won’t need a Rust toolchain.

Building cryptography requires having a working Rust toolchain. The current minimum supported Rust version is 1.63.0. **This is newer than the Rust some package managers ship**, so users may need to install with the instructions below.

Instructions for installing Rust can be found on the Rust Project’s website. We recommend installing Rust with **rustup** (as documented by the Rust Project) in order to ensure you have a recent version.

Rust is only required when building cryptography, meaning that you may install it for the duration of your pip install command and then remove it from a system. A Rust toolchain is not required to use cryptography. In deployments such as docker, you may use a multi-stage Dockerfile where you install Rust during the build phase but do not install it in the runtime image. This is the same as the C compiler toolchain which is also required to build cryptography, but not afterwards.

### 2.7 Changelog

#### 2.7.1 42.0.0 - main

**Note:** This version is not yet released and is under active development.

- **BACKWARDS INCOMPATIBLE:** Dropped support for LibreSSL < 3.7.
- **BACKWARDS INCOMPATIBLE:** Loading a PKCS7 with no content field using `load_pem_pkcs7_certificates()` or `load_der_pkcs7_certificates()` will now raise a **ValueError** rather than return an empty list.
- Parsing SSH certificates no longer permits malformed critical options with values, as documented in the 41.0.2 release notes.
- Updated the minimum supported Rust version (MSRV) to 1.63.0, from 1.56.0.
- We now publish both `py37` and `py39 abi3` wheels. This should resolve some errors relating to initializing a module multiple times per process.
- Support **PSS** for X.509 certificate signing requests and certificate revocation lists with the keyword-only argument `rsa_padding` on the `sign` methods for `CertificateSigningRequestBuilder` and `CertificateRevocationListBuilder`.
- Added support for obtaining X.509 certificate signing request signature algorithm parameters (including PSS) via `signature_algorithm_parameters()`.
- Added support for obtaining X.509 certificate revocation list signature algorithm parameters (including PSS) via `signature_algorithm_parameters()`.
- Added `mgf` property to **PSS**.
- Added `algorithm` and `mgf` properties to **OAEP**.
• Added the following properties that return timezone-aware \texttt{datetime} objects: \texttt{not_valid_before_utc()}, \texttt{not_valid_after_utc()}, \texttt{revocation_date_utc()}, \texttt{next_update_utc()}, \texttt{last_update_utc()}. These are timezone-aware variants of existing properties that return naïve \texttt{datetime} objects.

• Deprecated the following properties that return naïve \texttt{datetime} objects: \texttt{not_valid_before()}, \texttt{not_valid_after()}, \texttt{revocation_date()}, \texttt{next_update()}, \texttt{last_update()} in favor of the new timezone-aware variants mentioned above.

• Added support for \texttt{ChaCha20} on LibreSSL.

• Added support for RSA PSS signatures in PKCS7 with \texttt{add_signer()}.

• In the next release (43.0.0) of cryptography, loading an X.509 certificate with a negative serial number will raise an exception. This has been deprecated since 36.0.0.

• Added support for \texttt{AESGCMSIV} when using OpenSSL 3.2.0+.

• Added the \texttt{X.509 path validation} APIs for \texttt{Certificate} chains. These APIs should be considered unstable and not subject to our stability guarantees until documented as such in a future release.

• Added support for \texttt{SM4 GCM} when using OpenSSL 3.0 or greater.

\textbf{2.7.2 41.0.7 - 2023-11-27}

• Fixed compilation when using LibreSSL 3.8.2.

\textbf{2.7.3 41.0.6 - 2023-11-27}

• Fixed a null-pointer-dereference and segfault that could occur when loading certificates from a PKCS#7 bundle. Credit to \texttt{pkuzco} for reporting the issue. \texttt{CVE-2023-49083}

\textbf{2.7.4 41.0.5 - 2023-10-24}

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.1.4.

• Added a function to support an upcoming pyOpenSSL release.

\textbf{2.7.5 41.0.4 - 2023-09-19}

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.1.3.

\textbf{2.7.6 41.0.3 - 2023-08-01}

• Fixed performance regression loading DH public keys.

• Fixed a memory leak when using \texttt{ChaCha20Poly1305}.

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.1.2.
2.7.7 41.0.2 - 2023-07-10

- Fixed bugs in creating and parsing SSH certificates where critical options with values were handled incorrectly. Certificates are now created correctly and parsing accepts correct values as well as the previously generated invalid forms with a warning. In the next release, support for parsing these invalid forms will be removed.

2.7.8 41.0.1 - 2023-06-01

- Temporarily allow invalid ECDSA signature algorithm parameters in X.509 certificates, which are generated by older versions of Java.
- Allow null bytes in pass phrases when serializing private keys.

2.7.9 41.0.0 - 2023-05-30

- BACKWARDS INCOMPATIBLE: Support for OpenSSL less than 1.1.1d has been removed. Users on older version of OpenSSL will need to upgrade.
- BACKWARDS INCOMPATIBLE: Support for Python 3.6 has been removed.
- BACKWARDS INCOMPATIBLE: Dropped support for LibreSSL < 3.6.
- Updated the minimum supported Rust version (MSRV) to 1.56.0, from 1.48.0.
- Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.1.1.
- Added support for the OCSPAcceptableResponses OCSP extension.
- Added support for the MSCertificateTemplate proprietary Microsoft certificate extension.
- Implemented support for equality checks on all asymmetric public key types.
- Added support for aes256-gcm@openssh.com encrypted keys in load_ssh_private_key().
- Added support for obtaining X.509 certificate signature algorithm parameters (including PSS) via signature_algorithm_parameters().
- Support signing PSS X.509 certificates via the new keyword-only argument rsa_padding on sign().
- Added support for ChaCha20Poly1305 on BoringSSL.

2.7.10 40.0.2 - 2023-04-14

- Fixed compilation when using LibreSSL 3.7.2.
- Added some functions to support an upcoming pyOpenSSL release.

2.7.11 40.0.1 - 2023-03-24

- Fixed a bug where certain operations would fail if an object happened to be in the top-half of the memory-space. This only impacted 32-bit systems.
BACKWARDS INCOMPATIBLE: As announced in the 39.0.0 changelog, the way cryptography links OpenSSL has changed. This only impacts users who build cryptography from source (i.e., not from a wheel), and specify their own version of OpenSSL. For those users, the CFLAGS, LDFLAGS, INCLUDE, LIB, and CRYPTOGRAPHY_SUPPRESS_LINK_FLAGS environment variables are no longer valid. Instead, users need to configure their builds as documented here.

Support for Python 3.6 is deprecated and will be removed in the next release.

Deprecated the current minimum supported Rust version (MSRV) of 1.48.0. In the next release we will raise MSRV to 1.56.0. Users with the latest pip will typically get a wheel and not need Rust installed, but check Installation for documentation on installing a newer rustc if required.

Deprecated support for OpenSSL less than 1.1.1d. The next release of cryptography will drop support for older versions.

Deprecated support for DSA keys in load_ssh_public_key() and load_ssh_private_key().

Deprecated support for OpenSSH serialization in DSAPublicKey and DSAPrivateKey.

The minimum supported version of PyPy3 is now 7.3.10.

Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.1.0.

Added support for parsing SSH certificates in addition to public keys with load_ssh_public_identity(). load_ssh_public_key() continues to support only public keys.

Added support for generating SSH certificates with SSHCertificateBuilder.

Added verify_directly_issued_by() to Certificate.

Added a check to NameConstraints to ensure that DNSName constraints do not contain any * wildcards.

Removed many unused CFFI OpenSSL bindings. This will not impact you unless you are using cryptography to directly invoke OpenSSL's C API. Note that these have never been considered a stable, supported, public API by cryptography, this note is included as a courtesy.

The X.509 builder classes now raise UnsupportedAlgorithm instead of ValueError if an unsupported hash algorithm is passed.

Added public union type aliases for type hinting:

- Asymmetric types: PublicKeyTypes, PrivateKeyTypes, CertificatePublicKeyTypes, CertificateIssuerPublicKeyTypes, CertificateIssuerPrivateKeyTypes.
- SSH keys: SSHPublicKeyTypes, SSHPrivateKeyTypes, SSHCertPublicKeyTypes, SSHCertPrivateKeyTypes.
- PKCS12: PKCS12PrivateKeyTypes
- PKCS7: PKCS7HashTypes, PKCS7PrivateKeyTypes.
- Two-factor: HOTPHashTypes

Deprecated previously undocumented but not private type aliases in the cryptography.hazmat.primitives.asymmetric.types module in favor of new ones above.
2.7.13 39.0.2 - 2023-03-02

- Fixed a bug where the content type header was not properly encoded for PKCS7 signatures when using the Text option and SMIME encoding.

2.7.14 39.0.1 - 2023-02-07

- SECURITY ISSUE - Fixed a bug where Cipher.update_into accepted Python buffer protocol objects, but allowed immutable buffers. CVE-2023-23931
  - Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.8.

2.7.15 39.0.0 - 2023-01-01

- BACKWARDS INCOMPATIBLE: Support for OpenSSL 1.1.0 has been removed. Users on older version of OpenSSL will need to upgrade.
- BACKWARDS INCOMPATIBLE: Dropped support for LibreSSL < 3.5. The new minimum LibreSSL version is 3.5.0. Going forward our policy is to support versions of LibreSSL that are available in versions of OpenBSD that are still receiving security support.
- BACKWARDS INCOMPATIBLE: Removed the encode_point and from_encoded_point methods on EllipticCurvePublicNumbers, which had been deprecated for several years. public_bytes() and from_encoded_point() should be used instead.
- BACKWARDS INCOMPATIBLE: Support for using MD5 or SHA1 in CertificateBuilder, other X.509 builders, and PKCS7 has been removed.
- BACKWARDS INCOMPATIBLE: Dropped support for macOS 10.10 and 10.11, macOS users must upgrade to 10.12 or newer.
- ANNOUNCEMENT: The next version of cryptography (40.0) will change the way we link OpenSSL. This will only impact users who build cryptography from source (i.e., not from a wheel), and specify their own version of OpenSSL. For those users, the CFLAGS, LDFLAGS, INCLUDE, LIB, and CRYPTOGRAPHY_SUPPRESS_LINK_FLAGS environment variables will no longer be respected. Instead, users will need to configure their builds as documented here.
- Added support for disabling the legacy provider in OpenSSL 3.0.x.
- Added support for disabling RSA key validation checks when loading RSA keys via load_pem_private_key(), load_der_private_key(), and private_key(). This speeds up key loading but is unsafe if you are loading potentially attacker supplied keys.
- Significantly improved performance for ChaCha20Poly1305 when repeatedly calling encrypt or decrypt with the same key.
- Added support for creating OCSP requests with precomputed hashes using add_certificate_by_hash().
- Added support for loading multiple PEM-encoded X.509 certificates from a single input via load_pem_x509_certificates().
2.7.16 38.0.4 - 2022-11-27

• Fixed compilation when using LibreSSL 3.6.0.
• Fixed error when using py2app to build an application with a cryptography dependency.

2.7.17 38.0.3 - 2022-11-01

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.7, which resolves CVE-2022-3602 and CVE-2022-3786.

2.7.18 38.0.2 - 2022-10-11 (YANKED)

Attention: This release was subsequently yanked from PyPI due to a regression in OpenSSL.

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.6.

2.7.19 38.0.1 - 2022-09-07

• Fixed parsing TLVs in ASN.1 with length greater than 65535 bytes (typically seen in large CRLs).

2.7.20 38.0.0 - 2022-09-06

• Final deprecation of OpenSSL 1.1.0. The next release of cryptography will drop support.
• We no longer ship manylinux2010 wheels. Users should upgrade to the latest pip to ensure this doesn’t cause issues downloading wheels on their platform. We now ship manylinux_2_28 wheels for users on new enough platforms.
• Updated the minimum supported Rust version (MSRV) to 1.48.0, from 1.41.0. Users with the latest pip will typically get a wheel and not need Rust installed, but check Installation for documentation on installing a newer rustc if required.
• decrypt() and related methods now accept both str and bytes tokens.
• Parsing CertificateSigningRequest restores the behavior of enforcing that the Extension critical field must be correctly encoded DER. See the issue for complete details.
• Added two new OpenSSL functions to the bindings to support an upcoming pyOpenSSL release.
• When parsing CertificateRevocationList and CertificateSigningRequest values, it is now enforced that the version value in the input must be valid according to the rules of RFC 2986 and RFC 5280.
• Using MD5 or SHA1 in CertificateBuilder and other X.509 builders is deprecated and support will be removed in the next version.
• Added additional APIs to SignedCertificateTimestamp, including signature_hash_algorithm, signature_algorithm, signature, and extension_bytes.
• Added tbs_precertificate_bytes, allowing users to access the to-be-signed pre-certificate data needed for signed certificate timestamp verification.
• KBKDFHMAC and KBKDFCMAC now support MiddleFixed counter location.
• Fixed RFC 4514 name parsing to reverse the order of the RDNs according to the section 2.1 of the RFC, affecting method `from_rfc4514_string()`.
• It is now possible to customize some aspects of encryption when serializing private keys, using `encryption_builder()`.
• Removed several legacy symbols from our OpenSSL bindings. Users of pyOpenSSL versions older than 22.0 will need to upgrade.
• Added `AES128` and `AES256` classes. These classes do not replace `AES` (which allows all AES key lengths), but are intended for applications where developers want to be explicit about key length.

2.7.21 37.0.4 - 2022-07-05

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.5.

2.7.22 37.0.3 - 2022-06-21 (YANKED)

**Attention:** This release was subsequently yanked from PyPI due to a regression in OpenSSL.

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.4.

2.7.23 37.0.2 - 2022-05-03

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.3.
• Added a constant needed for an upcoming pyOpenSSL release.

2.7.24 37.0.1 - 2022-04-27

• Fixed an issue where parsing an encrypted private key with the public loader functions would hang waiting for console input on OpenSSL 3.0.x rather than raising an error.
• Restored some legacy symbols for older pyOpenSSL users. These will be removed again in the future, so pyOpenSSL users should still upgrade to the latest version of that package when they upgrade cryptography.

2.7.25 37.0.0 - 2022-04-26

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 3.0.2.
• **BACKWARDS INCOMPATIBLE:** Dropped support for LibreSSL 2.9.x and 3.0.x. The new minimum LibreSSL version is 3.1+.
• **BACKWARDS INCOMPATIBLE:** Removed `signer` and `verifier` methods from the public key and private key classes. These methods were originally deprecated in version 2.0, but had an extended deprecation timeline due to usage. Any remaining users should transition to `sign` and `verify`.
• Deprecated OpenSSL 1.1.0 support. OpenSSL 1.1.0 is no longer supported by the OpenSSL project. The next release of cryptography will be the last to support compiling with OpenSSL 1.1.0.
• Deprecated Python 3.6 support. Python 3.6 is no longer supported by the Python core team. Support for Python 3.6 will be removed in a future cryptography release.
• Deprecated the current minimum supported Rust version (MSRV) of 1.41.0. In the next release we will raise
MSRV to 1.48.0. Users with the latest pip will typically get a wheel and not need Rust installed, but check
Installation for documentation on installing a newer rustc if required.

• Deprecated CAST5, SEED, IDEA, and Blowfish because they are legacy algorithms with extremely low usage.
These will be removed in a future version of cryptography.

• Added limited support for distinguished names containing a bit string.

• We now ship universal2 wheels on macOS, which contain both arm64 and x86_64 architectures. Users on
macOS should upgrade to the latest pip to ensure they can use this wheel, although we will continue to ship
x86_64 specific wheels for now to ease the transition.

• This will be the final release for which we ship manylinux2010 wheels. Going forward the minimum sup-
ported manylinux ABI for our wheels will be manylinux2014. The vast majority of users will continue to
receive manylinux wheels provided they have an up to date pip. For PyPy wheels this release already requires
manylinux2014 for compatibility with binaries distributed by upstream.

• Added support for multiple OCSP SingleResponse in a OCSPResponse.

• Restored support for signing certificates and other structures in X.509 with SHA3 hash algorithms.

• TripleDES is disabled in FIPS mode.

• Added support for serialization of PKCS#12 CA friendly names/aliases in
serialize_key_and_certificates()

• Added support for 12-15 byte (96 to 120 bit) nonces to AESOCB3. This class previously supported only 12 byte
(96 bit).

• Added support for AESIV when using OpenSSL 3.0.0+.

• Added support for serializing PKCS7 structures from a list of certificates with serialize_certificates.

• Added support for parsing RFC 4514 strings with from_rfc4514_string().

• Added AUTO to PSS. This can be used to verify a signature where the salt length is not already known.

• Added DIGEST_LENGTH to PSS. This constant will set the salt length to the same length as the PSS hash algorithm.

• Added support for loading RSA-PSS key types with load_pem_private_key() and
load_der_private_key(). This functionality is limited to OpenSSL 1.1.1e+ and loads the key as a
normal RSA private key, discarding the PSS constraint information.

2.7.26 36.0.2 - 2022-03-15

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 1.1.1n.

2.7.27 36.0.1 - 2021-12-14

• Updated Windows, macOS, and Linux wheels to be compiled with OpenSSL 1.1.1m.
2.7.28 36.0.0 - 2021-11-21

- **FINAL DEPRECATION** Support for verifier and signer on our asymmetric key classes was deprecated in version 2.0. These functions had an extended deprecation due to usage, however the next version of cryptography will drop support. Users should migrate to sign and verify.
- The entire X.509 layer is now written in Rust. This allows alternate asymmetric key implementations that can support cloud key management services or hardware security modules provided they implement the necessary interface (for example: EllipticCurvePrivateKey).
- Deprecated the backend argument for all functions.
- Added support for AESOcb3.
- Added support for iterating over arbitrary request attributes.
- Deprecated the get_attribute_for_oid method on CertificateSigningRequest in favor of get_attribute_for_oid() on the new Attributes object.
- Fixed handling of PEM files to allow loading when certificate and key are in the same file.
- Fixed parsing of CertificatePolicies extensions containing legacy BMPString values in their explicitText.
- Allow parsing of negative serial numbers in certificates. Negative serial numbers are prohibited by RFC 5280 so a deprecation warning will be raised whenever they are encountered. A future version of cryptography will drop support for parsing them.
- Added support for parsing PKCS12 files with friendly names for all certificates with load_pkcs12(), which will return an object of type PKCS12KeyAndCertificates.
- rfc4514_string() and related methods now have an optional attr_name_overrides parameter to supply custom OID to name mappings, which can be used to match vendor-specific extensions.
- **BACKWARDS INCOMPATIBLE:** Reverted the nonstandard formatting of email address fields as E in rfc4514_string() methods from version 35.0. The previous behavior can be restored with: name.rfc4514_string({NameOID.EMAIL_ADDRESS: "E"})
- Allow X25519PublicKey and X448PublicKey to be used as public keys when parsing certificates or creating them with CertificateBuilder. These key types must be signed with a different signing algorithm as X25519 and X448 do not support signing.
- Extension values can now be serialized to a DER byte string by calling public_bytes().
- Added experimental support for compiling against BoringSSL. As BoringSSL does not commit to a stable API, cryptography tests against the latest commit only. Please note that several features are not available when building against BoringSSL.
- Parsing CertificateSigningRequest from DER and PEM now, for a limited time period, allows the Extension critical field to be incorrectly encoded. See the issue for complete details. This will be reverted in a future cryptography release.
- When OCSPNonce are parsed and generated their value is now correctly wrapped in an ASN.1 OCTET STRING. This conforms to RFC 6960 but conflicts with the original behavior specified in RFC 2560. For a temporary period for backwards compatibility, we will also parse values that are encoded as specified in RFC 2560 but this behavior will be removed in a future release.
2.7.29 35.0.0 - 2021-09-29

- Changed the version scheme. This will result in us incrementing the major version more frequently, but does not change our existing backwards compatibility policy.

- BACKWARDS INCOMPATIBLE: The X.509 PEM parsers now require that the PEM string passed have PEM delimiters of the correct type. For example, parsing a private key PEM concatenated with a certificate PEM will no longer be accepted by the PEM certificate parser.

- BACKWARDS INCOMPATIBLE: The X.509 certificate parser no longer allows negative serial numbers. RFC 5280 has always prohibited these.

- BACKWARDS INCOMPATIBLE: Additional forms of invalid ASN.1 found during X.509 parsing will raise an error on initial parse rather than when the malformed field is accessed.

- Rust is now required for building cryptography, the CRYPTOGRAPHY_DONT_BUILD_RUST environment variable is no longer respected.

- Parsers for X.509 no longer use OpenSSL and have been rewritten in Rust. This should be backwards compatible (modulo the items listed above) and improve both security and performance.

- Added support for OpenSSL 3.0.0 as a compilation target.

- Added support for SM3 and SM4, when using OpenSSL 1.1.1. These algorithms are provided for compatibility in regions where they may be required, and are not generally recommended.

- We now ship manylinux_2_24 and musllinux_1_1 wheels, in addition to our manylinux2010 and manylinux2014 wheels. Users on distributions like Alpine Linux should ensure they upgrade to the latest pip to correctly receive wheels.

- Added rfc4514_attribute_name attribute to x509.NameAttribute.

- Added KBKDFMAC.

2.7.30 3.4.8 - 2021-08-24

- Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1l.

2.7.31 3.4.7 - 2021-03-25

- Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1k.

2.7.32 3.4.6 - 2021-02-16

- Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1j.
2.7.33 3.4.5 - 2021-02-13

- Various improvements to type hints.
- Lower the minimum supported Rust version (MSRV) to >=1.41.0. This change improves compatibility with system-provided Rust on several Linux distributions.
- cryptography will be switching to a new versioning scheme with its next feature release. More information is available in our API stability documentation.

2.7.34 3.4.4 - 2021-02-09

- Added a py.typed file so that mypy will know to use our type annotations.
- Fixed an import cycle that could be triggered by certain import sequences.

2.7.35 3.4.3 - 2021-02-08

- Specify our supported Rust version (>=1.45.0) in our setup.py so users on older versions will get a clear error message.

2.7.36 3.4.2 - 2021-02-08

- Improvements to make the rust transition a bit easier. This includes some better error messages and small dependency fixes. If you experience installation problems Be sure to update pip first, then check the FAQ.

2.7.37 3.4.1 - 2021-02-07

- Fixed a circular import issue.
- Added additional debug output to assist users seeing installation errors due to outdated pip or missing rustc.

2.7.38 3.4 - 2021-02-07

- BACKWARDS INCOMPATIBLE: Support for Python 2 has been removed.
- We now ship manylinux2014 wheels and no longer ship manylinux1 wheels. Users should upgrade to the latest pip to ensure this doesn’t cause issues downloading wheels on their platform.
- cryptography now incorporates Rust code. Users building cryptography themselves will need to have the Rust toolchain installed. Users who use an officially produced wheel will not need to make any changes. The minimum supported Rust version is 1.45.0.
- cryptography now has PEP 484 type hints on nearly all of its public APIs. Users can begin using them to type check their code with mypy.
2.7.39 3.3.2 - 2021-02-07

- SECURITY ISSUE: Fixed a bug where certain sequences of `update()` calls when symmetrically encrypting very large payloads (>2GB) could result in an integer overflow, leading to buffer overflows. CVE-2020-36242
  
  Update: This fix is a workaround for CVE-2021-23840 in OpenSSL, fixed in OpenSSL 1.1.1j.

2.7.40 3.3.1 - 2020-12-09

- Re-added a legacy symbol causing problems for older pyOpenSSL users.

2.7.41 3.3 - 2020-12-08

- BACKWARDS INCOMPATIBLE: Support for Python 3.5 has been removed due to low usage and maintenance burden.

- BACKWARDS INCOMPATIBLE: The GCM and AESGCM now require 64-bit to 1024-bit (8 byte to 128 byte) initialization vectors. This change is to conform with an upcoming OpenSSL release that will no longer support sizes outside this window.

- BACKWARDS INCOMPATIBLE: When deserializing asymmetric keys we now raise ValueError rather than UnsupportedAlgorithm when an unsupported cipher is used. This change is to conform with an upcoming OpenSSL release that will no longer distinguish between error types.

- BACKWARDS INCOMPATIBLE: We no longer allow loading of finite field Diffie-Hellman parameters of less than 512 bits in length. This change is to conform with an upcoming OpenSSL release that no longer supports smaller sizes. These keys were already wildly insecure and should not have been used in any application outside of testing.

- Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1i.

- Python 2 support is deprecated in cryptography. This is the last release that will support Python 2.

- Added the `recover_data_from_signature()` function to `RSAPublicKey` for recovering the signed data from an RSA signature.

2.7.42 3.2.1 - 2020-10-27

- Disable blinding on RSA public keys to address an error with some versions of OpenSSL.

2.7.43 3.2 - 2020-10-25

- SECURITY ISSUE: Attempted to make RSA PKCS#1v1.5 decryption more constant time, to protect against Bleichenbacher vulnerabilities. Due to limitations imposed by our API, we cannot completely mitigate this vulnerability and a future release will contain a new API which is designed to be resilient to these for contexts where it is required. Credit to Hubert Kario for reporting the issue. CVE-2020-25659

- Support for OpenSSL 1.0.2 has been removed. Users on older version of OpenSSL will need to upgrade.

- Added basic support for PKCS7 signing (including SMIME) via `PKCS7SignatureBuilder`.
2.7.44 3.1.1 - 2020-09-22

• Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1h.

2.7.45 3.1 - 2020-08-26

• BACKWARDS INCOMPATIBLE: Removed support for idna based U-label parsing in various X.509 classes. This support was originally deprecated in version 2.1 and moved to an extra in 2.5.
• Deprecated OpenSSL 1.0.2 support. OpenSSL 1.0.2 is no longer supported by the OpenSSL project. The next version of cryptography will drop support for it.
• Deprecated support for Python 3.5. This version sees very little use and will be removed in the next release.
• backend arguments to functions are no longer required and the default backend will automatically be selected if no backend is provided.
• Added initial support for parsing certificates from PKCS7 files with `load_pem_pkcs7_certificates()` and `load_der_pkcs7_certificates()`.
• Calling `update` or `update_into` on `CipherContext` with `data` longer than $2^{31}$ bytes no longer raises an `OverflowError`. This also resolves the same issue in `Fernet (symmetric encryption)`.

2.7.46 3.0 - 2020-07-20

• BACKWARDS INCOMPATIBLE: Removed support for passing an `Extension` instance to `from_issuer_subject_key_identifier()`, as per our deprecation policy.
• BACKWARDS INCOMPATIBLE: Support for LibreSSL 2.7.x, 2.8.x, and 2.9.0 has been removed (2.9.1+ is still supported).
• BACKWARDS INCOMPATIBLE: Dropped support for macOS 10.9. macOS users must upgrade to 10.10 or newer.
• BACKWARDS INCOMPATIBLE: RSA `generate_private_key()` no longer accepts `public_exponent` values except 65537 and 3 (the latter for legacy purposes).
• BACKWARDS INCOMPATIBLE: X.509 certificate parsing now enforces that the `version` field contains a valid value, rather than deferring this check until `version` is accessed.
• Deprecated support for Python 2. At the time there is no time table for actually dropping support, however we strongly encourage all users to upgrade their Python, as Python 2 no longer receives support from the Python core team.

If you have trouble suppressing this warning in tests view the FAQ entry addressing this issue.
• Added support for OpenSSH serialization format for ec, ed25519, rsa and dsa private keys: `load_ssh_private_key()` for loading and OpenSSH for writing.
• Added support for OpenSSH certificates to `load_ssh_public_key()`.
• Added `encrypt_at_time()` and `decrypt_at_time()` to Fernet.
• Added support for the `SubjectInformationAccess` X.509 extension.
• Added support for parsing `SignedCertificateTimestamps` in OCSP responses.
• Added support for parsing attributes in certificate signing requests via `CertificateSigningRequest.get_attribute_for_oid`.
• Added support for encoding attributes in certificate signing requests via `add_attribute()`.
• On OpenSSL 1.1.1d and higher cryptography now uses OpenSSL's built-in CSPRNG instead of its own OS random engine because these versions of OpenSSL properly reseed on fork.

• Added initial support for creating PKCS12 files with `serialize_key_and_certificates()`.

### 2.7.47 2.9.2 - 2020-04-22

• Updated the macOS wheel to fix an issue where it would not run on macOS versions older than 10.15.

### 2.7.48 2.9.1 - 2020-04-21

• Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1g.

### 2.7.49 2.9 - 2020-04-02

• **BACKWARDS INCOMPATIBLE:** Support for Python 3.4 has been removed due to low usage and maintenance burden.

• **BACKWARDS INCOMPATIBLE:** Support for OpenSSL 1.0.1 has been removed. Users on older version of OpenSSL will need to upgrade.

• **BACKWARDS INCOMPATIBLE:** Support for LibreSSL 2.6.x has been removed.

• Removed support for calling `public_bytes()` with no arguments, as per our deprecation policy. You must now pass `encoding` and `format`.

• **BACKWARDS INCOMPATIBLE:** Reversed the order in which `rfc4514_string()` returns the RDNs as required by [RFC 4514](https://tools.ietf.org/html/rfc4514).

• Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1f.

• Added support for parsing `single_extensions` in an OCSP response.

• `NameAttribute` values can now be empty strings.

### 2.7.50 2.8 - 2019-10-16

• Updated Windows, macOS, and manylinux wheels to be compiled with OpenSSL 1.1.1d.

• Added support for Python 3.8.

• Added class methods `Poly1305.generate_tag` and `Poly1305.verify_tag` for Poly1305 sign and verify operations.

• Deprecated support for OpenSSL 1.0.1. Support will be removed in cryptography 2.9.

• We now ship manylinux2010 wheels in addition to our manylinux1 wheels.


• cryptography no longer depends on asn1crypto.

• `FreshestCRL` is now allowed as a `CertificateRevocationList` extension.
2.7.51 2.7 - 2019-05-30

• BACKWARDS INCOMPATIBLE: We no longer distribute 32-bit manylinux1 wheels. Continuing to produce them was a maintenance burden.

• BACKWARDS INCOMPATIBLE: Removed the cryptography.hazmat.primitives.mac.MACContext interface. The CMAC and HMAC APIs have not changed, but they are no longer registered as MACContext instances.

• Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.1c.

• Removed support for running our tests with setup.py test. Users interested in running our tests can continue to follow the directions in our development documentation.

• Add support for Poly1305 when using OpenSSL 1.1.1 or newer.

• Support serialization with Encoding.OpenSSH and PublicFormat.OpenSSH in Ed25519PublicKey.public_bytes.

• Correctly allow passing a SubjectKeyIdentifier to from_issuer_subject_key_identifier() and deprecate passing an Extension object. The documentation always required SubjectKeyIdentifier but the implementation previously required an Extension.

2.7.52 2.6.1 - 2019-02-27

• Resolved an error in our build infrastructure that broke our Python3 wheels for macOS and Linux.

2.7.53 2.6 - 2019-02-27

• BACKWARDS INCOMPATIBLE: Removed cryptography.hazmat.primitives.asymmetric.utils.encode_rfc6979_signature and cryptography.hazmat.primitives.asymmetric.utils.decode_rfc6979_signature, which had been deprecated for nearly 4 years. Use encode_dss_signature() and decode_dss_signature() instead.

• BACKWARDS INCOMPATIBLE: Removed cryptography.x509.Certificate.serial, which had been deprecated for nearly 3 years. Use serial_number instead.

• Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.1b.

• Added support for Ed448 signing when using OpenSSL 1.1.1b or newer.

• Added support for Ed25519 signing when using OpenSSL 1.1.1b or newer.

• load_ssh_public_key() can now load ed25519 public keys.

• Add support for easily mapping an object identifier to its elliptic curve class via get_curve_for_oid().

• Add support for OpenSSL when compiled with the no-engine (OPENSSL_NO_ENGINE) flag.

2.7.54 2.5 - 2019-01-22

• BACKWARDS INCOMPATIBLE: U-label strings were deprecated in version 2.1, but this version removes the default idna dependency as well. If you still need this deprecated path please install cryptography with the idna extra: pip install cryptography[idna].

• BACKWARDS INCOMPATIBLE: The minimum supported PyPy version is now 5.4.

• Numerous classes and functions have been updated to allow bytes-like types for keying material and passwords, including symmetric algorithms, AEAD ciphers, KDFs, loading asymmetric keys, and one time password classes.
• Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.1a.
• Added support for SHA512_224 and SHA512_256 when using OpenSSL 1.1.1.
• Added support for SHA3_224, SHA3_256, SHA3_384, and SHA3_512 when using OpenSSL 1.1.1.
• Added support for X448 key exchange when using OpenSSL 1.1.1.
• Added support for SHAKE128 and SHAKE256 when using OpenSSL 1.1.1.
• Added initial support for parsing PKCS12 files with load_key_and_certificates().
• Added support for IssuingDistributionPoint.
• Added rfc4514_string() method to x509.Name, x509.RelativeDistinguishedName, and x509.NameAttribute to format the name or component an RFC 4514 Distinguished Name string.
• Added from_encoded_point(), which immediately checks if the point is on the curve and supports compressed points. Deprecated the previous method from_encoded_point().
• Added signature_hash_algorithm to OCSPResponse.
• Updated X25519 key exchange support to allow additional serialization methods. Calling public_bytes() with no arguments has been deprecated.
• Added support for encoding compressed and uncompressed points via public_bytes(). Deprecated the previous method cryptography.hazmat.primitives.asymmetric.ec.EllipticCurvePublicNumbers.encode_point.

2.7.55 2.4.2 - 2018-11-21

• Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.0j.

2.7.56 2.4.1 - 2018-11-11

• Fixed a build breakage in our manylinux1 wheels.

2.7.57 2.4 - 2018-11-11

• BACKWARDS INCOMPATIBLE: Dropped support for LibreSSL 2.4.x.
• Deprecated OpenSSL 1.0.1 support. OpenSSL 1.0.1 is no longer supported by the OpenSSL project. At this time there is no time table for dropping support, however we strongly encourage all users to upgrade or install cryptography from a wheel.
• Added initial OCSP support.
• Added support for PrecertPoison.
2.7.58 2.3.1 - 2018-08-14

- Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.0i.

2.7.59 2.3 - 2018-07-18

- **SECURITY ISSUE:** `finalize_with_tag()` allowed tag truncation by default which can allow tag forgery in some cases. The method now enforces the `min_tag_length` provided to the `GCM` constructor. [CVE-2018-10903](https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2018-10903)
- Added support for Python 3.7.
- Added `extract_timestamp()` to get the authenticated timestamp of a `Fernet` token.
- Support for Python 2.7.x without `hmac.compare_digest` has been deprecated. We will require Python 2.7.7 or higher (or 2.7.6 on Ubuntu) in the next `cryptography` release.
- Fixed multiple issues preventing `cryptography` from compiling against LibreSSL 2.7.x.
- Added `get_revoked_certificate_by_serial_number` for quick serial number searches in CRLs.
- The `RelativeDistinguishedName` class now preserves the order of attributes. Duplicate attributes now raise an error instead of silently discarding duplicates.
- `aes_key_unwrap()` and `aes_key_unwrap_with_padding()` now raise `InvalidUnwrap` if the wrapped key is an invalid length, instead of `ValueError`.

2.7.60 2.2.2 - 2018-03-27

- Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.0h.

2.7.61 2.2.1 - 2018-03-20

- Reverted a change to `GeneralNames` which prohibited having zero elements, due to breakages.
- Fixed a bug in `aes_key_unwrap_with_padding()` that caused it to raise `InvalidUnwrap` when key length modulo 8 was zero.

2.7.62 2.2 - 2018-03-19

- **BACKWARDS INCOMPATIBLE:** Support for Python 2.6 has been dropped.
- Resolved a bug in HKDF that incorrectly constrained output size.
- Added `BrainpoolP256R1`, `BrainpoolP384R1`, and `BrainpoolP512R1` to support inter-operating with systems like German smart meters.
- Added token rotation support to `Fernet` with `rotate()`.
- Fixed a memory leak in `derive_private_key()`.
- Added support for AES key wrapping with padding via `aes_key_wrap_with_padding()` and `aes_key_unwrap_with_padding()`.
- Allow loading DSA keys with 224 bit q.

2.7. Changelog
2.7.63 2.1.4 - 2017-11-29

• Added X509_up_ref for an upcoming pyOpenSSL release.

2.7.64 2.1.3 - 2017-11-02

• Updated Windows, macOS, and manylinux1 wheels to be compiled with OpenSSL 1.1.0g.

2.7.65 2.1.2 - 2017-10-24

• Corrected a bug with the manylinux1 wheels where OpenSSL's stack was marked executable.

2.7.66 2.1.1 - 2017-10-12

• Fixed support for install with the system pip on Ubuntu 16.04.

2.7.67 2.1 - 2017-10-11

• FINAL DEPRECATION Python 2.6 support is deprecated, and will be removed in the next release of cryptography.

• BACKWARDS INCOMPATIBLE: Whirlpool, RIPEMD160, and UnsupportedExtension have been removed in accordance with our API stability policy.

• BACKWARDS INCOMPATIBLE: DNSName.value, RFC822Name.value, and UniformResourceIdentifier.value will now return an A-label string when parsing a certificate containing an internationalized domain name (IDN) or if the caller passed a U-label to the constructor. See below for additional deprecations related to this change.

• Installing cryptography now requires pip 6 or newer.

• Deprecated passing U-label strings to the DNSName, UniformResourceIdentifier, and RFC822Name constructors. Instead, users should pass values as A-label strings with idna encoding if necessary. This change will not affect anyone who is not processing internationalized domains.

• Added support for ChaCha20. In most cases users should choose ChaCha20Poly1305 rather than using this unauthenticated form.

• Added is_signature_valid() to CertificateRevocationList.

• Support BLAKE2b and BLAKE2s with HMAC.

• Added support for XTS mode for AES.

• Added support for using labels with OAEP when using OpenSSL 1.0.2 or greater.

• Improved compatibility with NSS when issuing certificates from an issuer that has a subject with non-UTF8String string types.

• Add support for the DeltaCRLIndicator extension.

• Add support for the TLSFeature extension. This is commonly used for enabling OCSP Must-Staple in certificates.

• Add support for the FreshestCRL extension.
2.7.68 2.0.3 - 2017-08-03

• Fixed an issue with weak linking symbols when compiling on macOS versions older than 10.12.

2.7.69 2.0.2 - 2017-07-27

• Marked all symbols as hidden in the manylinux1 wheel to avoid a bug with symbol resolution in certain scenarios.

2.7.70 2.0.1 - 2017-07-26

• Fixed a compilation bug affecting OpenBSD.
• Altered the manylinux1 wheels to statically link OpenSSL instead of dynamically linking and bundling the shared object. This should resolve crashes seen when using uwsgi or other binaries that link against OpenSSL independently.
• Fixed the stack level for the signer and verifier warnings.

2.7.71 2.0 - 2017-07-17

• BACKWARDS INCOMPATIBLE: Support for Python 3.3 has been dropped.
• We now ship manylinux1 wheels linked against OpenSSL 1.1.0f. These wheels will be automatically used with most Linux distributions if you are running the latest pip.
• Deprecated the use of signer on RSAPrivateKey, DSAPrivateKey, and EllipticCurvePrivateKey in favor of sign.
• Deprecated the use of verifier on RSAPublicKey, DSAPublicKey, and EllipticCurvePublicKey in favor of verify.
• Added support for parsing SignedCertificateTimestamp objects from X.509 certificate extensions.
• Added support for ChaCha20Poly1305.
• Added support for AESCCM.
• Added AESGCM, a “one shot” API for AES GCM encryption.
• Added support for X25519 key exchange.
• Added support for serializing and deserializing Diffie-Hellman parameters with load_pem_parameters(), load_der_parameters(), and parameter_bytes().
• The extensions attribute on Certificate, CertificateSigningRequest, CertificateRevocationList, and RevokedCertificate now caches the computed Extensions object. There should be no performance change, just a performance improvement for programs accessing the extensions attribute multiple times.
2.7.72  1.9 - 2017-05-29

• BACKWARDS INCOMPATIBLE: Elliptic Curve signature verification no longer returns True on success. This brings it in line with the interface’s documentation, and our intent. The correct way to use verify() has always been to check whether or not InvalidSignature was raised.

• BACKWARDS INCOMPATIBLE: Dropped support for macOS 10.7 and 10.8.

• BACKWARDS INCOMPATIBLE: The minimum supported PyPy version is now 5.3.

• Python 3.3 support has been deprecated, and will be removed in the next cryptography release.

• Add support for providing tag during GCM finalization via finalize_with_tag().

• Fixed an issue preventing cryptography from compiling against LibreSSL 2.5.x.

• Added key_size() and key_size() as convenience methods for determining the bit size of a secret scalar for the curve.

• Accessing an unrecognized extension marked critical on an X.509 object will no longer raise an UnsupportedExtension exception, instead an UnrecognizedExtension object will be returned. This behavior was based on a poor reading of the RFC, unknown critical extensions only need to be rejected on certificate verification.

• The CommonCrypto backend has been removed.

• MultiBackend has been removed.

• Whirlpool and RIPEMD160 have been deprecated.

2.7.73  1.8.2 - 2017-05-26

• Fixed a compilation bug affecting OpenSSL 1.1.0f.

• Updated Windows and macOS wheels to be compiled against OpenSSL 1.1.0f.

2.7.74  1.8.1 - 2017-03-10

• Fixed macOS wheels to properly link against 1.1.0 rather than 1.0.2.

2.7.75  1.8 - 2017-03-09

• Added support for Python 3.6.

• Windows and macOS wheels now link against OpenSSL 1.1.0.

• macOS wheels are no longer universal. This change significantly shrinks the size of the wheels. Users on macOS 32-bit Python (if there are any) should migrate to 64-bit or build their own packages.

• Changed ASN.1 dependency from pyasn1 to asn1crypto resulting in a general performance increase when encoding/decoding ASN.1 structures. Also, the pyasn1_modules test dependency is no longer required.

• Added support for update_into() on CipherContext.

• Added private_bytes() to DHPrivateKey.

• Added public_bytes() to DHPrivateKey.

• load_pem_private_key() and load_der_private_key() now require that password must be bytes if provided. Previously this was documented but not enforced.
• Added support for subgroup order in *Diffie-Hellman key exchange*.

2.7.76 1.7.2 - 2017-01-27

• Updated Windows and macOS wheels to be compiled against OpenSSL 1.0.2k.

2.7.77 1.7.1 - 2016-12-13

• Fixed a regression in `int_from_bytes` where it failed to accept `bytearray`.

2.7.78 1.7 - 2016-12-12

• Support for OpenSSL 1.0.0 has been removed. Users on older version of OpenSSL will need to upgrade.
• Added support for Diffie-Hellman key exchange using `exchange()`.
• The OS random engine for OpenSSL has been rewritten to improve compatibility with embedded Python and other edge cases. More information about this change can be found in the pull request.

2.7.79 1.6 - 2016-11-22

• Deprecated support for OpenSSL 1.0.0. Support will be removed in cryptography 1.7.
• Replaced the Python-based OpenSSL locking callbacks with a C version to fix a potential deadlock that could occur if a garbage collection cycle occurred while inside the lock.
• Added support for `BLAKE2b` and `BLAKE2s` when using OpenSSL 1.1.0.
• Added `signature_algorithm_oid` support to `Certificate`.
• Added `signature_algorithm_oid` support to `CertificateSigningRequest`.
• Added `signature_algorithm_oid` support to `CertificateRevocationList`.
• Added support for `Scrypt` when using OpenSSL 1.1.0.
• Added a workaround to improve compatibility with Python application bundling tools like `PyInstaller` and `cx_freeze`.
• Added support for generating a `random_serial_number()`.
• Added support for encoding IPv4Network and IPv6Network in X.509 certificates for use with `NameConstraints`.
• Added `public_bytes()` to `Name`.
• Added `RelativeDistinguishedName`.
  `DistributionPoint` now accepts `RelativeDistinguishedName` for `relative_name`. Deprecated use of `Name` as `relative_name`.
  `Name` now accepts an iterable of `RelativeDistinguishedName`. RDNs can be accessed via the `rdns` attribute. When constructed with an iterable of `NameAttribute`, each attribute becomes a single-valued RDN.
• Added `derive_private_key()`.
• Added support for signing and verifying RSA, DSA, and ECDSA signatures with `Prehashed` digests.
2.7.80 1.5.3 - 2016-11-05

- **SECURITY ISSUE**: Fixed a bug where HKDF would return an empty byte-string if used with a `length` less than `algorithm.digest_size`. Credit to Markus Döring for reporting the issue. CVE-2016-9243

2.7.81 1.5.2 - 2016-09-26

- Updated Windows and OS X wheels to be compiled against OpenSSL 1.0.2j.

2.7.82 1.5.1 - 2016-09-22

- Updated Windows and OS X wheels to be compiled against OpenSSL 1.0.2i.
- Resolved a `UserWarning` when used with cffi 1.8.3.
- Fixed a memory leak in name creation with X.509.
- Added a workaround for old versions of setuptools.
- Fixed an issue preventing `cryptography` from compiling against OpenSSL 1.0.2i.

2.7.83 1.5 - 2016-08-26

- Added `calculate_max_pss_salt_length()`.
- Added “one shot” `sign()` and `verify()` methods to DSA keys.
- Added “one shot” `sign()` and `verify()` methods to ECDSA keys.
- Switched back to the older callback model on Python 3.5 in order to mitigate the locking callback problem with OpenSSL <1.1.0.
- `CertificateBuilder`, `CertificateRevocationListBuilder`, and `RevokedCertificateBuilder` now accept timezone aware `datetime` objects as method arguments
- `cryptography` now supports OpenSSL 1.1.0 as a compilation target.

2.7.84 1.4 - 2016-06-04

- Support for OpenSSL 0.9.8 has been removed. Users on older versions of OpenSSL will need to upgrade.
- Added `KBKDFHMAC`.
- Added support for OpenSSH public key serialization.
- Added support for SHA-2 in RSA `OAEP` when using OpenSSL 1.0.2 or greater.
- Added “one shot” `sign()` and `verify()` methods to RSA keys.
- Deprecated the `serial` attribute on `Certificate`, in favor of `serial_number`. 
2.7.85 1.3.4 - 2016-06-03

- Added another OpenSSL function to the bindings to support an upcoming pyOpenSSL release.

2.7.86 1.3.3 - 2016-06-02

- Added two new OpenSSL functions to the bindings to support an upcoming pyOpenSSL release.

2.7.87 1.3.2 - 2016-05-04

- Updated Windows and OS X wheels to be compiled against OpenSSL 1.0.2h.
- Fixed an issue preventing cryptography from compiling against LibreSSL 2.3.x.

2.7.88 1.3.1 - 2016-03-21

- Fixed a bug that caused an AttributeError when using mock to patch some cryptography modules.

2.7.89 1.3 - 2016-03-18

- Added support for padding ANSI X.923 with ANSIX923.
- Deprecated support for OpenSSL 0.9.8. Support will be removed in cryptography 1.4.
- Added support for the PolicyConstraints X.509 extension including both parsing and generation using CertificateBuilder and CertificateSigningRequestBuilder.
- Added is_signature_valid to CertificateSigningRequest.
- Fixed an intermittent AssertionError when performing an RSA decryption on an invalid ciphertext, ValueError is now correctly raised in all cases.
- Added from_issuer_subject_key_identifier().

2.7.90 1.2.3 - 2016-03-01

- Updated Windows and OS X wheels to be compiled against OpenSSL 1.0.2g.

2.7.91 1.2.2 - 2016-01-29

- Updated Windows and OS X wheels to be compiled against OpenSSL 1.0.2f.
2.7.92 1.2.1 - 2016-01-08

- Reverts a change to an OpenSSL EVP_PKEY object that caused errors with pyOpenSSL.

2.7.93 1.2 - 2016-01-08

- BACKWARDS INCOMPATIBLE: RevokedCertificate extensions now uses extension classes rather than returning raw values inside the Extension value. The new classes are:
  - CertificateIssuer
  - CRLReason
  - InvalidityDate
- Deprecated support for OpenSSL 0.9.8 and 1.0.0. At this time there is no time table for actually dropping support, however we strongly encourage all users to upgrade, as those versions no longer receive support from the OpenSSL project.
- The Certificate class now has signature and tbs_certificate_bytes attributes.
- The CertificateSigningRequest class now has signature and tbs_certrequest_bytes attributes.
- The CertificateRevocationList class now has signature and tbs_certlist_bytes attributes.
- NameConstraints are now supported in the CertificateBuilder and CertificateSigningRequestBuilder.
- Add support for parsing CertificateRevocationList extensions() in the OpenSSL backend. The following extensions are currently supported:
  - AuthorityInformationAccess
  - AuthorityKeyIdentifier
  - CRLNumber
  - IssuerAlternativeName
- Added CertificateRevocationListBuilder and RevokedCertificateBuilder to allow creation of CRLs.
- Unrecognized non-critical X.509 extensions are now parsed into an UnrecognizedExtension object.

2.7.94 1.1.2 - 2015-12-10

- Fixed a SIGBUS crash with the OS X wheels caused by redefinition of a method.
- Fixed a runtime error undefined symbol EC_GFp_nistp224_method that occurred with some OpenSSL installations.
- Updated Windows and OS X wheels to be compiled against OpenSSL 1.0.2e.
2.7.95 1.1.1 - 2015-11-19

- Fixed several small bugs related to compiling the OpenSSL bindings with unusual OpenSSL configurations.
- Resolved an issue where, depending on the method of installation and which Python interpreter they were using, users on El Capitan (OS X 10.11) may have seen an InternalError on import.

2.7.96 1.1 - 2015-10-28

- Added support for Elliptic Curve Diffie-Hellman with ECDH.
- Added X963KDF.
- Added support for parsing certificate revocation lists (CRLs) using load_pem_x509_crl() and load_der_x509_crl().
- Add support for AES key wrapping with aes_key_wrap() and aes_key_unwrap().
- Added a __hash__ method to Name.
- Add support for encoding and decoding elliptic curve points to a byte string form using cryptography.hazmat.primitives.asymmetric.ec.EllipticCurvePublicNumbers.encode_point and from_encoded_point().
- Added get_extension_for_class().
- CertificatePolicies are now supported in the CertificateBuilder.
- countryName is now encoded as a PrintableString when creating subject and issuer distinguished names with the Certificate and CSR builder classes.

2.7.97 1.0.2 - 2015-09-27

- **SECURITY ISSUE**: The OpenSSL backend prior to 1.0.2 made extensive use of assertions to check response codes where our tests could not trigger a failure. However, when Python is run with -O these asserts are optimized away. If a user ran Python with this flag and got an invalid response code this could result in undefined behavior or worse. Accordingly, all response checks from the OpenSSL backend have been converted from assert to a true function call. Credit Emilia Käsper (Google Security Team) for the report.

2.7.98 1.0.1 - 2015-09-05

- We now ship OS X wheels that statically link OpenSSL by default. When installing a wheel on OS X 10.10+ (and using a Python compiled against the 10.10 SDK) users will no longer need to compile. See Installation for alternate installation methods if required.
- Set the default string mask to UTF-8 in the OpenSSL backend to resolve character encoding issues with older versions of OpenSSL.
- Several new OpenSSL bindings have been added to support a future pyOpenSSL release.
- Raise an error during install on PyPy < 2.6. 1.0+ requires PyPy 2.6+.
• Switched to the new cffi `set_source` out-of-line API mode for compilation. This results in significantly faster imports and lowered memory consumption. Due to this change we no longer support PyPy releases older than 2.6 nor do we support any released version of PyPy3 (until a version supporting cffi 1.0 comes out).

• Fix parsing of OpenSSH public keys that have spaces in comments.

• Support serialization of certificate signing requests using the `public_bytes` method of `CertificateSigningRequest`.

• Support serialization of certificates using the `public_bytes` method of `Certificate`.

• Add `get_provisioning_uri` method to `HOTP` and `TOTP` for generating provisioning URIs.

• Add `ConcatKDFHash` and `ConcatKDFHMAC`.

• Raise a `TypeError` when passing objects that are not text as the value to `NameAttribute`.

• Add support for `OtherName` as a general name type.

• Added new X.509 extension support in `Certificate` The following new extensions are now supported:
  - `OCSPNoCheck`
  - `InhibitAnyPolicy`
  - `IssuerAlternativeName`
  - `NameConstraints`

• Extension support was added to `CertificateSigningRequest`.

• Add support for creating signed certificates with `CertificateBuilder`. This includes support for the following extensions:
  - `BasicConstraints`
  - `SubjectAlternativeName`
  - `KeyUsage`
  - `ExtendedKeyUsage`
  - `SubjectKeyIdentifier`
  - `AuthorityKeyIdentifier`
  - `AuthorityInformationAccess`
  - `CRLDistributionPoints`
  - `InhibitAnyPolicy`
  - `IssuerAlternativeName`
  - `OCSPNoCheck`

• Add support for creating certificate signing requests with `CertificateSigningRequestBuilder`. This includes support for the same extensions supported in the `CertificateBuilder`.

• Deprecate `encode_rfc6979_signature` and `decode_rfc6979_signature` in favor of `encode_dss_signature()` and `decode_dss_signature()`. 
2.7.100 0.9.3 - 2015-07-09

• Updated Windows wheels to be compiled against OpenSSL 1.0.2d.

2.7.101 0.9.2 - 2015-07-04

• Updated Windows wheels to be compiled against OpenSSL 1.0.2c.

2.7.102 0.9.1 - 2015-06-06

• **SECURITY ISSUE**: Fixed a double free in the OpenSSL backend when using DSA to verify signatures. Note that this only affects PyPy 2.6.0 and (presently unreleased) CFFI versions greater than 1.1.0.

2.7.103 0.9 - 2015-05-13

• Removed support for Python 3.2. This version of Python is rarely used and caused support headaches. Users affected by this should upgrade to 3.3+.
• Deprecated support for Python 2.6. At the time there is no time table for actually dropping support, however we strongly encourage all users to upgrade their Python, as Python 2.6 no longer receives support from the Python core team.
• Add support for the **SECP256K1** elliptic curve.
• Fixed compilation when using an OpenSSL which was compiled with the `no-comp` (`OPENSSL_NO_COMP`) option.
• Support DER serialization of public keys using the `public_bytes` method of `RSAPublicKey`, `DSAPublicKey`, and `EllipticCurvePublicKey`.
• Support DER serialization of private keys using the `private_bytes` method of `RSAPrivateKey`, `DSAPrivateKey`, and `EllipticCurvePrivateKey`.
• Add support for parsing X.509 certificate signing requests (CSRs) with `load_pem_x509_csr()` and `load_der_x509_csr()`.
• Moved `cryptography.exceptions.InvalidToken` to `cryptography.hazmat.primitives.twofactor.InvalidToken` and deprecated the old location. This was moved to minimize confusion between this exception and `cryptography.fernet.InvalidToken`.
• Added support for X.509 extensions in `Certificate` objects. The following extensions are supported as of this release:
  - `BasicConstraints`
  - `AuthorityKeyIdentifier`
  - `SubjectKeyIdentifier`
  - `KeyUsage`
  - `SubjectAlternativeName`
  - `ExtendedKeyUsage`
  - `CRLDistributionPoints`
  - `AuthorityInformationAccess`
  - `CertificatePolicies`
Note that unsupported extensions with the critical flag raise `UnsupportedExtension` while unsupported extensions set to non-critical are silently ignored. Read the [X.509 documentation](#) for more information.

### 2.7.104 0.8.2 - 2015-04-10

- Fixed a race condition when initializing the OpenSSL or CommonCrypto backends in a multi-threaded scenario.

### 2.7.105 0.8.1 - 2015-03-20

- Updated Windows wheels to be compiled against OpenSSL 1.0.2a.

### 2.7.106 0.8 - 2015-03-08

- `load_ssh_public_key()` can now load elliptic curve public keys.
- Added `signature_hash_algorithm` support to `Certificate`.
- Added `rsa_recover_prime_factors()`.
- `KeyDerivationFunction` was moved from `cryptography.hazmat.primitives.interfaces` to `kdf`.
- Added support for parsing X.509 names. See the [X.509 documentation](#) for more information.
- Added `load_der_private_key()` to support loading of DER encoded private keys and `load_der_public_key()` to support loading DER encoded public keys.
- Fixed building against LibreSSL, a compile-time substitute for OpenSSL.
- FreeBSD 9.2 was removed from the continuous integration system.
- Updated Windows wheels to be compiled against OpenSSL 1.0.2.
- `load_pem_private_key()` and `load_der_private_key()` now support PKCS1 RSA public keys (in addition to the previous support for SubjectPublicKeyInfo format for RSA, EC, and DSA).
- Added `EllipticCurvePrivateKeyWithSerialization` and deprecated `EllipticCurvePrivateKeyWithNumbers`.
- Added `private_bytes()` to `EllipticCurvePrivateKey`.
- Added `RSAPrivateKeyWithSerialization` and deprecated `RSAPrivateKeyWithNumbers`.
- Added `private_bytes()` to `RSAPrivateKey`.
- Added `DSAPrivateKeyWithSerialization` and deprecated `DSAPrivateKeyWithNumbers`.
- Added `private_bytes()` to `DSAPrivateKey`.
- Added `RSAPublicKeyWithSerialization` and deprecated `RSAPublicKeyWithNumbers`.
- Added `public_bytes` to `RSAPublicKey`.
- Added `EllipticCurvePublicKeyWithSerialization` and deprecated `EllipticCurvePublicKeyWithNumbers`.
- Added `public_bytes` to `EllipticCurvePublicKey`.
- Added `DSAPublicKeyWithSerialization` and deprecated `DSAPublicKeyWithNumbers`.
- Added `public_bytes` to `DSAPublicKey`.
- `HashAlgorithm` and `HashContext` were moved from `cryptography.hazmat.primitives.interfaces` to `hashes.`
• **CipherContext**, **AEADCipherContext**, **AEADEncryptionContext**, **CipherAlgorithm**, and **BlockCipherAlgorithm** were moved from cryptography.hazmat.primitives.interfaces to ciphers.

• **Mode**, **ModeWithInitializationVector**, **ModeWithNonce**, and **ModeWithAuthenticationTag** were moved from cryptography.hazmat.primitives.interfaces to modes.

• **PaddingContext** was moved from cryptography.hazmat.primitives.interfaces to padding.

• **AsymmetricPadding** was moved from cryptography.hazmat.primitives.interfaces to padding.

• **AsymmetricSignatureContext** and **AsymmetricVerificationContext** were moved from cryptography.hazmat.primitives.interfaces to cryptography.hazmat.primitives.asymmetric.

• **DSAPrivateKey** and **DSAPublicKey** were moved from cryptography.hazmat.primitives.interfaces to dsa.

• **EllipticCurve**, **EllipticCurveSignatureAlgorithm**, **EllipticCurvePrivateKey**, **EllipticCurvePrivateKeyWithNumbers**, **EllipticCurvePublicKey** and **EllipticCurvePublicKeyWithNumbers** were moved from cryptography.hazmat.primitives.interfaces to ec.

• **RSAPrivateKey**, **RSAPrivateKeyWithNumbers**, **RSAPublicKey** and **RSAPublicKeyWithNumbers** were moved from cryptography.hazmat.primitives.interfaces to rsa.

### 2.7.107 0.7.2 - 2015-01-16

• Updated Windows wheels to be compiled against OpenSSL 1.0.11.

• enum34 is no longer installed on Python 3.4, where it is included in the standard library.

• Added a new function to the OpenSSL bindings to support additional functionality in pyOpenSSL.

### 2.7.108 0.7.1 - 2014-12-28

• Fixed an issue preventing compilation on platforms where OPENSSL_NO_SSL3 was defined.

### 2.7.109 0.7 - 2014-12-17

• Cryptography has been relicensed from the Apache Software License, Version 2.0, to being available under either the Apache Software License, Version 2.0, or the BSD license.

• Added key-rotation support to Fernet with MultiFernet.

• More bit-lengths are now supported for p and q when loading DSA keys from numbers.

• Added MACContext as a common interface for CMAC and HMAC and deprecated CMACContext.

• Added support for encoding and decoding RFC 6979 signatures in Asymmetric Utilities.

• Added load_ssh_public_key() to support the loading of OpenSSH public keys (RFC 4253). Only RSA and DSA keys are currently supported.

• Added initial support for X.509 certificate parsing. See the X.509 documentation for more information.
2.7.110 0.6.1 - 2014-10-15

- Updated Windows wheels to be compiled against OpenSSL 1.0.1j.
- Fixed an issue where OpenSSL 1.0.1j changed the errors returned by some functions.
- Added our license file to the cryptography-vectors package.
- Implemented DSA hash truncation support (per FIPS 186-3) in the OpenSSL backend. This works around an issue in 1.0.0, 1.0.0a, and 1.0.0b where truncation was not implemented.

2.7.111 0.6 - 2014-09-29

- Added load_pem_private_key() to ease loading private keys, and load_pem_public_key() to support loading public keys.
- Removed the, deprecated in 0.4, support for the salt_length argument to the MGF1 constructor. The salt_length should be passed to PSS instead.
- Fix compilation on OS X Yosemite.
- Deprecated elliptic_curve_private_key_from_numbers and elliptic_curve_public_key_from_numbers in favor of load_elliptic_curve_private_numbers and load_elliptic_curve_public_numbers on EllipticCurveBackend.
- Added EllipticCurvePrivateKeyWithNumbers and EllipticCurvePublicKeyWithNumbers support.
- Work around three GCM related bugs in CommonCrypto and OpenSSL.
  - On the CommonCrypto backend adding AAD but not subsequently calling update would return null tag bytes.
  - One the CommonCrypto backend a call to update without an empty add AAD call would return null ciphertext bytes.
  - On the OpenSSL backend with certain versions adding AAD only would give invalid tag bytes.
- Support loading EC private keys from PEM.

2.7.112 0.5.4 - 2014-08-20

- Added several functions to the OpenSSL bindings to support new functionality in pyOpenSSL.
- Fixed a redefined constant causing compilation failure with Solaris 11.2.

2.7.113 0.5.3 - 2014-08-06

- Updated Windows wheels to be compiled against OpenSSL 1.0.1i.
2.7.114 0.5.2 - 2014-07-09

- Add TraditionalOpenSSLSerializationBackend support to multibackend.
- Fix compilation error on OS X 10.8 (Mountain Lion).

2.7.115 0.5.1 - 2014-07-07

- Add PKCS8SerializationBackend support to multibackend.

2.7.116 0.5 - 2014-07-07

- **BACKWARDS INCOMPATIBLE:** GCM no longer allows truncation of tags by default. Previous versions of cryptography allowed tags to be truncated by default, applications wishing to preserve this behavior (not recommended) can pass the min_tag_length argument.
- Windows builds now statically link OpenSSL by default. When installing a wheel on Windows you no longer need to install OpenSSL separately. Windows users can switch between static and dynamic linking with an environment variable. See Installation for more details.
- Added HKDFExpand.
- Added CFB8 support for AES and TripleDES on commoncrypto and openssl.
- Added AES CTR support to the OpenSSL backend when linked against 0.9.8.
- Added PKCS8SerializationBackend and TraditionalOpenSSLSerializationBackend support to openssl.
- Added Elliptic curve cryptography and EllipticCurveBackend.
- Added ECB support for TripleDES on commoncrypto and openssl.
- Deprecated the concrete RSAPrivateKey class in favor of backend specific providers of the cryptography.hazmat.primitives.asymmetric.rsa.RSAPrivateKey interface.
- Deprecated the concrete RSAPublicKey in favor of backend specific providers of the cryptography.hazmat.primitives.asymmetric.rsa.RSAPublicKey interface.
- Deprecated the concrete DSAPrivateKey class in favor of backend specific providers of the cryptography.hazmat.primitives.asymmetric.dsa.DSAPrivateKey interface.
- Deprecated the concrete DSAPublicKey class in favor of backend specific providers of the cryptography.hazmat.primitives.asymmetric.dsa.DSAPublicKey interface.
- Deprecated the concrete DSAParameters class in favor of backend specific providers of the cryptography.hazmat.primitives.asymmetric.dsa.DSAParameters interface.
- Deprecated encrypt_rsa, decrypt_rsa, create_rsa_signature_ctx and create_rsa_verification_ctx on RSABackend.
- Deprecated create_dsa_signature_ctx and create_dsa_verification_ctx on DSABackend.
2.7.117 0.4 - 2014-05-03

- Deprecated `salt_length` on `MGF1` and added it to `PSS`. It will be removed from `MGF1` in two releases per our `API stability` policy.
- Added `SEED` support.
- Added `CMAC`.
- Added decryption support to `RSAPrivateKey` and encryption support to `RSAPublicKey`.
- Added signature support to `DSAPrivateKey` and verification support to `DSAPublicKey`.

2.7.118 0.3 - 2014-03-27

- Added `HOTP`.
- Added `TOTP`.
- Added `IDEA` support.
- Added signature support to `RSAPrivateKey` and verification support to `RSAPublicKey`.
- Moved test vectors to the new `cryptography_vectors` package.

2.7.119 0.2.2 - 2014-03-03

- Removed a constant definition that was causing compilation problems with specific versions of OpenSSL.

2.7.120 0.2.1 - 2014-02-22

- Fix a bug where importing cryptography from multiple paths could cause initialization to fail.

2.7.121 0.2 - 2014-02-20

- Added `commoncrypto`.
- Added initial `commoncrypto`.
- Removed `register_cipher_adapter` method from `CipherBackend`.
- Added support for the OpenSSL backend under Windows.
- Improved thread-safety for the OpenSSL backend.
- Fixed compilation on systems where OpenSSL's `ec.h` header is not available, such as CentOS.
- Added `PBKDF2HMAC`.
- Added `HKDF`.
- Added `multibackend`.
- Set default random for `openssl` to the OS random engine.
- Added `CAST5` (CAST-128) support.
2.8 Frequently asked questions

2.8.1 What issues can you help with in your issue tracker?

The primary purpose of our issue tracker is to enable us to identify and resolve bugs and feature requests in cryptography, so any time a user files a bug, we start by asking: Is this a cryptography bug, or is it a bug somewhere else?

That said, we do our best to help users to debug issues that are in their code or environments. Please note, however, that there’s a limit to our ability to assist users in resolving problems that are specific to their environments, particularly when we have no way to reproduce the issue.

Lastly, we’re not able to provide support for general Python or Python packaging issues.

2.8.2 I cannot suppress the deprecation warning that cryptography emits on import

Hint: The deprecation warning emitted on import does not inherit DeprecationWarning but inherits UserWarning instead.

If your pytest setup follows the best practices of failing on emitted warnings (filterwarnings = error), you may ignore it by adding the following line at the end of the list:

```python
ignore:Python 2 is no longer supported by the Python core team. Support for it is now deprecated in cryptography, and will be removed in a future release.:UserWarning
```

Note: Using cryptography.utils.CryptographyDeprecationWarning is not possible here because specifying it triggers import cryptography internally that emits the warning before the ignore rule even kicks in.

Ref: https://github.com/pytest-dev/pytest/issues/7524

The same applies when you use filterwarnings() in your code or invoke CPython with -W command line option.

2.8.3 cryptography failed to install!

If you are having issues installing cryptography the first troubleshooting step is to upgrade pip and then try to install again. For most users this will take the form of pip install -U pip, but on Windows you should do python -m pip install -U pip. If you are still seeing errors after upgrading and trying pip install cryptography again, please see the Installation documentation.
2.8.4 How does cryptography compare to NaCl (Networking and Cryptography Library)?

While cryptography and NaCl both share the goal of making cryptography easier, and safer, to use for developers, cryptography is designed to be a general purpose library, interoperable with existing systems, while NaCl features a collection of hand selected algorithms.

cryptography's recipes layer has similar goals to NaCl.
If you prefer NaCl's design, we highly recommend PyNaCl, which is also maintained by the PyCA team.

2.8.5 Why use cryptography?

If you've done cryptographic work in Python before you have likely encountered other libraries in Python such as M2Crypto, PyCrypto, or PyOpenSSL. In building cryptography we wanted to address a few issues we observed in the legacy libraries:

• Extremely error prone APIs and insecure defaults.
• Use of poor implementations of algorithms (i.e. ones with known side-channel attacks).
• Lack of maintenance.
• Lack of high level APIs.
• Lack of PyPy and Python 3 support.
• Absence of algorithms such as AES-GCM and HKDF.

2.8.6 Why does cryptography require Rust?

cryptography uses OpenSSL (see: Use of OpenSSL) for its cryptographic operations. OpenSSL is the de facto standard for cryptographic libraries and provides high performance along with various certifications that may be relevant to developers. However, it is written in C and lacks memory safety. We want cryptography to be as secure as possible while retaining the advantages of OpenSSL, so we've chosen to rewrite non-cryptographic operations (such as ASN.1 parsing) in a high performance memory safe language: Rust.

2.8.7 cryptography raised an InternalError and I'm not sure what to do?

Frequently InternalError is raised when there are errors on the OpenSSL error stack that were placed there by other libraries that are also using OpenSSL. Try removing the other libraries and see if the problem persists. If you have no other libraries using OpenSSL in your process, or they do not appear to be at fault, it's possible that this is a bug in cryptography. Please file an issue with instructions on how to reproduce it.

2.8.8 Installing cryptography with OpenSSL 0.9.8, 1.0.0, 1.0.1, 1.0.2, 1.1.0 fails

The OpenSSL project has dropped support for the 0.9.8, 1.0.0, 1.0.1, 1.0.2, and 1.1.0 release series. Since they are no longer receiving security patches from upstream, cryptography is also dropping support for them. To fix this issue you should upgrade to a newer version of OpenSSL (1.1.1 or later). This may require you to upgrade to a newer operating system.
2.8.9 Installing cryptography fails with error: Can not find Rust compiler

Building cryptography from source requires you have *Rust installed and available* on your PATH. You may be able to fix this by upgrading to a newer version of pip which will install a pre-compiled cryptography wheel. If not, you'll need to install Rust. Follow the *instructions* to ensure you install a recent Rust version.

Rust is only required during the build phase of cryptography, you do not need to have Rust installed after you’ve built cryptography. This is the same as the C compiler toolchain which is also required to build cryptography, but not afterwards.

2.8.10 I’m getting errors installing or importing cryptography on AWS Lambda

Make sure you’re following AWS’s documentation either for building .zip archives for Lambda or building container images for Lambda.

2.8.11 Why are there no wheels for my Python3.x version?

Our Python3 wheels are abi3 wheels. This means they support multiple versions of Python. The abi3 wheel can be used with any version of Python greater than or equal to the version it specifies. Recent versions of pip will automatically install abi3 wheels.

2.8.12 Why can’t I import my PEM file?

PEM is a format (defined by several RFCs, but originally RFC 1421) for encoding keys, certificates, and others cryptographic data into a regular form. The data is encoded as base64 and wrapped with a header and footer.

If you are having trouble importing PEM files, make sure your file fits the following rules:

- has a one-line header like this: `-----BEGIN [FILE TYPE]-----` (where [FILE TYPE] is CERTIFICATE, PUBLIC KEY, PRIVATE KEY, etc.)
- has a one-line footer like this: `-----END [FILE TYPE]-----`
- all lines, except for the final one, must consist of exactly 64 characters.

For example, this is a PEM file for a RSA Public Key:

```
-----BEGIN PUBLIC KEY-----
MIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEA7CsKFSzq2ONLb2VQDXma9DsDxtKADv0zi15hTIKG6Bex50eE9poEcvXNV4NzOo2jz2UgyRweRl/ DLU8SoN8+WWd6YWik4GZVvN7jOz2sh9Q5jRySxy4dmElFtIRHHiRhqd1Z06z4AzmKEGUXKOk Liy9cvwD+iXjpK20jWNNyavvjb5YZG6V60RbpyNtKpMh2+zRLgIk9sROEPQeYfK2zj2CNBMg5Geu0Po8Sdl1t/I/Fdh1aO3X411GxwCuPf1KSSAg61PJ00batftkJSG
v6X0j9vAhVj1HSN1BWamT4IR9+iJfKJHekOqvHQBCaC7Ja4kXz6GZ3M2j/1a3A2QIDAQAB
-----END PUBLIC KEY-----
```
2.8.13 What happened to the backend argument?

cryptography stopped requiring the use of backend arguments in version 3.1 and deprecated their use in version 36.0. If you are on an older version that requires these arguments please view the appropriate documentation version or upgrade to the latest release.

Note that for forward compatibility backend is still silently accepted by functions that previously required it, but it is ignored and no longer documented.

2.8.14 Will you upload wheels for my non-x86 non-ARM64 CPU architecture?

Maybe! But there’s some pre-requisites. For us to build wheels and upload them to PyPI, we consider it necessary to run our tests for that architecture as a part of our CI (i.e. for every commit). If we don’t run the tests, it’s hard to have confidence that everything works – particularly with cryptography, which frequently employs per-architecture assembly code.

For us to add something to CI we need a provider which offers builds on that architecture, which integrate into our workflows, has sufficient capacity, and performs well enough not to regress the contributor experience. We don’t think this is an insurmountable bar, but it’s also not one that can be cleared lightly.

If you are interested in helping support a new CPU architecture, we encourage you to reach out, discuss, and contribute that support. We will attempt to be supportive, but we cannot commit to doing the work ourselves.

2.9 Development

As an open source project, cryptography welcomes contributions of all forms. The sections below will help you get started.

File bugs and feature requests on our issue tracker on GitHub. If it is a bug check out what to put in your bug report.

2.9.1 Getting started

Development dependencies

Working on cryptography requires the installation of a small number of development dependencies in addition to the dependencies for Installation (including Rust). These are handled by the use of nox, which can be installed with pip.

```
$ # Create a virtualenv and activate it
$ # Set up your cryptography build environment
$ pip install nox
$ nox -e tests-nocoverage
```
OpenSSL on macOS

You must have installed OpenSSL (via Homebrew, MacPorts) before invoking nox or else pip will fail to compile.

Running tests

cryptography unit tests are found in the tests/ directory and are designed to be run using pytest. nox automatically invokes pytest:

```bash
$ nox -e tests-nocoverage
...
==== 3062 passed, 61 skipped in 16.02s ====
```

You can also specify a subset of tests to run as positional arguments:

```bash
$ # run the whole x509 testsuite, plus the fernet tests
$ nox -e tests-nocoverage -- tests/x509/ tests/test_fernet.py
```

2.9.2 Submitting patches

- Always make a new branch for your work.
- Patches should be small to facilitate easier review. Studies have shown that review quality falls off as patch size grows. Sometimes this will result in many small PRs to land a single large feature.
- Larger changes should be discussed on our mailing list before submission.
- New features and significant bug fixes should be documented in the Changelog.
- You must have legal permission to distribute any code you contribute to cryptography, and it must be available under both the BSD and Apache Software License Version 2.0 licenses.

If you believe you’ve identified a security issue in cryptography, please follow the directions on the security page.

Code

When in doubt, refer to PEP 8 for Python code. You can check if your code meets our automated requirements by formatting it with ruff format and running ruff against it. If you’ve installed the development requirements this will automatically use our configuration. You can also run the nox job with nox --e flake.

Write comments as complete sentences.

Class names which contains acronyms or initialisms should always be capitalized. A class should be named HTTPClient, not HttpClient.

Every code file must start with the boilerplate licensing notice:

```
# This file is dual licensed under the terms of the Apache License, Version 2.0, and the BSD License. See the LICENSE file in the root of this repository for complete details.
```
API considerations

Most projects’ APIs are designed with a philosophy of “make easy things easy, and make hard things possible”. One of the perils of writing cryptographic code is that secure code looks just like insecure code, and its results are almost always indistinguishable. As a result, cryptography has, as a design philosophy: “make it hard to do insecure things”. Here are a few strategies for API design that should be both followed, and should inspire other API choices:

If it is necessary to compare a user provided value with a computed value (for example, verifying a signature), there should be an API provided that performs the verification in a secure way (for example, using a constant time comparison), rather than requiring the user to perform the comparison themselves.

If it is incorrect to ignore the result of a method, it should raise an exception, and not return a boolean True/False flag. For example, a method to verify a signature should raise InvalidSignature, and not return whether the signature was valid.

```python
# This is bad.
def verify(sig: bytes) -> bool:
    # ...
    return is_valid

# Good!
def verify(sig: bytes) -> None:
    # ...
    if not is_valid:
        raise InvalidSignature
```

Every recipe should include a version or algorithmic marker of some sort in its output in order to allow transparent upgrading of the algorithms in use, as the algorithms or parameters needed to achieve a given security margin evolve.

C bindings

More information on C bindings can be found in the dedicated section of the documentation.

Tests

All code changes must be accompanied by unit tests with 100% code coverage (as measured by the combined metrics across our build matrix).

When implementing a new primitive or recipe cryptography requires that you provide a set of test vectors. See Test vectors for more details.

Documentation

All features should be documented with prose in the docs section. To ensure it builds you can run nox -e docs.

Because of the inherent challenges in implementing correct cryptographic systems, we want to make our documentation point people in the right directions as much as possible. To that end:

- When documenting a generic interface, use a strong algorithm in examples. (e.g. when showing a hashing example, don’t use MD5)
- When giving prescriptive advice, always provide references and supporting material.
- When there is real disagreement between cryptographic experts, represent both sides of the argument and describe the trade-offs clearly.
When documenting a new module in the `hazmat` package, its documentation should begin with the “Hazardous Materials” warning:

```
.. hazmat::
```

Always prefer terminology that is most broadly accepted. For example:

- When referring to class instances use “an instance of `Foo`” instead of “a `Foo` provider”.

When referring to a hypothetical individual (such as “a person receiving an encrypted message”) use gender neutral pronouns (they/them/their).

Docstrings are typically only used when writing abstract classes, but should be written like this if required:

```
def some_function(some_arg):
    """
    Does some things.
    :
    param some_arg: Some argument.
    """
```

So, specifically:

- Always use three double quotes.
- Put the three double quotes on their own line.
- No blank line at the end.
- Use Sphinx parameter/attribute documentation syntax.

### 2.9.3 Reviewing and merging patches

Everyone is encouraged to review open pull requests. We only ask that you try and think carefully, ask questions and are excellent to one another. Code review is our opportunity to share knowledge, design ideas and make friends.

When reviewing a patch try to keep each of these concepts in mind:

#### Intent

- What is the change being proposed?
- Do we want this feature or is the bug they’re fixing really a bug?

#### Architecture

- Is the proposed change being made in the correct place? Is it a fix in the backend when it should be in the primitives?
Implementation

- Does the change do what the author claims?
- Are there sufficient tests?
- Has it been documented?
- Will this change introduce new bugs?

Grammar and style

These are small things that are not caught by the automated style checkers.

- Does a variable need a better name?
- Should this be a keyword argument?

Merge requirements

Because cryptography is so complex, and the implications of getting it wrong so devastating, cryptography has a strict merge policy for committers:

- Patches must never be pushed directly to main, all changes (even the most trivial typo fixes!) must be submitted as a pull request.
- A committer may never merge their own pull request, a second party must merge their changes. If multiple people work on a pull request, it must be merged by someone who did not work on it.
- A patch that breaks tests, or introduces regressions by changing or removing existing tests should not be merged. Tests must always be passing on main.
- If somehow the tests get into a failing state on main (such as by a backwards incompatible release of a dependency) no pull requests may be merged until this is rectified.
- All merged patches must have 100% test coverage.

The purpose of these policies is to minimize the chances we merge a change that jeopardizes our users’ security.

2.9.4 Test vectors

Testing the correctness of the primitives implemented in cryptography requires trusted test vectors. Where possible these vectors are obtained from official sources such as NIST or IETF RFCs. When this is not possible cryptography has chosen to create a set of custom vectors using an official vector file as input.

Vectors are kept in the cryptography_vectors package rather than within our main test suite.

Sources

Project Wycheproof

We run vectors from Project Wycheproof – a collection of known edge-cases for various cryptographic algorithms. These are not included in the repository (or cryptography_vectors package), but rather cloned from Git in our continuous integration environments.

We have ensured all test vectors are used as of commit d9f6ec7d8bd8c96da0536899094e4a75ba5cb3d.
Asymmetric ciphers

- RSA FIPS 186-2 and PKCS1 v1.5 vulnerability test vectors from NIST CAVP.
- FIPS 186-2 and FIPS 186-3 DSA test vectors from NIST CAVP.
- FIPS 186-2 and FIPS 186-3 ECDSA test vectors from NIST CAVP.
- DH and ECDH and ECDH+KDF(17.4) test vectors from NIST CAVP.
- Ed25519 test vectors from the Ed25519 website.
- OpenSSL PEM RSA serialization vectors from the OpenSSL example key and GnuTLS key parsing tests.
- asymmetric/PEM_Serialization/rsa-bad-1025-q-is-2.pem from badkeys.
- OpenSSL PEM DSA serialization vectors from the GnuTLS example keys.
- PKCS #8 PEM serialization vectors from
  - GnuTLS: enc-rsa-pkcs8.pem, enc2-rsa-pkcs8.pem, unenc-rsa-pkcs8.pem, pkcs12_s2k_pem.c. The encoding error in unenc-rsa-pkcs8.pem was fixed, and the contents of enc-rsa-pkcs8.pem was re-encrypted to include it. The contents of enc2-rsa-pkcs8.pem was re-encrypted using a stronger PKCS#8 cipher.
  - Botan’s ECC private keys.
- asymmetric/public/PKCS1/dsa.pub.pem is a PKCS1 DSA public key from the Ruby test suite.
- X25519 and X448 test vectors from RFC 7748.
- RSA OAEP with custom label from the BoringSSL evp tests.
- Ed448 test vectors from RFC 8032.

Custom asymmetric vectors

SECP256K1 vector creation

This page documents the code that was used to generate the SECP256K1 elliptic curve test vectors as well as code used to verify them against another implementation.

Creation

The vectors are generated using a pure Python ecdsa implementation. The test messages and combinations of algorithms are derived from the NIST vector data.

```python
import hashlib
import os
from binascii import hexlify
from collections import defaultdict
from ecdsa import SECP256k1, SigningKey
from ecdsa.util import sigdecode_der, sigencode_der
from cryptography_vectors import open_vector_file
```

(continues on next page)
from tests.utils import load_fips_ecdsa_signing_vectors, load_vectors_from_file

HASHLIB_HASH_TYPES = {
    "SHA-1": hashlib.sha1,
    "SHA-224": hashlib.sha224,
    "SHA-256": hashlib.sha256,
    "SHA-384": hashlib.sha384,
    "SHA-512": hashlib.sha512,
}

class TruncatedHash:
    def __init__(self, hasher):
        self.hasher = hasher

    def __call__(self, data):
        self.hasher.update(data)
        return self

    def digest(self):
        return self.hasher.digest()[: 256 // 8]

def build_vectors(fips_vectors):
    vectors = defaultdict(list)
    for vector in fips_vectors:
        vectors[vector["digest_algorithm"]).append(vector["message"])

    for digest_algorithm, messages in vectors.items():
        if digest_algorithm not in HASHLIB_HASH_TYPES:
            yield ""
        yield f"{K-256, {digest_algorithm}]"
        yield ""

        for message in messages:
            # Make a hash context
            hash_func = TruncatedHash(HASHLIB_HASH_TYPES[digest_algorithm]())

            # Sign the message using warner/ecdsa
            secret_key = SigningKey.generate(curve=SECP256k1)
            public_key = secret_key.get_verifying_key()
            signature = secret_key.sign(
                message, hashfunc=hash_func, sigencode=sigencode_der
            )

            r, s = sigdecode_der(signature, None)

            yield f"Msg = {hexlify(message}]"
            yield f"d = {secret_key.privkey.secret_multiplier:x]"
            yield f"Qx = {public_key.pubkey.point.x():x]"
```python
def write_file(lines, dest):
    for line in lines:
        print(line)
        print(line, file=dest)
```

source_path = os.path.join("asymmetric", "ECDSA", "FIPS_186-3", "SigGen.txt")
dest_path = os.path.join("asymmetric", "ECDSA", "SECP256K1", "SigGen.txt")

fips_vectors = load_vectors_from_file(
    source_path, load_fips_ecdsa_signing_vectors
)

with open_vector_file(dest_path, "w") as dest_file:
    write_file(build_vectors(fips_vectors), dest_file)
```

Download link: generate_secp256k1.py

**Verification**

cryptography was modified to support the SECP256K1 curve. Then the following python script was run to generate the vector files.

```python
import os

from cryptography.hazmat.primitives import hashes
from cryptography.hazmat.primitives.asymmetric import ec
from cryptography.hazmat.primitives.asymmetric.utils import (encode_dss_signature,
)
from tests.utils import load_fips_ecdsa_signing_vectors, load_vectors_from_file

CRYPTOGRAPHY_HASH_TYPES = {
    "SHA-1": hashes.SHA1,
    "SHA-224": hashes.SHA224,
    "SHA-256": hashes.SHA256,
    "SHA-384": hashes.SHA384,
    "SHA-512": hashes.SHA512,
}

def verify_one_vector(vector):
    digest_algorithm = vector["digest_algorithm"]
    message = vector["message"]
    x = vector["x"]
```

(continues on next page)
y = vector["y"]
signature = encode_dss_signature(vector["r"], vector["s"])

numbers = ec.EllipticCurvePublicNumbers(x, y, ec.SECP256K1())

key = numbers.public_key()

verifier = key.verifier(
    signature, ec.ECDSA(CRYPTOGRAPHY_HASH_TYPES[digest_algorithm]())
)
verifier.update(message)
verifier.verify()

def verify_vectors(vectors):
    for vector in vectors:
        verify_one_vector(vector)

vector_path = os.path.join("asymmetric", "ECDSA", "SECP256K1", "SigGen.txt")

secp256k1_vectors = load_vectors_from_file(
    vector_path, load_fips_ecdsa_signing_vectors
)

verify_vectors(secp256k1_vectors)

Download link: verify_secp256k1.py

### RSA OAEP SHA2 vector creation

This page documents the code that was used to generate the RSA OAEP SHA2 test vectors as well as code used to verify them against another implementation.

#### Creation

cryptography was modified to allow the use of SHA2 in OAEP encryption. Then the following python script was run to generate the vector files.

```python
# This file is dual licensed under the terms of the Apache License, Version
# 2.0, and the BSD License. See the LICENSE file in the root of this repository
# for complete details.

import binascii
import itertools
import os

from cryptography.hazmat.primitives import hashes
from cryptography.hazmat.primitives.asymmetric import padding, rsa
from tests.utils import load_pkcs1_vectors, load_vectors_from_file
```

(continues on next page)
def build_vectors(mgf1alg, hashalg, filename):
    vectors = load_vectors_from_file(filename, load_pkcs1_vectors)

    output = []
    for vector in vectors:
        # RSA keys for this must be long enough to accommodate the length of
        # the underlying hash function. This means we can't use the keys from
        # the sha1 test vectors for sha512 tests because 1024-bit keys are too
        # small. Instead we parse the vectors for the test cases, then
        # generate our own 2048-bit keys for each.
        private, _ = vector
        skey = rsa.generate_private_key(65537, 2048)
        pn = skey.private_numbers()
        examples = private["examples"]
        output.append("# =============================================")
        output.append("# Example")
        output.append("# Public key")
        output.append("# Modulus:"),
        output.append(format(pn.public_numbers.n, "x"))
        output.append("# Exponent:"),
        output.append(format(pn.public_numbers.e, "x"))
        output.append("# Private key")
        output.append("# Modulus:"),
        output.append(format(pn.public_numbers.n, "x"))
        output.append("# Public exponent:"),
        output.append(format(pn.public_numbers.e, "x"))
        output.append("# Exponent:"),
        output.append(format(pn.d, "x"))
        output.append("# Prime 1:"),
        output.append(format(pn.p, "x"))
        output.append("# Prime 2:"),
        output.append(format(pn.q, "x"))
        output.append("# Prime exponent 1:"),
        output.append(format(pn.dmp1, "x"))
        output.append("# Prime exponent 2:"),
        output.append(format(pn.dmq1, "x"))
        output.append("# Coefficient:"),
        output.append(format(pn.iqmp, "x"))
        pkey = skey.public_key()
        vectorkey = rsa.RSAPrivateNumbers(
            p=private["p"],
            q=private["q"],
            d=private["private_exponent"],
            dmp1=private["dmp1"],
            dmq1=private["dmq1"],
            iqmp=private["iqmp"],
            public_numbers=rsa.RSAPublicNumbers(
                e=private["public_exponent"], n=private["modulus"]
            ),
        ).private_key()
        (continues on next page)
count = 1

for example in examples:
    message = vectorkey.decrypt(
        binascii.unhexlify(example["encryption"]),
        padding.OAEP(
            mgf=padding.MGF1(algorithm=hashes.SHA1()),
            algorithm=hashes.SHA1(),
            label=None,
        ),
    )
    assert message == binascii.unhexlify(example["message"])
ct = pkey.encrypt(
    message,
    padding.OAEP(
        mgf=padding.MGF1(algorithm=mgf1alg),
        algorithm=hashalg,
        label=None,
    ),
)
output.append("# OAEP Example {} alg={} mgf1={}".format(
    count, hashalg.name, mgf1alg.name
))

count += 1
output.append("# Message:")
output.append(example["message"].decode("utf-8"))
output.append("# Encryption:")
output.append(binascii.hexlify(ct).decode("utf-8"))

return "\n".join(output)

def write_file(data, filename):
    with open(filename, "w") as f:
        f.write(data)

oaep_path = os.path.join(
    "asymmetric", "RSA", "pkcs-1v2-1d2-vec", "oaep_vect.txt"
)
hashalgs = [
    hashes.SHA1(),
    hashes.SHA224(),
    hashes.SHA256(),
    hashes.SHA384(),
    hashes.SHA512(),
]
for hashtuple in itertools.product(hashalgs, hashalgs):
    if isinstance(hashtuple[0], hashes.SHA1) and isinstance(
        hashtuple[1], hashes.SHA1
    )
    hashtuple
   )])
(continued from previous page)

```java
continue

write_file(
    build_vectors(hashtuple[0], hashtuple[1], oaep_path),
    f"oaep-{hashtuple[0].name}-{hashtuple[1].name}.txt",
)
```

Download link: generate_rsa_oaep_sha2.py

## Verification

A Java 8 program was written using Bouncy Castle to load and verify the test vectors.

```java
import java.io.BufferedReader;
import java.io.FileReader;
import java.io.IOException;
import java.math.BigInteger;
import java.security.AlgorithmParameters;
import java.security.GeneralSecurityException;
import java.security.KeyFactory;
import java.security.PrivateKey;
import java.security.Security;
import java.security.spec.AlgorithmParameterSpec;
import java.security.spec.MGF1ParameterSpec;
import java.security.spec.RSAPrivateKeySpec;
import java.util.Arrays;
import javax.crypto.Cipher;
import javax.crypto.spec.OAEPParameterSpec;
import javax.crypto.spec.PSource;
import javax.xml.bind.DatatypeConverter;
import org.bouncycastle.jce.provider.BouncyCastleProvider;

class TestVectorData {
    public BigInteger pub_key_modulus;
    public BigInteger pub_key_exponent;
    public BigInteger priv_key_public_exponent;
    public BigInteger priv_key_modulus;
    public BigInteger priv_key_exponent;
    public BigInteger priv_key_prime_1;
    public BigInteger priv_key_prime_2;
    public BigInteger priv_key_prime_exponent_1;
    public BigInteger priv_key_prime_exponent_2;
    public BigInteger priv_key_coefficient;
    public byte[] plaintext;
    public byte[] ciphertext;
}

class TestVectorLoader {

(continues on next page)
private static final String FILE_HEADER = "# RSA OAEP SHA2 vectors built";
private static final String EXAMPLE_HEADER = "# =====";
private static final String EXAMPLE = "# Example";
private static final String PUBLIC_KEY = "# Public key";
private static final String PUB_MODULUS = "# Modulus:";
private static final String PUB_EXPONENT = "# Exponent:";
private static final String PRIVATE_KEY = "# Private key";
private static final String PRIV_MODULUS = "# Modulus:";
private static final String PRIV_PUBLIC_EXPONENT = "# Public exponent:";
private static final String PRIV_EXPONENT = "# Exponent:";
private static final String PRIV_PRIME_1 = "# Prime 1:";
private static final String PRIV_PRIME_2 = "# Prime 2:";
private static final String PRIV_PRIME_EXPONENT_1 = "# Prime exponent 1:";
private static final String PRIV_PRIME_EXPONENT_2 = "# Prime exponent 2:";
private static final String PRIV_COEFFICIENT = "# Coefficient:";
private static final String OAEP_EXAMPLE_HEADER = "# OAEP Example";
private static final String MESSAGE = "# Message:";
private static final String ENCRYPTION = "# Encryption:";

private BufferedReader m_reader = null;
private FileReader m_file_reader = null;
private TestVectorData m_data = null;

TestVectorLoader() {
}

protected void finalize() {
    close();
}

public void open(String path) throws IOException {
    close();
    m_file_reader = new FileReader(path);
    m_reader = new BufferedReader(m_file_reader);
    m_data = new TestVectorData();
}

public void close() {
    try {
        if (m_reader != null) {
            m_reader.close();
            m_reader = null;
        }
        if (m_file_reader != null) {
            m_file_reader.close();
            m_file_reader = null;
        }
        m_data = null;
    } catch (IOException e) {
        System.out.println("Exception closing files");
        e.printStackTrace();
    }
}
public TestVectorData loadNextTest() throws IOException {
   if (m_file_reader == null || m_reader == null || m_data == null) {
      throw new IOException("A test vector file must be opened first");
   }

   String line = m_reader.readLine();
   if (line == null) {
      // end of file
      return null;
   }

   if (line.startsWith(FILE_HEADER)) {
      // start of file
      skipFileHeader(m_reader);
      line = m_reader.readLine();
   }

   if (line.startsWith(OAEP_EXAMPLE_HEADER)) {
      // Next example, keep existing keys and load next message
      loadMessage(m_reader, m_data);
      return m_data;
   }

   // otherwise it's a new example
   if (!line.startsWith(EXAMPLE_HEADER)) {
      throw new IOException("Test Header Missing");
   }

   startNewTest(m_reader);
   m_data = new TestVectorData();

   line = m_reader.readLine();
   if (!line.startsWith(PUBLIC_KEY))
      throw new IOException("Public Key Missing");
   loadPublicKey(m_reader, m_data);

   line = m_reader.readLine();
   if (!line.startsWith(PRIVATE_KEY))
      throw new IOException("Private Key Missing");
   loadPrivateKey(m_reader, m_data);

   line = m_reader.readLine();
   if (!line.startsWith(OAEP_EXAMPLE_HEADER))
      throw new IOException("Message Missing");
   loadMessage(m_reader, m_data);

   return m_data;
}
private byte[] unhexlify(String line) {
    byte[] bytes = DatatypeConverter.parseHexBinary(line);
    return bytes;
}

private BigInteger readBigInteger(BufferedReader br) throws IOException {
    return new BigInteger(br.readLine(), 16);
}

private void skipFileHeader(BufferedReader br) throws IOException {
    br.readLine(); // # # Derived from the NIST OAEP SHA1 vectors
    br.readLine(); // # # Verified against the Bouncy Castle OAEP SHA2 implementation
    br.readLine(); // #
}

private void startNewTest(BufferedReader br) throws IOException {
    String line = br.readLine();
    if (!line.startsWith(EXAMPLE))
        throw new IOException("Example Header Missing");
}

private void loadPublicKey(BufferedReader br, TestVectorData data) throws IOException {
    String line = br.readLine();
    if (!line.startsWith(PUB_MODULUS))
        throw new IOException("Public Key Modulus Missing");
    data.pub_key_modulus = readBigInteger(br);
    line = br.readLine();
    if (!line.startsWith(PUB_EXPONENT))
        throw new IOException("Public Key Exponent Missing");
    data.pub_key_exponent = readBigInteger(br);
}

private void loadPrivateKey(BufferedReader br, TestVectorData data) throws IOException {
    String line = br.readLine();
    if (!line.startsWith(PRIV_MODULUS))
        throw new IOException("Private Key Modulus Missing");
    data.priv_key_modulus = readBigInteger(br);
    line = br.readLine();
    if (!line.startsWith(PRIV_PUBLIC_EXPONENT))
        throw new IOException("Private Key Public Exponent Missing");
    data.priv_key_public_exponent = readBigInteger(br);
    line = br.readLine();
    if (!line.startsWith(PRIV_EXPONENT))
        throw new IOException("Private Key Exponent Missing");
    data.priv_key_exponent = readBigInteger(br);
    line = br.readLine();
}
if (!line.startsWith(PRIV_PRIME_1))
    throw new IOException("Private Key Prime 1 Missing");
data.priv_key_prime_1 = readBigInteger(br);

line = br.readLine();
if (!line.startsWith(PRIV_PRIME_2))
    throw new IOException("Private Key Prime 2 Missing");
data.priv_key_prime_2 = readBigInteger(br);

line = br.readLine();
if (!line.startsWith(PRIV_PRIME_EXPONENT_1))
    throw new IOException("Private Key Prime Exponent 1 Missing");
data.priv_key_prime_exponent_1 = readBigInteger(br);

line = br.readLine();
if (!line.startsWith(PRIV_PRIME_EXPONENT_2))
    throw new IOException("Private Key Prime Exponent 2 Missing");
data.priv_key_prime_exponent_2 = readBigInteger(br);

line = br.readLine();
if (!line.startsWith(PRIV_COEFFICIENT))
    throw new IOException("Private Key Coefficient Missing");
data.priv_key_coefficient = readBigInteger(br);

private void loadMessage(BufferedReader br, TestVectorData data) throws IOException {
    String line = br.readLine();
    if (!line.startsWith(MESSAGE))
        throw new IOException("Plaintext Missing");
data.plaintext = unhexlify(br.readLine());

    line = br.readLine();
    if (!line.startsWith(ENCRYPTION))
        throw new IOException("Ciphertext Missing");
data.ciphertext = unhexlify(br.readLine());
}

public class VerifyRSAOAEP SHA2 {

    public enum SHAHash {
        SHA1, SHA224, SHA256, SHA384, SHA512
    }

    private SHAHash m_mgf1_hash;
    private SHAHash m_alg_hash;
    private Cipher m_cipher;
    private PrivateKey m_private_key;
    private AlgorithmParameters m_algo_param;

    VerifyRSAOAEP SHA2(SHAHash mgf1_hash, SHAHash alg_hash, TestVectorData test_data)
throws Exception {
    m_mgf1_hash = mgf1_hash;
    m_alg_hash = alg_hash;

    MGF1ParameterSpec mgf1_spec = getMGF1ParameterSpec(m_mgf1_hash);
    AlgorithmParameterSpec algo_param_spec = getAlgorithmParameterSpec(m_alg_hash, mgf1_spec);

    m_algo_param = AlgorithmParameters.getInstance("OAEP");
    m_algo_param.init(algo_param_spec);

    m_private_key = loadPrivateKey(test_data);

    m_cipher = getCipher(m_alg_hash);
}

private Cipher getCipher(SHAHash alg_hash) throws GeneralSecurityException {
    Cipher cipher = null;

    switch (alg_hash) {
    case SHA1:
        cipher = Cipher.getInstance("RSA/ECB/OAEPwithSHA1andMGF1Padding", "BC");
        break;

    case SHA224:
        cipher = Cipher.getInstance("RSA/ECB/OAEPwithSHA-224andMGF1Padding", "BC");
        break;

    case SHA256:
        cipher = Cipher.getInstance("RSA/ECB/OAEPwithSHA-256andMGF1Padding", "BC");
        break;

    case SHA384:
        cipher = Cipher.getInstance("RSA/ECB/OAEPwithSHA-384andMGF1Padding", "BC");
        break;

    case SHA512:
        cipher = Cipher.getInstance("RSA/ECB/OAEPwithSHA-512andMGF1Padding", "BC");
        break;
    }

    return cipher;
}

private MGF1ParameterSpec getMGF1ParameterSpec(SHAHash mgf1_hash) {
    MGF1ParameterSpec mgf1 = null;

    switch (mgf1_hash) {
    case SHA1:
    (continues on next page)
mgf1 = MGF1ParameterSpec.SHA1;
break;
case SHA224:
    mgf1 = MGF1ParameterSpec.SHA224;
    break;

case SHA256:
    mgf1 = MGF1ParameterSpec.SHA256;
    break;

case SHA384:
    mgf1 = MGF1ParameterSpec.SHA384;
    break;

case SHA512:
    mgf1 = MGF1ParameterSpec.SHA512;
    break;
}
return mgf1;
}

private AlgorithmParameterSpec getAlgorithmParameterSpec(SHAHash alg_hash,
MGF1ParameterSpec mgf1_spec) {
    OAEPParameterSpec oaep_spec = null;
    switch (alg_hash) {
        case SHA1:
            oaep_spec = new OAEPParameterSpec("SHA1", "MGF1", mgf1_spec, PSource.
PSpecified.DEFAULT);
            break;
        case SHA224:
            oaep_spec = new OAEPParameterSpec("SHA-224", "MGF1", mgf1_spec, PSource.
PSpecified.DEFAULT);
            break;
        case SHA256:
            oaep_spec = new OAEPParameterSpec("SHA-256", "MGF1", mgf1_spec, PSource.
PSpecified.DEFAULT);
            break;
        case SHA384:
            oaep_spec = new OAEPParameterSpec("SHA-384", "MGF1", mgf1_spec, PSource.
PSpecified.DEFAULT);
            break;
        case SHA512:
            oaep_spec = new OAEPParameterSpec("SHA-512", "MGF1", mgf1_spec, PSource.
PSpecified.DEFAULT);
            break;
    }
    return oaep_spec;
}
break;
}
return oaep_spec;
}

private PrivateKey loadPrivateKey(TestVectorData test_data) throws Exception {
    KeyFactory kf = KeyFactory.getInstance("RSA");

    RSAPrivateKeySpec keySpec = new RSAPrivateKeySpec(test_data.priv_key_modulus,
    test_data.priv_key_exponent);

    return kf.generatePrivate(keySpec);
}

public void testDecrypt(byte[] plaintext, byte[] ciphertext) throws Exception {
    System.out.println("Verifying OAEP with mgf1_hash: " + m_mgf1_hash + " alg_hash:
    " + m_alg_hash + " - "
    + ciphertext.length + " bytes ciphertext - "
    + plaintext.length + " bytes plaintext");

    m_cipher.init(Cipher.DECRYPT_MODE, m_private_key, m_algo_param);
    byte[] java_plaintext = m_cipher.doFinal(ciphertext);

    if (Arrays.equals(java_plaintext, plaintext) == false) {
        throw new Exception("Verification failure - plaintext does not match after
        decryption.");
    }
}

public static void main(String[] args) {
    Security.addProvider(new BouncyCastleProvider());

    // assume current directory if no path given on command line
    String vector_path = "./vectors/cryptography_vectors/asymmetric/RSA/oaep-custom";

    if (args.length > 0) {
        vector_path = args[0];
    }

    System.out.println("Vector file path: " + vector_path);

    try {
        // loop over each combination of hash loading the vector file
        // to verify for each
        for (SHAHash mgf1_hash : SHAHash.values()) {
            for (SHAHash alg_hash : SHAHash.values()) {
                if (mgf1_hash.name().toLowerCase().equals("sha1") &&
                alg_hash.name().toLowerCase().equals("sha1")) {
                    continue;
                }
            }
            String filename = "oaep-" + mgf1_hash.name().toLowerCase() +
            (continues on next page)
"-" + alg_hash.name().toLowerCase() + ".txt";

System.out.println("Loading " + filename + "...");

TestVectorLoader loader = new TestVectorLoader();
loader.open(vector_path + filename);

TestVectorData test_data;

// load each test in the file and verify
while ((test_data = loader.loadNextTest()) != null) {
    VerifyRSAOAEPSHA2 verify = new VerifyRSAOAEPSHA2(mgf1_hash, alg_
    hash, test_data);
    verify.testDecrypt(test_data.plaintext, test_data.ciphertext);
}

System.out.println("Verifying " + filename + " completed successfully.");

System.out.println("All verification completed successfully");

} catch (Exception e) {
    // if any exception is thrown the verification has failed
    e.printStackTrace();
    System.out.println("Verification Failed!");
}

} // end class

Download link: VerifyRSAOAEPSHA2.java

Using the Verifier

Download and install the Java SDK. Initial verification was performed using jdk-8u77-macosx-x64.dmg.
Download the latest Bouncy Castle JAR. Initial verification was performed using bcprov-jdk15on-154.jar.
Set the -classpath to include the Bouncy Castle jar and the path to VerifyRSAOAEPSHA2.java and compile the program.

$ javac -classpath ~/Downloads/bcprov-jdk15on-154.jar:.: / VerifyRSAOAEPSHA2.java

Finally, run the program with the path to the SHA-2 vectors:

$ java -classpath ~/Downloads/bcprov-jdk15on-154.jar:.: / VerifyRSAOAEPSHA2

- asymmetric/PEM_Serialization/ec_private_key.pem and asymmetric/DER_Serialization/ ec_private_key.der - Contains an Elliptic Curve key generated by OpenSSL from the curve secp256r1.
- asymmetric/PEM_Serialization/ec_private_key_encrypted.pem and asymmetric/ DER_Serialization/ec_private_key_encrypted.der - Contains the same Elliptic Curve key as ec_private_key.pem, except that it is encrypted with AES-128 with the password “123456”.

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• asymmetric/PEM_Serialization/ec_public_key.pem and asymmetric/DER_Serialization/ec_public_key.der - Contains the public key corresponding to ec_private_key.pem, generated using OpenSSL.

• asymmetric/PEM_Serialization/rsa_private_key.pem - Contains an RSA 2048 bit key generated using OpenSSL, protected by the secret “123456” with DES3 encryption.

• asymmetric/PEM_Serialization/rsa_public_key.pem and asymmetric/DER_Serialization/rsa_public_key.der - Contains an RSA 2048 bit public generated using OpenSSL from rsa_private_key.pem.

• asymmetric/PEM_Serialization/dsa_4096.pem - Contains a 4096-bit DSA private key generated using OpenSSL.

• asymmetric/PEM_Serialization/dsaparam.pem - Contains 2048-bit DSA parameters generated using OpenSSL; contains no keys.

• asymmetric/PEM_Serialization/dsa_private_key.pem - Contains a DSA 2048 bit key generated using OpenSSL from the parameters in dsaparam.pem, protected by the secret “123456” with DES3 encryption.

• asymmetric/DER_Serialization/dsa_public_key.pem and asymmetric/DER_Serialization/dsa_public_key.der - Contains a DSA 2048 bit key generated using OpenSSL from dsa_private_key.pem.

• asymmetric/DER_Serialization/dsa_public_key_no_params.der - Contains a DSA public key with the optional parameters removed.

• asymmetric/DER_Serialization/dsa_public_key_invalid_bit_string.der - Contains a DSA public key with the bit string padding value set to 2 rather than the required 0.

• asymmetric/PKCS8/unenc-dsa-pkcs8.pem and asymmetric/DER_Serialization/unenc-dsa-pkcs8.der - Contains a DSA 1024 bit key generated using OpenSSL.

• asymmetric/PKCS8/unenc-dsa-pkcs8.pub.pem and asymmetric/DER_Serialization/unenc-dsa-pkcs8.pub.der - Contains a DSA 2048 bit public key generated using OpenSSL from unenc-dsa-pkcs8.pem.

• DER conversions of the GnuTLS example keys for DSA as well as the OpenSSL example key for RSA.


• asymmetric/public/PKCS1/rsa.pub.pem and asymmetric/public/PKCS1/rsa.pub.der are PKCS1 conversions of the public key from asymmetric/PKCS8/unenc-rsa-pkcs8.pem using PEM and DER encoding.

• x509/custom/ca/ca_key.pem - An unencrypted PKCS8 secp256r1 key. It is the private key for the certificate x509/custom/ca/ca.pem.

• pkcs12/ca/ca_key.pem - An unencrypted PKCS8 secp256r1 key. It is the private key for the certificate pkcs12/ca/ca.pem. This key is encoded in several of the PKCS12 custom vectors.

• x509/custom/ca/rsa_key.pem - An unencrypted PKCS8 4096 bit RSA key. It is the private key for the certificate x509/custom/ca/rsa_ca.pem.

• asymmetric/EC/compressed_points.txt - Contains compressed public points generated using OpenSSL.

• asymmetric/X448/x448-pkcs8-enc.pem and asymmetric/X448/x448-pkcs8-enc.der contain an X448 key encrypted with AES 256 CBC with the password password.

• asymmetric/X448/x448-pkcs8.pem and asymmetric/X448/x448-pkcs8.der contain an unencrypted X448 key.

• asymmetric/X448/x448-pub.pem and asymmetric/X448/x448-pub.der contain an X448 public key.
• asymmetric/Ed25519/ed25519-pkcs8-enc.pem and asymmetric/Ed25519/ed25519-pkcs8-enc.der contain an Ed25519 key encrypted with AES 256 CBC with the password password.


• asymmetric/Ed25519/ed25519-pub.pem and asymmetric/Ed25519/ed25519-pub.der contain an Ed25519 public key.

• asymmetric/X25519/x25519-pkcs8-enc.pem and asymmetric/X25519/x25519-pkcs8-enc.der contain an X25519 key encrypted with AES 256 CBC with the password password.

• asymmetric/X25519/x25519-pkcs8.pem and asymmetric/X25519/x25519-pkcs8.der contain an unencrypted X25519 key.

• asymmetric/X25519/x25519-pub.pem and asymmetric/X25519/x25519-pub.der contain an X25519 public key.

• asymmetric/Ed448/ed448-pkcs8-enc.pem and asymmetric/Ed448/ed448-pkcs8-enc.der contain an Ed448 key encrypted with AES 256 CBC with the password password.

• asymmetric/Ed448/ed448-pkcs8.pem and asymmetric/Ed448/ed448-pkcs8.der contain an unencrypted Ed448 key.

• asymmetric/Ed448/ed448-pub.pem and asymmetric/Ed448/ed448-pub.der contain an Ed448 public key.

• asymmetric/PKCS8/rsa_pss_2048.pem - A 2048-bit RSA PSS key with no explicit parameters set.

• asymmetric/PKCS8/rsa_pss_2048_pub.der - The public key corresponding to asymmetric/PKCS8/rsa_pss_2048.pem.

• asymmetric/PKCS8/rsa_pss_2048_hash.pem - A 2048-bit RSA PSS key with the hash algorithm PSS parameter set to SHA256.

• asymmetric/PKCS8/rsa_pss_2048_hash_mask.pem - A 2048-bit RSA PSS key with with the hash (SHA256) and mask algorithm (SHA256) PSS parameters set.

• asymmetric/PKCS8/rsa_pss_2048_hash_mask_diff.pem - A 2048-bit RSA PSS key with the hash (SHA256), mask algorithm (SHA512) PSS parameters set.

• asymmetric/PKCS8/rsa_pss_2048_hash_mask_salt.pem - A 2048-bit RSA PSS key with the hash (SHA256), mask algorithm (SHA256), and salt length (32) PSS parameters set.

Key exchange

• vectors/cryptography_vectors/asymmetric/DH/rfc3526.txt contains several standardized Diffie-Hellman groups from RFC 3526.

• vectors/cryptography_vectors/asymmetric/DH/RFC5114.txt contains Diffie-Hellman examples from appendix A.1, A.2 and A.3 of RFC 5114.

• vectors/cryptography_vectors/asymmetric/DH/vec.txt contains Diffie-Hellman examples from botan.

• vectors/cryptography_vectors/asymmetric/DH/bad_exchange.txt contains Diffie-Hellman vector pairs that were generated using OpenSSL DH_generate_parameters_ex and DH_generate_key.

• vectors/cryptography_vectors/asymmetric/DH/dhp.pem, vectors/cryptography_vectors/asymmetric/DH/dhkey.pem and vectors/cryptography_vectors/asymmetric/DH/dhpub.pem contains Diffie-Hellman parameters and key respectively. The keys were generated using OpenSSL following DHKE guide. vectors/cryptography_vectors/asymmetric/DH/dhkey.txt contains all parameter in 2.9. Development 265


• vectors/cryptography_vectors/asymmetric/DH/dhp.der, vectors/cryptography_vectors/asymmetric/DH/dhkey.der and vectors/cryptography_vectors/asymmetric/DH/dhpub.der contains are the above parameters and keys in DER format.

• vectors/cryptography_vectors/asymmetric/DH/dhp_rfc5114_2.pem, vectors/cryptography_vectors/asymmetric/DH/dhkey_rfc5114_2.pem and vectors/cryptography_vectors/asymmetric/DH/dhpub_rfc5114_2.pem contains Diffie-Hellman parameters and key respectively. The keys were generated using OpenSSL following DHKE guide. When creating the parameters we added the -pkeyopt dh_rfc5114:2 option to use RFC 5114 2048 bit DH parameters with 224 bit subgroup. vectors/cryptography_vectors/asymmetric/DH/dhkey_rfc5114_2.txt contains all parameter in text. vectors/cryptography_vectors/asymmetric/DH/dhp_rfc5114_2.der, vectors/cryptography_vectors/asymmetric/DH/dhkey_rfc5114_2.der and vectors/cryptography_vectors/asymmetric/DH/dhpub_rfc5114_2.der contains are the above parameters and keys in DER format.

• vectors/cryptography_vectors/asymmetric/DH/dh_key_256.pem contains a PEM PKCS8 encoded DH key with a 256-bit key size.

• vectors/cryptography_vectors/asymmetric/ECDH/brainpool.txt contains Brainpool vectors from RFC 7027.

X.509

• PKITS test suite from NIST PKI Testing.

• v1_cert.pem from the OpenSSL source tree (testx509.pem).

• ecdsa_root.pem - DigiCert Global Root G3, a secp384r1 ECDSA root certificate.

• verisign-md2-root.pem - A legacy Verisign public root signed using the MD2 algorithm. This is a PEM conversion of the root data in the NSS source tree.

• cryptography.io.pem - A leaf certificate issued by RapidSSL for the cryptography website.

• cryptography.io.old_header.pem - A leaf certificate issued by RapidSSL for the cryptography website. This certificate uses the X509 CERTIFICATE legacy PEM header format.

• cryptography.io.chain.pem - The same as cryptography.io.pem, but rapidssl_sha256_ca_g3.pem is concatenated to the end.

• cryptography.io.with_headers.pem - The same as cryptography.io.pem, but with an unrelated (encrypted) private key concatenated to the end.

• cryptography.io.chain_with_garbage.pem - The same as cryptography.io.chain.pem, but with other sections and text around it.

• cryptography.io.with_garbage.pem - The same as cryptography.io.pem, but with other sections and text around it.

• rapidssl_sha256_ca_g3.pem - The intermediate CA that issued the cryptography.io.pem certificate.

• cryptography.io.precert.pem - A pre-certificate with the CT poison extension for the cryptography website.

• cryptography-scts.pem - A leaf certificate issued by Let’s Encrypt for the cryptography website which contains signed certificate timestamps.

• wildcard_san.pem - A leaf certificate issued by a public CA for langui.sh that contains wildcard entries in the SAN extension.
• san_edipartyname.der - A DSA certificate from a Mozilla bug containing a SAN extension with an ediPartyName general name.

• san_x400address.der - A DSA certificate from a Mozilla bug containing a SAN extension with an x400Address general name.

• department-of-state-root.pem - The intermediary CA for the Department of State, issued by the United States Federal Government’s Common Policy CA. Notably has a critical policy constraints extensions.

• e-trust.ru.der - A certificate from a Russian CA signed using the GOST cipher and containing numerous unusual encodings such as NUMERICSTRING in the subject DN.

• alternate-rsa-sha1-oid.der - A certificate that uses an alternate signature OID for RSA with SHA1. This certificate has an invalid signature.

• badssl-sct.pem - A certificate with the certificate transparency signed certificate timestamp extension.

• badssl-sct-none-hash.der - The same as badssl-sct.pem, but DER-encoded and with the SCT’s signature hash manually changed to “none” (0x00).

• badssl-sct-anonymous-sig.der - The same as badssl-sct.pem, but DER-encoded and with the SCT’s signature algorithm manually changed to “anonymous” (0x00).

• bigoid.pem - A certificate with a rather long OID in the Certificate Policies extension. We need to make sure we can parse long OIDs.

• wosign-bc-invalid.pem - A certificate issued by WoSign that contains a basic constraints extension with CA set to false and a path length of zero in violation of RFC 5280.

• tls-feature-ocsp-staple.pem - A certificate issued by Let’s Encrypt that contains a TLS Feature extension with the status_request feature (commonly known as OCSP Must-Staple).

• unique-identifier.pem - A certificate containing a distinguished name with an x500UniqueIdentifier.

• utf8-dnsname.pem - A certificate containing non-ASCII characters in the DNS name entries of the SAN extension.

• badasn1time.pem - A certificate containing an incorrectly specified UTCTime in its validity->not_after.

• letsencryptx3.pem - A subordinate certificate used by Let’s Encrypt to issue end entity certificates.

• ed25519/rfc8410.pem - A certificate containing an X25519 public key with an ed25519 signature taken from RFC 8410.

• root-ed25519.pem - An ed25519 root certificate (ed25519 signature with ed25519 public key) from the OpenSSL test suite. (root-ed25519.pem)

• server-ed25519-cert.pem - An ed25519 server certificate (RSA signature with ed25519 public key) from the OpenSSL test suite. (server-ed25519-cert.pem)

• server-ed448-cert.pem - An ed448 server certificate (RSA signature with ed448 public key) from the OpenSSL test suite. (server-ed448-cert.pem)

• accvraiz1.pem - An RSA root certificate that contains an explicitText entry with a BMPString type.

• scottishpower-bitstring-dn.pem - An ECDSA certificate that contains a subject DN with a bit string type.

• cryptography-scts-tbs-precert.der - The “to-be-signed” pre-certificate bytes from cryptography-scts.pem, with the SCT list extension removed.

• belgian-eid-invalid-visiblestring.pem - A certificate with UTF-8 bytes in a VisibleString type.

• ee-pss-sha1-cert.pem - An RSA PSS certificate using a SHA1 signature and SHA1 for MGF1 from the OpenSSL test suite.
Custom X.509 Vectors

- **invalid_version.pem** - Contains an RSA 2048 bit certificate with the X.509 version field set to 0x7.
- **post2000utctime.pem** - Contains an RSA 2048 bit certificate with the notBefore and notAfter fields encoded as post-2000 UTCTime.
- **dsa_selfsigned_ca.pem** - Contains a DSA self-signed CA certificate generated using OpenSSL.
- **ec_no_named_curve.pem** - Contains an ECDSA certificate that does not have an embedded OID defining the curve.
- **all_supported_names.pem** - An RSA 2048 bit certificate generated using OpenSSL that contains a subject and issuer that have two of each supported attribute type from RFC 5280.
- **unsupported_subject_name.pem** - An RSA 2048 bit self-signed CA certificate generated using OpenSSL that contains the unsupported “initials” name.
- **utf8_common_name.pem** - An RSA 2048 bit self-signed CA certificate generated using OpenSSL that contains a UTF8String common name with the value “We heart UTF8™”.
- **invalid_utf8_common_name.pem** - A certificate that contains a UTF8String common name with an invalid UTF-8 byte sequence.
- **two_basic_constraints.pem** - An RSA 2048 bit self-signed certificate containing two basic constraints extensions.
- **basic_constraints_not_critical.pem** - An RSA 2048 bit self-signed certificate containing a basic constraints extension that is not marked as critical.
- **bc_path_length_zero.pem** - An RSA 2048 bit self-signed certificate containing a basic constraints extension with a path length of zero.
- **unsupported_extension.pem** - An RSA 2048 bit self-signed certificate containing an unsupported extension type. The OID was encoded as “1.2.3.4” with an extnValue of “value”.
- **unsupported_extension_2.pem** - A secp256r1 certificate containing two unsupported extensions. The OIDs are 1.3.6.1.4.1.41482.2 with an extnValue of 1.3.6.1.4.1.41482.1.2 and 1.3.6.1.4.1.45724.2.1.1 with an extnValue of \x93\x82\x040
- **unsupported_extension_critical.pem** - An RSA 2048 bit self-signed certificate containing an unsupported extension type marked critical. The OID was encoded as “1.2.3.4” with an extnValue of “value”.
- **san_email_dns_ip_dirname_uri.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with the following general names: rfc822Name, dNSName, iPAddress, directoryName, and uniformResourceIdentifier.
- **san_empty_hostname.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative extension with an empty dNSName general name.
- **san_other_name.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with the otherName general name.
- **san_registered_id.pem** - An RSA 1024 bit certificate containing a subject alternative name extension with the registeredID general name.
- **all_key_usages.pem** - An RSA 2048 bit self-signed certificate containing a key usage extension with all nine purposes set to true.
- **extended_key_usage.pem** - An RSA 2048 bit self-signed certificate containing an extended key usage extension with eight usages.
• **san_idna_names.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with rfc822Name, dNSName, and uniformResourceIdentifier general names with IDNA (RFC 5895) encoding.

• **san_wildcard_idna.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with a dNSName general name with a wildcard IDNA (RFC 5895) domain.

• **san_idna2003_dnsname.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with an IDNA 2003 (RFC 3490) dNSName.

• **san/rfc822_names.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with various rfc822Name values.

• **san/rfc822_idna.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with an IDNA rfc822Name.

• **san_uri_with_port.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with various uniformResourceIdentifier values.

• **san_ipaddr.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with an IPAddress value.

• **san_dirname.pem** - An RSA 2048 bit self-signed certificate containing a subject alternative name extension with a directoryName value.

• **inhibit_any_policy_5.pem** - An RSA 2048 bit self-signed certificate containing an inhibit any policy extension with the value 5.

• **inhibit_any_policy_negative.pem** - An RSA 2048 bit self-signed certificate containing an inhibit any policy extension with the value -1.

• **authority_key_identifier.pem** - An RSA 2048 bit self-signed certificate containing an authority key identifier extension with key identifier, authority certificate issuer, and authority certificate serial number fields.

• **authority_key_identifier_no_keyid.pem** - An RSA 2048 bit self-signed certificate containing an authority key identifier extension with authority certificate issuer and authority certificate serial number fields.

• **aia_ocsp_ca_issuers.pem** - An RSA 2048 bit self-signed certificate containing an authority information access extension with two OCSP and one CA issuers entry.

• **aia_ocsp.pem** - An RSA 2048 bit self-signed certificate containing an authority information access extension with an OCSP entry.

• **aia_ca_issuers.pem** - An RSA 2048 bit self-signed certificate containing an authority information access extension with a CA issuers entry.

• **cdp_empty_hostname.pem** - An RSA 2048 bit self-signed certificate containing a CRL distribution point extension with fullName URI without a hostname.

• **cdp_fullname_reasons_crl_issuer.pem** - An RSA 1024 bit certificate containing a CRL distribution points extension with fullName, cRLIssuer, and reasons data.

• **cdp_crl_issuer.pem** - An RSA 1024 bit certificate containing a CRL distribution points extension with cRLIssuer data.

• **cdp_all_reasons.pem** - An RSA 1024 bit certificate containing a CRL distribution points extension with all reasons bits set.

• **cdp_reason_aa_compromise.pem** - An RSA 1024 bit certificate containing a CRL distribution points extension with the AACompromise reasons bit set.

• **nc_permitted_excluded.pem** - An RSA 2048 bit self-signed certificate containing a name constraints extension with both permitted and excluded elements. Contains IPv4 and IPv6 addresses with network mask as well as dNSName with a leading period.
• nc_permitted_excluded_2.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with both permitted and excluded elements. Unlike nc_permitted_excluded.pem, the general names do not contain any name constraints specific values.

• nc_permitted.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with permitted elements.

• nc_permitted_2.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with permitted elements that do not contain any name constraints specific values.

• nc_excluded.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with excluded elements.

• nc_invalid_ip_netmask.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with a permitted element that has an IPv6 IP and an invalid network mask.

• nc_invalid_ip4_netmask.der - An RSA 2048 bit self-signed certificate containing a name constraints extension with a permitted element that has an IPv4 IP and an invalid network mask. The signature on this certificate is invalid.

• nc_single_ip_netmask.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with a permitted element that has two IPs with /32 and /128 network masks.

• nc_ip_invalid_length.pem - An RSA 2048 bit self-signed certificate containing a name constraints extension with a permitted element that has an invalid length (33 bytes instead of 32) for an IPv6 address with network mask. The signature on this certificate is invalid.

• cp_user_notice_with_notice_reference.pem - An RSA 2048 bit self-signed certificate containing a certificate policies extension with a notice reference in the user notice.

• cp_user_notice_with_explicit_text.pem - An RSA 2048 bit self-signed certificate containing a certificate policies extension with explicit text and no notice reference.

• cp_cps_uri.pem - An RSA 2048 bit self-signed certificate containing a certificate policies extension with a CPS URI and no user notice.

• cp_user_notice_no_explicit_text.pem - An RSA 2048 bit self-signed certificate containing a certificate policies extension with a user notice with no explicit text.

• cp_invalid.pem - An RSA 2048 bit self-signed certificate containing a certificate policies extension with invalid data. The policyQualifierId is for id-qt-unotice but the value is an id-qt-cps ASN.1 structure.

• cp_invalid2.der - An RSA 2048 bit self-signed certificate containing a certificate policies extension with invalid data. The policyQualifierId is for id-qt-cps but the value is an id-qt-unotice ASN.1 structure. The signature on this certificate is invalid.

• ian_uri.pem - An RSA 2048 bit certificate containing an issuer alternative name extension with a URI general name.

• ocsp_nocheck.pem - An RSA 2048 bit self-signed certificate containing an OCSPNoCheck extension.

• pc_inhibit_require.pem - An RSA 2048 bit self-signed certificate containing a policy constraints extension with both inhibit policy mapping and require explicit policy elements.

• pc_inhibit.pem - An RSA 2048 bit self-signed certificate containing a policy constraints extension with an inhibit policy mapping element.

• pc_require.pem - An RSA 2048 bit self-signed certificate containing a policy constraints extension with a require explicit policy element.

• unsupported_subject_public_key_info.pem - A certificate whose public key is an unknown OID (1.3.6.1.4.1.8432.1.1.2).
• policy_constraints_explicit.pem - A self-signed certificate containing a policyConstraints extension with a requireExplicitPolicy value.
• freshestcrl.pem - A self-signed certificate containing a freshestCRL extension.
• sia.pem - An RSA 2048 bit self-signed certificate containing a subject information access extension with both a CA repository entry and a custom OID entry.
• ca/ca.pem - A self-signed certificate with basicConstraints set to true. Its private key is ca/ca_key.pem.
• pkcs12/ca/ca.pem - A self-signed certificate with basicConstraints set to true. Its private key is pkcs12/ca/ca_key.pem. This key is encoded in several of the PKCS12 custom vectors.
• negative_serial.pem - A certificate with a serial number that is a negative number.
• rsa_pss.pem - A certificate with an RSA PSS signature.
• root-ed448.pem - An ed448 self-signed CA certificate using ed448-pkcs8.pem as key.
• ca/rsa_ca.pem - A self-signed RSA certificate with basicConstraints set to true. Its private key is ca/rsa_key.pem.
• invalid-sct-version.der - A certificate with an SCT with an unknown version.
• invalid-sct-length.der - A certificate with an SCT with an internal length greater than the amount of data.
• bad_country.pem - A certificate with country name and jurisdiction country name values in its subject and issuer distinguished names which are longer than 2 characters.
• rsa_pss_cert.pem - A self-signed certificate with an RSA PSS signature with asymmetric/PKCS8/rsa_pss_2048.pem as its key.
• rsa_pss_cert_invalid_mgf.der - A self-signed certificate with an invalid RSA PSS signature that has a non-MGF1 OID for its mask generation function in the signature algorithm.
• rsa_pss_cert_no_sig_params.der - A self-signed certificate with an invalid RSA PSS signature algorithm that is missing signature parameters for PSS.
• rsa_pss_cert_unsupported_mgf_hash.der - A self-signed certificate with an unsupported MGF1 hash algorithm in the signature algorithm.
• long-form-name-attribute.pem - A certificate with subject and issuer names containing attributes whose value’s tag is encoded in long-form.
• mismatch_inner_outer_sig_algorithm.der - A leaf certificate derived from x509/cryptography.io.pem but modifying the tbs_cert.signature_algorithm OID to not match the outer signature algorithm OID.
• ms-certificate-template.pem - A certificate with a msCertificateTemplate extension.
• rsa_pss_sha256_no_null.pem - A certificate with an RSA PSS signature with no encoded NULL for the PSS hash algorithm parameters. This certificate was generated by LibreSSL.
• ecdsa_null_alg.pem - A certificate with an ECDSA signature with NULL algorithm parameters. This encoding is invalid, but was generated by Java 11.
• dsa_null_alg_params.pem - A certificate with a DSA signature with NULL algorithm parameters. This encoding is invalid, but was generated by Java 20.
Custom X.509 Request Vectors

- dsa_sha1.pem and dsa_sha1.der - Contain a certificate request using 1024-bit DSA parameters and SHA1 generated using OpenSSL.
- rsa_md4.pem and rsa_md4.der - Contain a certificate request using 2048 bit RSA and MD4 generated using OpenSSL.
- rsa_sha1.pem and rsa_sha1.der - Contain a certificate request using 2048 bit RSA and SHA1 generated using OpenSSL.
- rsa_sha256.pem and rsa_sha256.der - Contain a certificate request using 2048 bit RSA and SHA256 generated using OpenSSL.
- ec_sha256.pem and ec_sha256.der - Contain a certificate request using EC (secp384r1) and SHA256 generated using OpenSSL.
- ec_sha256_old_header.pem - Identical to ec_sha256.pem, but uses the -----BEGIN NEW CERTIFICATE REQUEST----- legacy PEM header format.
- san_rsa_sha1.pem and san_rsa_sha1.der - Contain a certificate request using RSA and SHA1 with a subject alternative name extension generated using OpenSSL.
- two_basic_constraints.pem - A certificate signing request for an RSA 2048 bit key containing two basic constraints extensions. The signature on this CSR is invalid.
- unsupported_extension.pem - A certificate signing request for an RSA 2048 bit key containing containing an unsupported extension type. The OID was encoded as “1.2.3.4” with an extnValue of “value”. The signature on this CSR is invalid.
- unsupported_extension_critical.pem - A certificate signing request for an RSA 2048 bit key containing containing an unsupported extension type marked critical. The OID was encoded as “1.2.3.4” with an extnValue of “value”. The signature on this CSR is invalid.
- basic_constraints.pem - A certificate signing request for an RSA 2048 bit key containing a basic constraints extension marked as critical. The signature on this CSR is invalid.
- invalid_signature.pem - A certificate signing request for an RSA 1024 bit key containing an invalid signature with correct padding.
- challenge.pem - A certificate signing request for an RSA 2048 bit key containing a challenge password.
- challenge-invalid.der - A certificate signing request for an RSA 2048 bit key containing a challenge password attribute that has been encoded as an ASN.1 integer rather than a string.
- challenge-unstructured.pem - A certificate signing request for an RSA 2048 bit key containing a challenge password attribute and an unstructured name attribute.
- challenge-multi-valued.der - A certificate signing request for an RSA 2048 bit key containing a challenge password attribute with two values inside the ASN.1 set. The signature on this request is invalid.
- freeipa-bad-critical.pem - A certificate signing request where the extensions value has a critical value of False explicitly encoded.
- bad-version.pem - A certificate signing request where the version is invalid.
- long-form-attribute.pem - A certificate signing request containing an attribute whose value’s tag is encoded in the long form.
Custom X.509 Certificate Revocation List Vectors

- **crl_all_reasons.pem** - Contains a CRL with 12 revoked certificates, whose serials match their list position. It includes one revocation without any entry extensions, 10 revocations with every supported reason code and one revocation with an unsupported, non-critical entry extension with the OID value set to “1.2.3.4”. The signature on this CRL is invalid.

- **crl_dup_entry_ext.pem** - Contains a CRL with one revocation which has a duplicate entry extension. The signature on this CRL is invalid.

- **crl_md2_unknown_crit_entry_ext.pem** - Contains a CRL with one revocation which contains an unsupported critical entry extension with the OID value set to “1.2.3.4”. The CRL uses an unsupported MD2 signature algorithm, and the signature on this CRL is invalid.

- **crl_unsupported_reason.pem** - Contains a CRL with one revocation which has an unsupported reason code. The signature on this CRL is invalid.

- **crl_inval_cert_issuer_entry_ext.pem** - Contains a CRL with one revocation which has one entry extension for certificate issuer with an empty value. The signature on this CRL is invalid.

- **crl_empty.pem** - Contains a CRL with no revoked certificates.

- **crl_empty_no_sequence.der** - Contains a CRL with no revoked certificates and the optional ASN.1 sequence for revoked certificates is omitted.

- **crl_ian_aia_aki.pem** - Contains a CRL with IssuerAlternativeName, AuthorityInformationAccess, AuthorityKeyIdentifier and CRLNumber extensions.

- **valid_signature_crl.pem** - Contains a CRL with a valid signature.

- **valid_signature_cert.pem** - Contains a cert whose public key corresponds to the private key that produced the signature for valid_signature_crl.pem.

- **invalid_signature_crl.pem** - Contains a CRL with the last signature byte incremented by 1 to produce an invalid signature.

- **invalid_signature_cert.pem** - Contains a cert whose public key corresponds to the private key that produced the signature for invalid_signature_crl.pem.

- **crl_delta_crl_indicator.pem** - Contains a CRL with the DeltaCRLIndicator extension.

- **crl_idp_fullname_only.pem** - Contains a CRL with an IssuingDistributionPoints extension with only a fullname for the distribution point.

- **crl_idp_only_ca.pem** - Contains a CRL with an IssuingDistributionPoints extension that is only valid for CA certificate revocation.

- **crl_idp_fullname_only_aa.pem** - Contains a CRL with an IssuingDistributionPoints extension that sets a fullname and is only valid for attribute certificate revocation.

- **crl_idp_fullname_only_user.pem** - Contains a CRL with an IssuingDistributionPoints extension that sets a fullname and is only valid for user certificate revocation.

- **crl_idp_fullname_indirect_crl.pem** - Contains a CRL with an IssuingDistributionPoints extension that sets a fullname and the indirect CRL flag.

- **crl_idp_reasons_only.pem** - Contains a CRL with an IssuingDistributionPoints extension that is only valid for revocations with the keyCompromise reason.

- **crl_idp_relative_user_all_reasons.pem** - Contains a CRL with an IssuingDistributionPoints extension that sets all revocation reasons as allowed.

- **crl_idp_relativename_only.pem** - Contains a CRL with an IssuingDistributionPoints extension with only a relativename for the distribution point.
• crl_unrecognized_extension.der - Contains a CRL containing an unsupported extension type. The OID was encoded as "1.2.3.4.5" with an extnValue of abcdef.

• crl_invalid_time.der - Contains a CRL with an invalid UTCTime value in thisUpdate. The signature on this CRL is invalid.

• crl_no_next_time.pem - Contains a CRL with no nextUpdate value. The signature on this CRL is invalid.

• crl_bad_version.pem - Contains a CRL with an invalid version.

• crl_almost_10k.pem - Contains a CRL with 9,999 entries.

• crl_inner_outer_mismatch.der - A CRL created from valid_signature_crl.pem but with a mismatched inner and outer signature algorithm. The signature on this CRL is invalid.

**X.509 OCSP Test Vectors**

• x509/ocsp/resp-sha256.der - An OCSP response for cryptography.io with a SHA256 signature.

• x509/ocsp/resp-unauthorized.der - An OCSP response with an unauthorized status.

• x509/ocsp/resp-revoked.der - An OCSP response for revoked.badssl.com with a revoked status.

• x509/ocsp/resp-delegate-unknown-cert.der - An OCSP response for an unknown cert from AC Camerafirma. This response also contains a delegate certificate.

• x509/ocsp/resp-responder-key-hash.der - An OCSP response from the DigiCert OCSP responder that uses a key hash for the responder ID.

• x509/ocsp/resp-revoked-reason.der - An OCSP response from the QuoVadis OCSP responder that contains a revoked certificate with a revocation reason.

• x509/ocsp/resp-revoked-no-next-update.der - An OCSP response that contains a revoked certificate and no nextUpdate value.

• x509/ocsp/resp-invalid-signature-oid.der - An OCSP response that was modified to contain an MD2 signature algorithm object identifier.

• x509/ocsp/resp-single-extension-reason.der - An OCSP response that contains a CRLReason single extension.

• x509/ocsp/resp-sct-extension.der - An OCSP response containing a CT Certificate SCTs single extension, from the SwissSign OCSP responder.

• x509/ocsp/army.deps.mil-resp.der - An OCSP response containing multiple SINGLERESP values.

• x509/ocsp/resp-response-type-unknown-oid.der - An OCSP response with an unknown OID for response type. The signature on this response is invalid.

• x509/ocsp/resp-successful-no-response-bytes.der - An OCSP request with a successful response type but the response bytes are missing.

• x509/ocsp/resp-unknown-response-status.der - An OCSP response with an unknown response status.
Custom X.509 OCSP Test Vectors

- x509/ocsp/req-sha1.der - An OCSP request containing a single request and using SHA1 as the hash algorithm.
- x509/ocsp/req-multi-sha1.der - An OCSP request containing multiple requests.
- x509/ocsp/req-invalid-hash-alg.der - An OCSP request containing an invalid hash algorithm OID.
- x509/ocsp/req-ext-nonce.der - An OCSP request containing a nonce extension.
- x509/ocsp/req-ext-unknown-oid.der - An OCSP request containing an extension with an unknown OID.
- x509/ocsp/req-duplicate-ext.der - An OCSP request with duplicate extensions.
- x509/ocsp/resp-unknown-extension.der - An OCSP response containing an extension with an unknown OID.
- x509/ocsp/resp-unknown-hash-alg.der - An OCSP response containing an invalid hash algorithm OID.
- x509/ocsp/req-acceptable-responses.der - An OCSP request containing an acceptable responses extension.

Custom PKCS12 Test Vectors

- pkcs12/cert-key-aes256cbc.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) both encrypted with AES 256 CBC with the password cryptography.
- pkcs12/cert-none-key-none.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with no encryption. The password (used for integrity checking only) is cryptography.
- pkcs12/cert-rc2-key-3des.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) encrypted with RC2 and key (pkcs12/ca/ca_key.pem) encrypted via 3DES with the password cryptography.
- pkcs12/no-password.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with no encryption and no password.
- pkcs12/no-cert-key-aes256cbc.p12 - A PKCS12 file containing a key (pkcs12/ca/ca_key.pem) encrypted via AES 256 CBC with the password cryptography and no certificate.
- pkcs12/cert-aes256cbc-no-key.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) encrypted via AES 256 CBC with the password cryptography and no private key.
- pkcs12/no-name-no-pwd.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem).
- pkcs12/name-all-no-pwd.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with friendly name name, as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2 and name3, respectively.
- pkcs12/name-1-no-pwd.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with friendly name name, as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem).
- pkcs12/name-2-3-no-pwd.p12 - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2 and name3, respectively.
• **pkcs12/name-2-no-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem), the first having friendly name name2.

• **pkcs12/name-3-no-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem), the latter having friendly name name3.

• **pkcs12/name-unicode-no-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with friendly name, as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names ä and ç, respectively.

• **pkcs12/no-name-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem), encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/name-all-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with friendly name, as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2 and name3 respectively, encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/name-1-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with friendly name name, as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem), encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/name-2-3-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2' and 'name3 respectively, encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/name-2-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem), the first having friendly name name2, encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/name-3-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem), as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem), the latter having friendly name name2, encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/name-unicode-pwd.p12** - A PKCS12 file containing a cert (pkcs12/ca/ca.pem) and key (pkcs12/ca/ca_key.pem) with friendly name, as well as two additional certificates (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names ä and ç respectively, encrypted via AES 256 CBC with the password cryptography.

• **pkcs12/no-cert-no-name-no-pwd.p12** - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem).

• **pkcs12/no-cert-name-all-no-pwd.p12** - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2 and name3, respectively.

• **pkcs12/no-cert-name-2-no-pwd.p12** - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem), the first having friendly name name2.

• **pkcs12/no-cert-name-3-no-pwd.p12** - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem), the second having friendly name name3.

• **pkcs12/no-cert-name-unicode-no-pwd.p12** - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names ä and ç.
• pkcs12/no-cert-no-name-pwd.p12 - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem), encrypted via AES 256 CBC with the password cryptography.

• pkcs12/no-cert-name-all-pwd.p12 - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2 and name3, respectively, encrypted via AES 256 CBC with the password cryptography.

• pkcs12/no-cert-name-2-pwd.p12 - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem), the first with friendly name name2, encrypted via AES 256 CBC with the password cryptography.

• pkcs12/no-cert-name-3-pwd.p12 - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem), the second with friendly name name3, encrypted via AES 256 CBC with the password cryptography.

• pkcs12/no-cert-name-unicode-pwd.p12 - A PKCS12 file containing two certs (x509/cryptography.io.pem and x509/letsencryptx3.pem) with friendly names name2 and name3, respectively, encrypted via AES 256 CBC with the password cryptography.

Custom PKCS7 Test Vectors

• pkcs7/isrg.pem - A PEM encoded PKCS7 file containing the ISRG X1 root CA.

• pkcs7/amazon-roots.p7b - A BER encoded PKCS7 file containing Amazon Root CA 2 and 3 generated by Apple Keychain.

• pkcs7/amazon-roots.der - A DER encoded PKCS7 file containing Amazon Root CA 2 and 3 generated by OpenSSL.

• pkcs7/enveloped.pem - A PEM encoded PKCS7 file with enveloped data.

Custom OpenSSH Test Vectors

• ed25519-aesgcm-psw.key and ed25519-aesgcm-psw.key.pub generated by exporting an Ed25519 key from 1password 8 with the password “password”. This key is encrypted using the aes256-gcm@openssh.com algorithm.

Generated by asymmetric/OpenSSH/gen.sh using command-line tools from OpenSSH_7.6p1 package.

• dsa-nopsw.key, dsa-nopsw.key.pub, dsa-nopsw.key-cert.pub - DSA-1024 private key; and corresponding public key in plain format and with self-signed certificate.

• dsa-psw.key, dsa-psw.key.pub - Password-protected DSA-1024 private key and corresponding public key. Password is “password”.

• ecdsa-nopsw.key, ecdsa-nopsw.key.pub, ecdsa-nopsw.key-cert.pub - SECP256R1 private key; and corresponding public key in plain format and with self-signed certificate.

• ecdsa-psw.key, ecdsa-psw.key.pub - Password-protected SECP384R1 private key and corresponding public key. Password is “password”.

• ed25519-nopsw.key, ed25519-nopsw.key.pub, ed25519-nopsw.key-cert.pub - Ed25519 private key; and corresponding public key in plain format and with self-signed certificate.

• ed25519-psw.key, ed25519-psw.key.pub - Password-protected Ed25519 private key and corresponding public key. Password is “password”.

• rsa-nopsw.key, rsa-nopsw.key.pub, rsa-nopsw.key-cert.pub - RSA-2048 private key; and corresponding public key in plain format and with self-signed certificate.
• rsa-psw.key, rsa-psw.key.pub - Password-protected RSA-2048 private key and corresponding public key. Password is “password”.

Custom OpenSSH Certificate Test Vectors

• p256-p256-duplicate-extension.pub - A certificate with a duplicate extension.
• p256-p256-non-lexical-extensions.pub - A certificate with extensions in non-lexical order.
• p256-p256-duplicate-crit-opts.pub - A certificate with a duplicate critical option.
• p256-p256-non-lexical-crit-opts.pub - A certificate with critical options in non-lexical order.
• p256-ed25519-non-singular-crit-opt-val.pub - A certificate with a critical option that contains more than one value.
• p256-ed25519-non-singular-ext-val.pub - A certificate with an extension that contains more than one value.
• dsa-p256.pub - A certificate with a DSA public key signed by a P256 CA.
• p256-dsa.pub - A certificate with a P256 public key signed by a DSA CA.
• p256-p256-broken-signature-key-type.pub - A certificate with a P256 public key signed by a P256 CA, but the signature key type is set to rsa-sha2-512.
• p256-p256-empty-principals.pub - A certificate with a P256 public key signed by a P256 CA with an empty valid principals list.
• p256-p256-invalid-cert-type.pub - A certificate with a P256 public key signed by a P256 CA with an invalid certificate type.
• p256-p384.pub - A certificate with a P256 public key signed by a P384 CA.
• p256-p521.pub - A certificate with a P256 public key signed by a P521 CA.
• p256-rsa-sha1.pub - A certificate with a P256 public key signed by a RSA CA using SHA1.
• p256-rsa-sha256.pub - A certificate with a P256 public key signed by a RSA CA using SHA256.
• p256-rsa-sha512.pub - A certificate with a P256 public key signed by a RSA CA using SHA512.

Hashes

• MD5 from RFC 1321.
• RIPEMD160 from the RIPEMD website.
• SHA1 from NIST CAVP.
• SHA2 (224, 256, 384, 512, 512/224, 512/256) from NIST CAVP.
• SHA3 (224, 256, 384, 512) from NIST CAVP.
• SHAKE (128, 256) from NIST CAVP.
• Blake2s and Blake2b from OpenSSL test/evptests.txt.
HMAC

- HMAC-MD5 from RFC 2202.
- HMAC-SHA1 from RFC 2202.
- HMAC-RIPEMD160 from RFC 2286.
- HMAC-SHA2 (224, 256, 384, 512) from RFC 4231.

Key derivation functions

- HKDF (SHA1, SHA256) from RFC 5869.
- PBKDF2 (HMAC-SHA1) from RFC 6070.
- scrypt from the draft RFC.
- X9.63 KDF from NIST CAVP.
- SP 800-108 Counter Mode KDF (HMAC-SHA1, HMAC-SHA224, HMAC-SHA256, HMAC-SHA384, HMAC-SHA512) from NIST CAVP.

Key wrapping

- AES key wrap (AESKW) and 3DES key wrap test vectors from NIST CAVP.
- AES key wrap with padding vectors from Botan’s key wrap vectors.

Recipes

- Fernet from its specification repository.

Symmetric ciphers

- AES (CBC, CFB, ECB, GCM, OFB, CCM) from NIST CAVP.
- AES CTR from RFC 3686.
- AES-GCM-SIV (KEY-LENGTH: 128, 256) from OpenSSL’s evpciph_aes_gcm_siv.txt.
- AES-GCM-SIV (KEY-LENGTH: 192) generated by this project. See AES-GCM-SIV vector creation.
- AES OCB3 from RFC 7253, dkg’s additional OCB3 vectors, and OpenSSL’s OCB vectors.
- AES SIV from OpenSSL’s evpciph_aes_siv.txt.
- 3DES (CBC, CFB, ECB, OFB) from NIST CAVP.
- ARC4 (KEY-LENGTH: 40, 56, 64, 80, 128, 192, 256) from RFC 6229.
- ARC4 (KEY-LENGTH: 160) generated by this project. See: ARC4 vector creation.
- Blowfish (CBC, CFB, ECB, OFB) from Bruce Schneier’s vectors.
- Camellia (ECB) from NTT’s Camellia page as linked by CRYPTREC.
- Camellia (CBC, CFB, OFB) from OpenSSL’s test vectors.
- CAST5 (ECB) from RFC 2144.
• CAST5 (CBC, CFB, OFB) generated by this project. See: CAST5 vector creation
• ChaCha20 from RFC 7539 and generated by this project. See: ChaCha20 vector creation
• ChaCha20Poly1305 from RFC 7539, OpenSSL’s evpciph.txt, and the BoringSSL ChaCha20Poly1305 tests.
• IDEA (ECB) from the NESSIE IDEA vectors created by NESSIE.
• IDEA (CBC, CFB, OFB) generated by this project. See: IDEA vector creation
• SEED (ECB) from RFC 4269.
• SEED (CBC) from RFC 4196.
• SEED (CFB, OFB) generated by this project. See: SEED vector creation
• SM4 (CBC, CFB, CTR, ECB, OFB) from draft-ribose-cfrg-sm4-10.
• SM4 (GCM) from RFC 8998.

Two factor authentication

• HOTP from RFC 4226
• TOTP from RFC 6238 (Note that an errata for the test vectors in RFC 6238 exists)

CMAC

• AES-128, AES-192, AES-256, 3DES from NIST SP-800-38B

Poly1305

• Test vectors from RFC 7539.

Creating test vectors

When official vectors are unavailable cryptography may choose to build its own using existing vectors as source material.

Created Vectors

AES-GCM-SIV vector creation

This page documents the code that was used to generate the AES-GCM-SIV test vectors for key lengths not available in the OpenSSL test vectors. All the vectors were generated using OpenSSL and verified with Rust.
Creation

The following Python script was run to generate the vector files. The OpenSSL test vectors were used as a base and modified to have 192-bit key length.

```python
# This file is dual licensed under the terms of the Apache License, Version
# 2.0, and the BSD License. See the LICENSE file in the root of this repository
# for complete details.

import binascii

from cryptography.hazmat.primitives.ciphers.aead import AESGCMSIV

def convert_key_to_192_bits(key: str) -> str:
    """
    This takes existing 128 and 256-bit keys from test vectors from OpenSSL
    and makes them 192-bit by either appending 0 or truncating the key.
    """
    new_key = binascii.unhexlify(key)
    if len(new_key) == 16:
        new_key += b"\x00" * 8
    elif len(new_key) == 32:
        new_key = new_key[0:24]
    else:
        raise RuntimeError("Unexpected key length. OpenSSL AES-GCM-SIV test vectors only "
                            "contain 128-bit and 256-bit keys"
                            )
    return binascii.hexlify(new_key).decode("ascii")

def encrypt(key: str, iv: str, plaintext: str, aad: str) -> (str, str):
    aesgcmsiv = AESGCMSIV(binascii.unhexlify(key))
    encrypted_output = aesgcmsiv.encrypt(
        binascii.unhexlify(iv),
        binascii.unhexlify(plaintext),
        binascii.unhexlify(aad) if aad else None,
    )
    ciphertext, tag = encrypted_output[:-16], encrypted_output[-16:]
    return (binascii.hexlify(ciphertext).decode("ascii"),
            binascii.hexlify(tag).decode("ascii"),
    )

def build_vectors(filename):
    count = 0
    output = []
    key = None
    iv = None
```

(continues on next page)
aad = None
plaintext = None

with open(filename) as vector_file:
    for line in vector_file:
        line = line.strip()
        if line.startswith("Key"):  
            if count != 0:
                ciphertext, tag = encrypt(key, iv, plaintext, aad)
                output.append(f"Tag = {tag}\nCiphertext = {ciphertext}\n")
                output.append(f"\nCOUNT = {count}\n")
            count += 1
            aad = None
            _, key = line.split(" = ")
            key = convert_key_to_192_bits(key)
            output.append(f"Key = {key}\n")
        elif line.startswith("IV"):  
            _, iv = line.split(" = ")
            output.append(f"IV = {iv}\n")
        elif line.startswith("AAD"):  
            _, aad = line.split(" = ")
            output.append(f"AAD = {aad}\n")
        elif line.startswith("Plaintext"):  
            _, plaintext = line.split(" = ")
            output.append(f"Plaintext = {plaintext}\n")

        ciphertext, tag = encrypt(key, iv, plaintext, aad)
        output.append(f"Tag = {tag}\nCiphertext = {ciphertext}\n")
        return \n"\n".join(output)

def write_file(data, filename):  
    with open(filename, "w") as f:
        f.write(data)

path = "vectors/cryptography_vectors/ciphers/AES/GCM-SIV/openssl.txt"
write_file(build_vectors(path), "aes-192-gcm-siv.txt")

Download link: generate_aes192gcmsiv.py

Verification

The following Rust program was used to verify the vectors.

```rust
use aes_gcm_siv::{
    aead::{Aead, KeyInit},
    AesGcmSiv, Nonce,
};

use aes::Aes192;
```
use aes_gcm_siv::aead::generic_array::GenericArray;
use aes_gcm_siv::aead::Payload;
use std::fs::File;
use std::io;
use std::io::BufRead;
use std::path::Path;

pub type Aes192GcmSiv = AesGcmSiv<Aes192>;

struct VectorArgs {
    nonce: String,
    key: String,
    aad: String,
    tag: String,
    plaintext: String,
    ciphertext: String,
}

fn validate(v: &VectorArgs) {
    let key_bytes = hex::decode(&v.key).unwrap();
    let nonce_bytes = hex::decode(&v.nonce).unwrap();
    let aad_bytes = hex::decode(&v.aad).unwrap();
    let plaintext_bytes = hex::decode(&v.plaintext).unwrap();
    let expected_ciphertext_bytes = hex::decode(&v.ciphertext).unwrap();
    let expected_tag_bytes = hex::decode(&v.tag).unwrap();

    let key_array: [u8; 24] = key_bytes.try_into().unwrap();
    let cipher = Aes192GcmSiv::new(&GenericArray::from(key_array));

    let payload = Payload {
        msg: plaintext_bytes.as_slice(),
        aad: aad_bytes.as_slice(),
    };
    let encrypted_bytes = cipher
        .encrypt(Nonce::from_slice(nonce_bytes.as_slice()), payload)
        .unwrap();
    let (ciphertext_bytes, tag_bytes) = encrypted_bytes.split_at(plaintext_bytes.len());
    assert_eq!(ciphertext_bytes, expected_ciphertext_bytes);
    assert_eq!(tag_bytes, expected_tag_bytes);
}

fn validate_vectors(filename: &Path) {
    let file = File::open(filename).expect("Failed to open file");
    let reader = io::BufReader::new(file);
    let mut vector: Option<VectorArgs> = None;

    for line in reader.lines() {
        let line = line.expect("Failed to read line");
        let segments: Vec<&str> = line.splitn(2, " = ").collect();
        match segments.first() {
        }
Some("COUNT") => {
    if let Some(v) = vector.take() {
        validate(&v);
    }
    vector = Some(VectorArgs {
        nonce: String::new(),
        key: String::new(),
        aad: String::new(),
        tag: String::new(),
        plaintext: String::new(),
        ciphertext: String::new(),
    });
}
Some("IV") => {
    if let Some(v) = &mut vector {
        v.nonce = segments[1].parse().expect("Failed to parse IV");
    }
}
Some("Key") => {
    if let Some(v) = &mut vector {
        v.key = segments[1].to_string();
    }
}
Some("AAD") => {
    if let Some(v) = &mut vector {
        v.aad = segments[1].to_string();
    }
}
Some("Tag") => {
    if let Some(v) = &mut vector {
        v.tag = segments[1].to_string();
    }
}
Some("Plaintext") => {
    if let Some(v) = &mut vector {
        v.plaintext = segments[1].to_string();
    }
}
Some("Ciphertext") => {
    if let Some(v) = &mut vector {
        v.ciphertext = segments[1].to_string();
    }
}
_ => {}
fn main() {
    validate_vectors(Path::new(
        "vectors/cryptography_vectors/ciphers/AES/GCM-SIV/aes-192-gcm-siv.txt",
    ));
    println!("AES-192-GCM-SIV OK.")
}

Download link: main.rs

ARC4 vector creation

This page documents the code that was used to generate the ARC4 test vectors for key lengths not available in RFC 6229. All the vectors were generated using OpenSSL and verified with Go.

Creation

cryptography was modified to support ARC4 key lengths not listed in RFC 6229. Then the following Python script was run to generate the vector files.

```python
# This file is dual licensed under the terms of the Apache License, Version 2.0, and the BSD License. See the LICENSE file in the root of this repository for complete details.

import binascii

from cryptography.hazmat.primitives import ciphers
from cryptography.hazmat.primitives.ciphers import algorithms

_RFC6229_KEY_MATERIALS = [
    (True,
     8 * "0102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20",
    ),
    (False,
     8 * "1ada31d5cf688221c109163908be51debb46227c6cc8b37641910833222772a",
    ),
]

_RFC6229_OFFSETS = [
    0,
    16,
    240,
    256,
    496,
    512,
    752,
    768,
    1008,
]"
1024,
1520,
1536,
2032,
2048,
3056,
3072,
4080,
4096,

_SIZES_TO_GENERATE = [160]

def _key_for_size(size, keyinfo):
    msb, key = keyinfo
    if msb:
        return key[: size // 4]
    else:
        return key[-size // 4 :]

def _build_vectors():
    count = 0
    output = []
    key = None
    plaintext = binascii.unhexlify(32 * '0')
    for size in _SIZES_TO_GENERATE:
        for keyinfo in _RFC6229_KEY_MATERIALS:
            key = _key_for_size(size, keyinfo)
            cipher = ciphers.Cipher(
                algorithms.ARC4(binascii.unhexlify(key)),
                None,
            )
            encryptor = cipher.encryptor()
            current_offset = 0
            for offset in _RFC6229_OFFSETS:
                if offset % 16 != 0:
                    raise ValueError(
                        f"Offset {offset} is not evenly divisible by 16"
                    )
                while current_offset < offset:
                    encryptor.update(plaintext)
                    current_offset += len(plaintext)
            output.append(f"\nCOUNT = {count}")
            count += 1
            output.append(f"KEY = {key}")
            output.append(f"OFFSET = {offset}")
            output.append(f"PLAINTEXT = {binascii.hexlify(plaintext)}")
            output.append(f"CIPHERTEXT = {}".format(}
binascii.hexlify(encryptor.update(plaintext))
    )
    current_offset += len(plaintext)
assert not encryptor.finalize()
return \n'.join(output)

def _write_file(data, filename):
    with open(filename, "w") as f:
        f.write(data)

if __name__ == "__main__":
    _write_file(_build_vectors(), "arc4.txt")

Download link: generate_arc4.py

Verification

The following Go code was used to verify the vectors.

```
package main

import (
    "bufio"
    "bytes"
    "crypto/rc4"
    "encoding/hex"
    "fmt"
    "os"
    "strconv"
    "strings"
)

func unhexlify(s string) []byte {
    bytes, err := hex.DecodeString(s)
    if err != nil {
        panic(err)
    }
    return bytes
}

type vectorArgs struct {
    count    string
    offset   uint64
    key      string
    plaintext string
    ciphertext string
}
```
type vectorVerifier interface {
    validate(count string, offset uint64, key, plaintext, expectedCiphertext []byte)
}

type arc4Verifier struct{

    func (o arc4Verifier) validate(count string, offset uint64, key, plaintext, expectedCiphertext []byte) {  
        if offset%16 != 0 || len(plaintext) != 16 || len(expectedCiphertext) != 16 {  
            panic(fmt.Errorf("Unexpected input value encountered: offset=%v; len(plaintext)=%v; len(expectedCiphertext)=%v", offset, len(plaintext), len(expectedCiphertext)))
        }
        stream, err := rc4.NewCipher(key)
        if err != nil {  
            panic(err)
        }
        var currentOffset uint64 = 0
        ciphertext := make([]byte, len(plaintext))
        for currentOffset <= offset {  
            stream.XORKeyStream(ciphertext, plaintext)
            currentOffset += uint64(len(plaintext))
        }
        if !bytes.Equal(ciphertext, expectedCiphertext) {  
            panic(fmt.Errorf("vector mismatch @ COUNT = %s:
 %s != %s
", count, hex.EncodeToString(expectedCiphertext), hex.EncodeToString(ciphertext)))
        }
    }

    func validateVectors(verifier vectorVerifier, filename string) {
        vectors, err := os.Open(filename)
        if err != nil {  
            panic(err)
        }
        defer vectors.Close()
        var segments []string
        var vector *vectorArgs
        scanner := bufio.NewScanner(vectors)
        for scanner.Scan() {  
            segments = strings.Split(scanner.Text(), " = ")
            switch {  
                case strings.ToUpper(segments[0]) == "COUNT":
                    if vector != nil {  
                        verifier.validate(vector.count,
                    }
            }
        }
    }
}
vector.offset,
unhexlify(vector.key),
unhexlify(vector.plaintext),
unhexlify(vector.ciphertext))

} else {
    vectorArgs = &vectorArgs{count: segments[1]}
    case strings.ToUpper(segments[0]) == "OFFSET":
        vector.offset, err = strconv.ParseUint(segments[1], 10, 64)
        if err != nil {
            panic(err)
        }
    case strings.ToUpper(segments[0]) == "KEY":
        vector.key = segments[1]
    case strings.ToUpper(segments[0]) == "PLAINTEXT":
        vector.plaintext = segments[1]
    case strings.ToUpper(segments[0]) == "CIPHERTEXT":
        vector.ciphertext = segments[1]
    }
}
if vector != nil {
    verifier.validate(vector.count,
        vector.offset,
        unhexlify(vector.key),
        unhexlify(vector.plaintext),
        unhexlify(vector.ciphertext))
}

func main() {
    validateVectors(arc4Verifier{}, "vectors/cryptography_vectors/ciphers/ARC4/arc4.txt")
    fmt.Println("ARC4 OK.")
}

CAST5 vector creation

This page documents the code that was used to generate the CAST5 CBC, CFB, OFB, and CTR test vectors as well as the code used to verify them against another implementation. The CBC, CFB, and OFB vectors were generated using OpenSSL and the CTR vectors were generated using Apple’s CommonCrypto. All the generated vectors were verified with Go.

Download link: verify_arc4.go
Creation

cryptography was modified to support CAST5 in CBC, CFB, and OFB modes. Then the following Python script was run to generate the vector files.

```python
# This file is dual licensed under the terms of the Apache License, Version
# 2.0, and the BSD License. See the LICENSE file in the root of this repository
# for complete details.

import binascii

from cryptography.hazmat.primitives.ciphers import algorithms, base, modes

def encrypt(mode, key, iv, plaintext):
    cipher = base.Cipher(
        algorithms.CAST5(binascii.unhexlify(key)),
        mode(binascii.unhexlify(iv)),
    )
    encryptor = cipher.encryptor()
    ct = encryptor.update(binascii.unhexlify(plaintext))
    ct += encryptor.finalize()
    return binascii.hexlify(ct)

def build_vectors(mode, filename):
    count = 0
    output = []
    key = None
    iv = None
    plaintext = None

    with open(filename) as vector_file:
        for line in vector_file:
            line = line.strip()
            if line.startswith("KEY"):  
                if count != 0:
                    output.append(f"CIPHERTEXT = {encrypt(mode, key, iv, plaintext)}")
                    output.append(f"\n\n\nCOUNT = {count}"
                    count += 1
                _, key = line.split(" = ")
                output.append(f"KEY = {key}"
            elif line.startswith("IV"):
                _, iv = line.split(" = ")
                iv = iv[0:16]
                output.append(f"IV = {iv}"
            elif line.startswith("PLAINTEXT"):
                _, plaintext = line.split(" = ")
                output.append(f"PLAINTEXT = {plaintext}"
            output.append(f"CIPHERTEXT = {encrypt(mode, key, iv, plaintext)}")
    return "\n".join(output)
```

(continues on next page)
def write_file(data, filename):
    with open(filename, "w") as f:
        f.write(data)

cbc_path = "tests/hazmat/primitives/vectors/ciphers/AES/CBC/CBCMMT128.rsp"
write_file(build_vectors(modes.CBC, cbc_path), "cast5-cbc.txt")
ofb_path = "tests/hazmat/primitives/vectors/ciphers/AES/OFB/OFBMMT128.rsp"
write_file(build_vectors(modes.OFB, ofb_path), "cast5-ofb.txt")
cfb_path = "tests/hazmat/primitives/vectors/ciphers/AES/CFB/CFB128MMT128.rsp"
write_file(build_vectors(modes.CFB, cfb_path), "cast5-cfb.txt")
ctr_path = "tests/hazmat/primitives/vectors/ciphers/AES/CTR/aes-128-ctr.txt"
write_file(build_vectors(modes.CTR, ctr_path), "cast5-ctr.txt")

Download link: generate_cast5.py

**Verification**

The following Go code was used to verify the vectors.

```go
package main

import (
    "bufio"
    "bytes"
    "golang.org/x/crypto/cast5"
    "crypto/cipher"
    "encoding/hex"
    "fmt"
    "os"
    "strings"
)

func unhexlify(s string) []byte {
    bytes, err := hex.DecodeString(s)
    if err != nil {
        panic(err)
    }
    return bytes
}

type vectorArgs struct {
    count        string
    key          string
    iv           string
    plaintext    string
    ciphertext   string
}
```

(continues on next page)
type vectorVerifier interface {
    validate(count string, key, iv, plaintext, expectedCiphertext []byte)
}

type ofbVerifier struct{
    func (o ofbVerifier) validate(count string, key, iv, plaintext, expectedCiphertext []byte) {
        block, err := cast5.NewCipher(key)
        if err != nil {
            panic(err)
        }
        ciphertext := make([]byte, len(plaintext))
        stream := cipher.NewOFB(block, iv)
        stream.XORKeyStream(ciphertext, plaintext)
        if !bytes.Equal(ciphertext, expectedCiphertext) {
            panic(fmt.Errorf("vector mismatch @ COUNT = %s: \n %s != %s\n", count, hex.EncodeToString(expectedCiphertext), hex.EncodeToString(ciphertext)))
        }
    }
}

type cbcVerifier struct{
    func (o cbcVerifier) validate(count string, key, iv, plaintext, expectedCiphertext []byte) {
        block, err := cast5.NewCipher(key)
        if err != nil {
            panic(err)
        }
        ciphertext := make([]byte, len(plaintext))
        mode := cipher.NewCBCDecrypter(block, iv)
        mode.XORKeyStream(ciphertext, plaintext)
        if !bytes.Equal(ciphertext, expectedCiphertext) {
            panic(fmt.Errorf("vector mismatch @ COUNT = %s: \n %s != %s\n", count, hex.EncodeToString(expectedCiphertext), hex.EncodeToString(ciphertext)))
        }
    }
}

type cfbVerifier struct{
    func (o cfbVerifier) validate(count string, key, iv, plaintext, expectedCiphertext []byte) {
        block, err := cast5.NewCipher(key)
        if err != nil {
            panic(err)
        }
        ciphertext := make([]byte, len(plaintext))
panic(err)
}
ciphertext := make([]byte, len(plaintext))
stream := cipher.NewCFBEncrypter(block, iv)
stream.XORKeyStream(ciphertext, plaintext)

if !bytes.Equal(ciphertext, expectedCiphertext) {
    panic(fmt.Errorf("vector mismatch @ COUNT = %s:
        %s != %s\n", count,
            hex.EncodeToString(expectedCiphertext),
            hex.EncodeToString(ciphertext)))
}
}

type ctrVerifier struct{}

func (o ctrVerifier) validate(count string, key, iv, plaintext, expectedCiphertext ...[]byte) {
    block, err := cast5.NewCipher(key)
    if err != nil {
        panic(err)
    }

ciphertext := make([]byte, len(plaintext))
stream := cipher.NewCTR(block, iv)
stream.XORKeyStream(ciphertext, plaintext)

if !bytes.Equal(ciphertext, expectedCiphertext) {
    panic(fmt.Errorf("vector mismatch @ COUNT = %s:
        %s != %s\n", count,
            hex.EncodeToString(expectedCiphertext),
            hex.EncodeToString(ciphertext)))
}
}

func validateVectors(verifier vectorVerifier, filename string) {
    vectors, err := os.Open(filename)
    if err != nil {
        panic(err)
    }

deffer vectors.Close()

    var segments []string
    var vector *vectorArgs

    scanner := bufio.NewScanner(vectors)
    for scanner.Scan() {
        segments = strings.Split(scanner.Text(), " = ")

        switch {
        case strings.ToUpper(segments[0]) == "COUNT":
            // Processing vector "COUNT"...
        // Other cases...
        }
    }
}
if vector != nil {
    verifier.validate(vector.count,
    unhexlify(vector.key),
    unhexlify(vector.iv),
    unhexlify(vector.plaintext),
    unhexlify(vector.ciphertext))
}
vector = &vectorArgs{count: segments[1]}
    case strings.ToUpper(segments[0]) == "IV":
        vector.iv = segments[1][:16]
    case strings.ToUpper(segments[0]) == "KEY":
        vector.key = segments[1]
    case strings.ToUpper(segments[0]) == "PLAINTEXT":
        vector.plaintext = segments[1]
    case strings.ToUpper(segments[0]) == "CIPHERTEXT":
        vector.ciphertext = segments[1]
}
}

func main() {
    validateVectors(ofbVerifier{},
    "vectors/cryptography_vectors/ciphers/CAST5/cast5-ofb.txt")
    fmt.Println("OFB OK.")
    validateVectors(cfbVerifier{},
    "vectors/cryptography_vectors/ciphers/CAST5/cast5-cfb.txt")
    fmt.Println("CFB OK.")
    validateVectors(cbcVerifier{},
    "vectors/cryptography_vectors/ciphers/CAST5/cast5-cbc.txt")
    fmt.Println("CBC OK.")
    validateVectors(ctrVerifier{},
    "vectors/cryptography_vectors/ciphers/CAST5/cast5-ctr.txt")
    fmt.Println("CTR OK.")
}

Download link: verify_cast5.go

**ChaCha20 vector creation**

This page documents the code that was used to generate the vectors to test the counter overflow behavior in ChaCha20 as well as code used to verify them against another implementation.
Creation

The following Python script was run to generate the vector files.

```python
# This file is dual licensed under the terms of the Apache License, Version
# 2.0, and the BSD License. See the LICENSE file in the root of this repository
# for complete details.

import binascii
import struct

from cryptography.hazmat.primitives import ciphers
from cryptography.hazmat.primitives.ciphers import algorithms

_N_BLOCKS = [1, 1.5, 2, 2.5, 3]
_INITIALIZIAL_COUNTERS = [2**32 - 1, 2**64 - 1]

def _build_vectors():
    count = 0
    output = []
    key = "0" * 64
    nonce = "0" * 16
    for blocks in _N_BLOCKS:
        plaintext = binascii.unhexlify("0" * int(128 * blocks))
        for counter in _INITIAL_COUNTERS:
            full_nonce = struct.pack("<Q", counter) + binascii.unhexlify(nonce)
            cipher = ciphers.Cipher(
                algorithms.ChaCha20(binascii.unhexlify(key), full_nonce),
                None,
            )
            encryptor = cipher.encryptor()
            output.append(f"\n\n\nCOUNT = {count}\n\nKEY = {key}\n\nNONCE = {nonce}\n\nINITIAL_BLOCK_COUNTER = {counter}\n\nPLAINTEXT = {binascii.hexlify(plaintext)}\n\nCIPHERTEXT = {binascii.hexlify(encryptor.update(plaintext))}\n\n")
            count += 1
        output.append(f"\n\n")
    return ";

_write_file(data, filename):
    with open(filename, "w") as f:
        f.write(data)

if __name__ == "__main__":
    _write_file(_build_vectors(), "counter-overflow.txt")
```

Download link: generate_chacha20_overflow.py
Verification

The following Python script was used to verify the vectors. The counter overflow is handled manually to avoid relying on the same code that generated the vectors.

```python
import binascii
import math
import struct
from pathlib import Path
from cryptography.hazmat.primitives.ciphers import Cipher, algorithms
from tests.utils import load_nist_vectors

BLOCK_SIZE = 64
MAX_COUNTER = 2**64 - 1

def encrypt(
    key: bytes, nonce: bytes, initial_block_counter: int, plaintext: bytes
) -> bytes:
    full_nonce = struct.pack("<Q", initial_block_counter) + nonce
    encryptor = Cipher(
        algorithms.ChaCha20(key, full_nonce), mode=None
    ).encryptor()

    plaintext_len_blocks = math.ceil(len(plaintext) / BLOCK_SIZE)
    blocks_until_overflow = MAX_COUNTER - initial_block_counter + 1

    if plaintext_len_blocks <= blocks_until_overflow:
        return binascii.hexlify(encryptor.update(plaintext))
    else:
        bytes_until_overflow = min(blocks_until_overflow * 64, len(plaintext))  
        first_batch = binascii.hexlify(encryptor.update(plaintext[:bytes_until_overflow]))

        # We manually handle the overflow by resetting the counter to zero once we surpass MAX_COUNTER blocks. This way we can check the vectors are correct without relying on the same logic that generated them.
        full_nonce = struct.pack("<Q", 0) + nonce
        encryptor = Cipher(
            algorithms.ChaCha20(key, full_nonce), mode=None
        ).encryptor()
        second_batch = binascii.hexlify(encryptor.update(plaintext[bytes_until_overflow:]))

        return first_batch + second_batch

def verify_vectors(filename: Path):
```

(continues on next page)
with open(filename) as f:
    vector_file = f.read().splitlines()

vectors = load_nist_vectors(vector_file)
for vector in vectors:
    key = binascii.unhexlify(vector["key"])  
    nonce = binascii.unhexlify(vector["nonce"])  
    ibc = int(vector["initial_block_counter"])  
    pt = binascii.unhexlify(vector["plaintext"])  

    computed_ct = encrypt(key, nonce, ibc, pt)

    assert computed_ct == vector["ciphertext"]

overflow_path = Path(
    "vectors/cryptography_vectors/ciphers/ChaCha20/counter-overflow.txt"
)
verify_vectors(overflow_path)

Download link: verify_chacha20_overflow.py

**IDEA vector creation**

This page documents the code that was used to generate the IDEA CBC, CFB, and OFB test vectors as well as the code used to verify them against another implementation. The vectors were generated using OpenSSL and verified with Botan.

**Creation**

cryptography was modified to support IDEA in CBC, CFB, and OFB modes. Then the following python script was run to generate the vector files.

```python
import binascii

from cryptography.hazmat.primitives.ciphers import algorithms, base, modes

def encrypt(mode, key, iv, plaintext):
    cipher = base.Cipher(
        algorithms.IDEA(binascii.unhexlify(key)),
        mode(binascii.unhexlify(iv)),
    )
    encryptor = cipher.encryptor()
    ct = encryptor.update(binascii.unhexlify(plaintext))
    ct += encryptor.finalize()
    return binascii.hexlify(ct)

def build_vectors(mode, filename):
```

(continues on next page)
with open(filename) as f:
    vector_file = f.read().splitlines()

count = 0
output = []
key = None
iv = None
plaintext = None
for line in vector_file:
    line = line.strip()
    if line.startswith("KEY"):
        if count != 0:
            output.append(f"CIPHERTEXT = {encrypt(mode, key, iv, plaintext)}"
        
        output.append(f"\n\n\nCOUNT = {count}"
        count += 1
        _, key = line.split(" = ")
        output.append(f"KEY = {key}"

    elif line.startswith("IV"):
        _, iv = line.split(" = ")
        iv = iv[0:16]
        output.append(f"IV = {iv}"

    elif line.startswith("PLAINTEXT"):
        _, plaintext = line.split(" = ")
        output.append(f"PLAINTEXT = {plaintext}"

    output.append(f"CIPHERTEXT = {encrypt(mode, key, iv, plaintext)}"
return "\n\n\n".join(output)

def write_file(data, filename):
    with open(filename, "w") as f:
        f.write(data)

CBC_PATH = "tests/hazmat/primitives/vectors/ciphers/AES/CBC/CBCMMT128.rsp"
write_file(build_vectors(modes.CBC, CBC_PATH), "idea-cbc.txt")
OFB_PATH = "tests/hazmat/primitives/vectors/ciphers/AES/OFB/OFBMMT128.rsp"
write_file(build_vectors(modes.OFB, OFB_PATH), "idea-ofb.txt")
CFB_PATH = "tests/hazmat/primitives/vectors/ciphers/AES/CFB/CFB128MMT128.rsp"
write_file(build_vectors(modes.CFB, CFB_PATH), "idea-cfb.txt")

Download link: generate_idea.py
Verification

The following Python code was used to verify the vectors using the Botan project’s Python bindings.

```python
import binascii
import botan
from tests.utils import load_nist_vectors

BLOCK_SIZE = 64

def encrypt(mode, key, iv, plaintext):
    encryptor = botan.Cipher(
        f"IDEA/{mode}/NoPadding", "encrypt", binascii.unhexlify(key)
    )
    cipher_text = encryptor.cipher(
        binascii.unhexlify(plaintext), binascii.unhexlify(iv)
    )
    return binascii.hexlify(cipher_text)

def verify_vectors(mode, filename):
    with open(filename) as f:
        vector_file = f.read().splitlines()

    vectors = load_nist_vectors(vector_file)
    for vector in vectors:
        ct = encrypt(mode, vector["key"], vector["iv"], vector["plaintext"])
        assert ct == vector["ciphertext"]

cbc_path = "tests/hazmat/primitives/vectors/ciphers/IDEA/idea-cbc.txt"
verify_vectors("CBC", cbc_path)
ofb_path = "tests/hazmat/primitives/vectors/ciphers/IDEA/idea-ofb.txt"
verify_vectors("OFB", ofb_path)
cfb_path = "tests/hazmat/primitives/vectors/ciphers/IDEA/idea-cfb.txt"
verify_vectors("CFB", cfb_path)

Download link: verify_idea.py
```
SEED vector creation

This page documents the code that was used to generate the SEED CFB and OFB test vectors as well as the code used to verify them against another implementation. The vectors were generated using OpenSSL and verified with Botan.

Creation

cryptography was modified to support SEED in CFB and OFB modes. Then the following python script was run to generate the vector files.

```python
import binascii

from cryptography.hazmat.primitives.ciphers import algorithms, base, modes

def encrypt(mode, key, iv, plaintext):
    cipher = base.Cipher(
        algorithms.SEED(binascii.unhexlify(key)),
        mode(binascii.unhexlify(iv)),
    )
    encryptor = cipher.encryptor()
    ct = encryptor.update(binascii.unhexlify(plaintext))
    ct += encryptor.finalize()
    return binascii.hexlify(ct)

def build_vectors(mode, filename):
    with open(filename) as f:
        vector_file = f.read().splitlines()

    count = 0
    output = []
    key = None
    iv = None
    plaintext = None
    for line in vector_file:
        line = line.strip()
        if line.startswith("KEY"):  
            if count != 0:
                output.append("CIPHERTEXT = \n" + encrypt(mode, key, iv, plaintext))
            output.append("\nCOUNT = \n" + str(count))
            count += 1
            _, key = line.split(" = ")
            output.append("KEY = \n" + key)
        elif line.startswith("IV"):  
            _, iv = line.split(" = ")
            output.append("IV = \n" + iv)
        elif line.startswith("PLAINTEXT"):  
            _, plaintext = line.split(" = ")
            output.append("PLAINTEXT = \n" + plaintext)

    output = \
    for line in output:
        print(line)
```

(continues on next page)
output.append(f"CIPHERTEXT = {encrypt(mode, key, iv, plaintext)}")
return "\n".join(output)

def write_file(data, filename):
    with open(filename, "w") as f:
        f.write(data)

OFB_PATH = "vectors/cryptography_vectors/ciphers/AES/OFB/OFBMMT128.rsp"
write_file(build_vectors(modes.OFB, OFB_PATH), "seed-ofb.txt")
CFB_PATH = "vectors/cryptography_vectors/ciphers/AES/CFB/CFB128MMT128.rsp"
write_file(build_vectors(modes.CFB, CFB_PATH), "seed-cfb.txt")

Download link: generate_seed.py

Verification

The following Python code was used to verify the vectors using the Botan project’s Python bindings.

```python
import binascii
import botan
from tests.utils import load_nist_vectors

def encrypt(mode, key, iv, plaintext):
    encryptor = botan.Cipher(
        f"SEED/{mode}/NoPadding", "encrypt", binascii.unhexlify(key)
    )
    cipher_text = encryptor.cipher(
        binascii.unhexlify(plaintext), binascii.unhexlify(iv)
    )
    return binascii.hexlify(cipher_text)

def verify_vectors(mode, filename):
    with open(filename) as f:
        vector_file = f.read().splitlines()
    vectors = load_nist_vectors(vector_file)
    for vector in vectors:
        ct = encrypt(mode, vector["key"], vector["iv"], vector["plaintext"])
        assert ct == vector["ciphertext"]

ofb_path = "vectors/cryptography_vectors/ciphers/SEED/seed-ofb.txt"
verify_vectors("OFB", ofb_path)
```

(continues on next page)
Download link: verify_seed.py

**HKDF vector creation**

This page documents the code that was used to generate a longer HKDF test vector (1200 bytes) than is available in RFC 5869. All the vectors were generated using OpenSSL and verified with Go.

**Creation**

The following Python script was run to generate the vector files.

```python
# This file is dual licensed under the terms of the Apache License, Version
# 2.0, and the BSD License. See the LICENSE file in the root of this repository
# for complete details.

import binascii

from cryptography.hazmat.primitives import hashes
from cryptography.hazmat.primitives.kdf.hkdf import HKDF

IKM = binascii.unhexlify(b"0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b
if __name__ == "__main__":
    _write_file(_build_vectors(), "hkdf.txt")

Download link: generate_hkdf.py

Verification

The following Go code was used to verify the vectors.

```go
package main

import {
    "bufio"
    "bytes"
    "crypto/sha256"
    "encoding/hex"
    "fmt"
    "golang.org/x/crypto/hkdf"
    "io"
    "os"
    "strconv"
    "strings"
}

func unhexlify(s string) []byte {
    bytes, err := hex.DecodeString(s)
    if err != nil {
        panic(err)
    }
    return bytes
}

func verifier(l uint64, ikm, okm []byte) bool {
    hash := sha256.New
    hkdf := hkdf.New(hash, ikm, nil, nil)
    okmComputed := make([]byte, l)
    io.ReadFull(hkdf, okmComputed)
    return bytes.Equal(okmComputed, okm)
}

func validateVectors(filename string) bool {
    vectors, err := os.Open(filename)
    if err != nil {
        panic(err)
    }
    defer vectors.Close()

    var segments []string
    var l uint64
    var ikm, okm string
```
scanner := bufio.NewScanner(vectors)
for scanner.Scan() {
    segments = strings.Split(scanner.Text(), " = ")
    switch {
    case strings.ToUpper(segments[0]) == "L":
        l, err = strconv.ParseUint(segments[1], 10, 64)
        if err != nil {
            panic(err)
        }
    case strings.ToUpper(segments[0]) == "IKM":
        ikm = segments[1]
    case strings.ToUpper(segments[0]) == "OKM":
        okm = segments[1]
    }
    return verifier(l, unhexlify(ikm), unhexlify(okm))
}

func main() {
    if validateVectors("vectors/cryptography_vectors/KDF/hkdf-generated.txt") {
        fmt.Println("HKDF OK.")
    } else {
        fmt.Println("HKDF failed.")
        os.Exit(1)
    }
}

Download link: verify_hkdf.go

If official test vectors appear in the future the custom generated vectors should be discarded.

Any vectors generated by this method must also be prefixed with the following header format (substituting the correct information):

```
# CAST5 CBC vectors built for https://github.com/pyca/cryptography
# Derived from the AESVS MMT test data for CBC
# Verified against the CommonCrypto and Go crypto packages
# Key Length : 128
```

### 2.9.5 C bindings

C bindings are bindings to C libraries, using cffi whenever possible.

Bindings live in cryptography.hazmat.bindings.

When modifying the bindings you will need to recompile the C extensions to test the changes. This can be accomplished with `pip install -e` in the project root. If you do not do this a `RuntimeError` will be raised.
Style guide

Don’t name parameters:

```c
/* Good */
long f(long);
/* Bad */
long f(long x);
```

…unless they’re inside a struct:

```c
struct my_struct {
    char *name;
    int number;
    ...
};
```

Include `void` if the function takes no arguments:

```c
/* Good */
long f(void);
/* Bad */
long f();
```

Wrap lines at 80 characters like so:

```c
/* Pretend this went to 80 characters */
long f(long, long, int *)
```

Include a space after commas between parameters:

```c
/* Good */
long f(int, char *)
/* Bad */
long f(int,char *)
```

Use C-style `/* */` comments instead of C++-style `//`:

```c
// Bad
/* Good */
```

Values set by `#define` should be assigned the appropriate type. If you see this:

```c
#define SOME_INTEGER_LITERAL 0x0;
#define SOME_UNSIGNED_INTEGER_LITERAL 0x0001U;
#define SOME_STRING_LITERAL "hello";
```

…it should be added to the bindings like so:

```c
static const int SOME_INTEGER_LITERAL;
static const unsigned int SOME_UNSIGNED_INTEGER_LITERAL;
static const char *const SOME_STRING_LITERAL;
```
Adding constant, types, functions...

You can create bindings for any name that exists in some version of the library you’re binding against. However, the project also has to keep supporting older versions of the library. In order to achieve this, binding modules have a CUSTOMIZATIONS constant, and there is a CONDITIONAL_NAMES constants in src/cryptography/hazmat/bindings/openssl/_conditional.py.

Let’s say you want to enable quantum transmogrification. The upstream library implements this as the following API:

```c
static const int QM_TRANSMOGRIFICATION_ALIGNMENT_LEFT;
static const int QM_TRANSMOGRIFICATION_ALIGNMENT_RIGHT;
typedef ... QM_TRANSMOGRIFICATION_CTX;
int QM_transmogrify(QM_TRANSMOGRIFICATION_CTX *, int);
```

To start, create a new constant that defines if the actual library has the feature you want, and add it to TYPES:

```c
static const long Cryptography_HAS_QUANTUM_TRANSMOGRIFICATION;
```

This should start with Cryptography_, since we’re adding it in this library. This prevents namespace collisions.

Then, define the actual features (constants, types, functions…) you want to expose. If it’s a constant, just add it to TYPES:

```c
static const int QM_TRANSMOGRIFICATION_ALIGNMENT_LEFT;
static const int QM_TRANSMOGRIFICATION_ALIGNMENT_RIGHT;
```

If it’s a struct, add it to TYPES as well. The following is an opaque struct:

```c
typedef ... QM_TRANSMOGRIFICATION_CTX;
```

… but you can also make some or all items in the struct accessible:

```c
typedef struct {
    /* Fundamental constant k for your particular universe */
    BIGNUM *k;
    ...
} QM_TRANSMOGRIFICATION_CTX;
```

For functions just add the signature to FUNCTIONS:

```c
int QM_transmogrify(QM_TRANSMOGRIFICATION_CTX *, int);
```

Then, we define the CUSTOMIZATIONS entry. To do that, we have to come up with a C preprocessor expression that decides whether or not a feature exists in the library. For example:

```c
#ifdef QM_transmogrify
static const long Cryptography_HAS_QUANTUM_TRANSMOGRIFICATION = 1;
#else
static const long Cryptography_HAS_QUANTUM_TRANSMOGRIFICATION = 0;
```

Then, in that #else block, we define the names that aren’t available as dummy values. For an integer constant, use 0:
static const int QM_TRANSMOGRIFICATION_ALIGNMENT_LEFT = 0;
static const int QM_TRANSMOGRIFICATION_ALIGNMENT_RIGHT = 0;

For a function, it's a bit trickier. You have to define a function pointer of the appropriate type to be NULL:

```c
int (*QM_transmogrify)(QM_TRANSMOGRIFICATION_CTX *, int) = NULL;
```

(To do that, copy the signature, put a `*` in front of the function name and wrap it in parentheses, and then put `= NULL` at the end).

Note how types don’t need to be conditionally defined, as long as all the necessarily type definitions are in place.

Finally, add an entry to `CONDITIONAL_NAMES` with all of the things you want to conditionally export:

```python
def cryptography_has_quantum_transmogrification():
    return [
        "QM_TRANSMOGRIFICATION_ALIGNMENT_LEFT",
        "QM_TRANSMOGRIFICATION_ALIGNMENT_RIGHT",
        "QM_transmogrify",
    ]
```

`CONDITIONAL_NAMES = {
...
"Cryptography_HAS_QUANTUM_TRANSMOGRIFICATION": (cryptography_has_quantum_transmogrification),
}
```

Caveats

Sometimes, a set of loosely related features are added in the same version, and it’s impractical to create `#ifdef` statements for each one. In that case, it may make sense to either check for a particular version. For example, to check for OpenSSL 1.1.1 or newer:

```c
#if CRYPTOGRAPHY_OPENSSL_111_OR_GREATER
```

Sometimes, the version of a library on a particular platform will have features that you thought it wouldn’t, based on its version. Occasionally, packagers appear to ship arbitrary VCS checkouts. As a result, sometimes you may have to add separate `#ifdef` statements for particular features. This kind of issue is typically only caught by running the tests on a wide variety of systems, which is the job of our continuous integration infrastructure.

2.10 Use of OpenSSL

cryptography depends on the OpenSSL C library for all cryptographic operation. OpenSSL is the de facto standard for cryptographic libraries and provides high performance along with various certifications that may be relevant to developers.

A list of supported versions can be found in our Installation documentation.

In general the backend should be considered an internal implementation detail of the project, but there are some public methods available for debugging purposes.
cryptography.hazmat.backends.openssl.backend

openssl_version_text()

Return text
The friendly string name of the loaded OpenSSL library. This is not necessarily the same version as it was compiled against.

openssl_version_number()

New in version 1.8.

Return int
The integer version of the loaded OpenSSL library. This is defined in opensslv.h as OPENSSL_VERSION_NUMBER and is typically shown in hexadecimal (e.g. 0x1010003f). This is not necessarily the same version as it was compiled against.

2.10.1 Legacy provider in OpenSSL 3.x

New in version 39.0.0.

Users can set CRYPTOGRAPHY_OPENSSL_NO_LEGACY environment variable to disable the legacy provider in OpenSSL 3.x. This will disable legacy cryptographic algorithms, including Blowfish, CAST5, SEED, ARC4, and RC2 (which is used by some encrypted serialization formats).

2.11 Security

We take the security of cryptography seriously. The following are a set of policies we have adopted to ensure that security issues are addressed in a timely fashion.

2.11.1 Known vulnerabilities

A list of all known vulnerabilities in cryptography can be found on osv.dev, as well as other ecosystem vulnerability databases. They can automatically be scanned for using tools such as pip-audit or osv-scan.

2.11.2 Infrastructure

In addition to cryptography’s code, we’re also concerned with the security of the infrastructure we run (primarily cryptography.io). If you discover a security vulnerability in our infrastructure, we ask you to report it using the same procedure.

2.11.3 What is a security issue?

Anytime it’s possible to write code using cryptography’s public API which does not provide the guarantees that a reasonable developer would expect it to based on our documentation.

That’s a bit academic, but basically it means the scope of what we consider a vulnerability is broad, and we do not require a proof of concept or even a specific exploit, merely a reasonable threat model under which cryptography could be attacked.

To give a few examples of things we would consider security issues:
• If a recipe, such as Fernet, made it easy for a user to bypass confidentiality or integrity with the public API (e.g. if the API let a user reuse nonces).
• If, under any circumstances, we used a CSPRNG which wasn’t fork-safe.
• If cryptography used an API in an underlying C library and failed to handle error conditions safely.

Examples of things we wouldn’t consider security issues:

• Offering ECB mode for symmetric encryption in the Hazmat layer. Though ECB is critically weak, it is documented as being weak in our documentation.
• Using a variable time comparison somewhere, if it’s not possible to articulate any particular program in which this would result in problematic information disclosure.

In general, if you’re unsure, we request that you to default to treating things as security issues and handling them sensitively, the worst thing that can happen is that we’ll ask you to file a public issue.

### 2.11.4 Reporting a security issue

We ask that you do not report security issues to our normal GitHub issue tracker.

If you believe you’ve identified a security issue with cryptography, please report it via our security advisory page. Once you’ve submitted an issue, you should receive an acknowledgment within 48 hours, and depending on the action to be taken, you may receive further follow-up.

### 2.11.5 Supported Versions

At any given time, we will provide security support for the main branch as well as the most recent release.

### 2.11.6 New releases for OpenSSL updates

As of versions 0.5, 1.0.1, and 2.0.0, cryptography statically links OpenSSL in binary distributions for Windows, macOS, and Linux respectively, to ease installation. Due to this, cryptography will release a new version whenever OpenSSL has a security or bug fix release to avoid shipping insecure software.

Like all our other releases, this will be announced on the mailing list and we strongly recommend that you upgrade as soon as possible.

### 2.11.7 Disclosure Process

When we become aware of a security bug in cryptography, we will endeavor to fix it and issue a release as quickly as possible. We will generally issue a new release for any security issue.

The steps for issuing a security release are described in our Doing a release documentation.
2.12 Known security limitations

2.12.1 Secure memory wiping

Memory wiping is used to protect secret data or key material from attackers with access to deallocated memory. This is a defense-in-depth measure against vulnerabilities that leak application memory.

Many `cryptography` APIs which accept `bytes` also accept types which implement the buffer interface. Thus, users wishing to do so can pass `memoryview` or another mutable type to `cryptography` APIs, and overwrite the contents once the data is no longer needed.

However, `cryptography` does not clear memory by default, as there is no way to clear immutable structures such as `bytes`. As a result, `cryptography`, like almost all software in Python is potentially vulnerable to this attack. The CERT secure coding guidelines assesses this issue as “Severity: medium, Likelihood: unlikely, Remediation Cost: expensive to repair” and we do not consider this a high risk for most users.

2.12.2 RSA PKCS1 v1.5 constant time decryption

RSA decryption has several different modes, one of which is PKCS1 v1.5. When used in online contexts, a secure protocol implementation requires that peers not be able to tell whether RSA PKCS1 v1.5 decryption failed or succeeded, even by timing variability.

`cryptography` does not provide an API that makes this possible, due to the fact that RSA decryption raises an exception on failure, which takes a different amount of time than returning a value in the success case.

Fixing this would require a new API in `cryptography`, but OpenSSL does not expose an API for straightforwardly implementing this while reusing its own constant-time logic. See issue 6167 for more information.

For this reason we recommend not implementing online protocols that use RSA PKCS1 v1.5 decryption with `cryptography` – independent of this limitation, such protocols generally have poor security properties due to their lack of forward security.

2.13 API stability

From its first release, `cryptography` has had a strong API stability policy.

2.13.1 What does this policy cover?

This policy includes any API or behavior that is documented in this documentation.

2.13.2 What does “stable” mean?

- Public APIs will not be removed or renamed without providing a compatibility alias.
- The behavior of existing APIs will not change.
2.13.3 What doesn't this policy cover?

- We may add new features, things like the result of `dir(obj)` or the contents of `obj.__dict__` may change.
- Objects are not guaranteed to be pickleable, and pickled objects from one version of `cryptography` may not be loadable in future versions.
- Unless otherwise documented, types in `cryptography` are not intended to be sub-classed, and we do not guarantee that behavior with respect to sub-classes will be stable.
- Development versions of `cryptography`. Before a feature is in a release, it is not covered by this policy and may change.

Security

One exception to our API stability policy is for security. We will violate this policy as necessary in order to resolve a security issue or harden `cryptography` against a possible attack.

2.13.4 Versioning

Version 35.0.0+

Beginning with release 35.0.0 `cryptography` uses a Firefox-inspired version scheme.

Given a version `cryptography X.Y.Z`,

- X indicates the major version number. This is incremented on any feature release.
- Y is always 0.
- Z is an integer that is incremented for minor backward-compatible releases (such as fixing security issues or correcting regressions in a major release).

This scheme is compatible with SemVer, though many major releases will not include any backwards-incompatible changes.

Deprecation

From time to time we will want to change the behavior of an API or remove it entirely. In that case, here’s how the process will work:

- In `cryptography X.0.0` the feature exists.
- In `cryptography (X + 1).0.0` using that feature will emit a `CryptographyDeprecationWarning` (base class `UserWarning`).
- In `cryptography (X + 2).0.0` using that feature will emit a `CryptographyDeprecationWarning`.
- In `cryptography (X + 3).0.0` the feature will be removed or changed.

In short, code that runs without warnings will always continue to work for a period of two major releases.

From time to time, we may decide to deprecate an API that is particularly widely used. In these cases, we may decide to provide an extended deprecation period, at our discretion.
Previous Scheme

Before version 35.0.0 this project uses a custom versioning scheme as described below.

Given a version cryptography X.Y.Z,

- X.Y is a decimal number that is incremented for potentially-backwards-incompatible releases.
  - This increases like a standard decimal. In other words, 0.9 is the ninth release, and 1.0 is the tenth (not 0.10). The dividing decimal point can effectively be ignored.
- Z is an integer that is incremented for backward-compatible releases.

2.14 Doing a release

Doing a release of cryptography requires a few steps.

2.14.1 Security Releases

In addition to the other steps described below, for a release which fixes a security vulnerability, you should also include the following steps:

- Request a CVE from MITRE. Once you have received the CVE, it should be included in the Changelog. Ideally you should request the CVE before starting the release process so that the CVE is available at the time of the release.
- Document the CVE in the git commit that fixes the issue.
- Ensure that the Changelog entry credits whoever reported the issue and contains the assigned CVE.
- Publish a GitHub Security Advisory on the repository with all relevant information.
- The release should be announced on the oss-security mailing list, in addition to the regular announcement lists.

2.14.2 Verifying OpenSSL version

The release process creates wheels bundling OpenSSL for Windows, macOS, and Linux. Check that the Windows, macOS, and Linux builders (the manylinux containers) have the latest OpenSSL. If anything is out of date follow the instructions for upgrading OpenSSL.

2.14.3 Upgrading OpenSSL

Use the upgrading OpenSSL issue template.
2.14.4 Bumping the version number

The next step in doing a release is bumping the version number in the software.

- Run `python release.py bump-version {new_version}`
- Set the release date in the *Changelog*.
- Do a commit indicating this.
- Send a pull request with this.
- Wait for it to be merged.

2.14.5 Performing the release

The commit that merged the version number bump is now the official release commit for this release. You will need to have `git` configured to perform signed tags. Once this has happened:

- Run `python release.py release`.

The release should now be available on PyPI and a tag should be available in the repository.

2.14.6 Verifying the release

You should verify that `pip install cryptography` works correctly:

```python
>>> import cryptography
>>> cryptography.__version__
'...
>>> import cryptography_vectors
>>> cryptography_vectors.__version__
'...
```

Verify that this is the version you just released.

For the Windows wheels check the builds for the `cryptography-wheel-builder` job and verify that the final output for each build shows it loaded and linked the expected OpenSSL version.

2.14.7 Post-release tasks

- Send an email to the mailing list and `python-announce` announcing the release.
- Close the milestone for the previous release on GitHub.
- For major version releases, send a pull request to `pyOpenSSL` increasing the maximum `cryptography` version pin and perform a `pyOpenSSL` release.
- Update the version number to the next major (e.g. `0.5.dev1`) with `python release.py bump-version {new_version}`.
- Add new *Changelog* entry with next version and note that it is under active development
- Send a pull request with these items
- Check for any outstanding code undergoing a deprecation cycle by looking in `cryptography.utils` for `DeprecatedIn**` definitions. If any exist open a ticket to increment them for the next release.
2.15 Community

You can find cryptography all over the web:

- Mailing list
- Source code
- Issue tracker
- Documentation
- IRC: #pyca on irc.libera.chat

Wherever we interact, we adhere to the Python Community Code of Conduct.

2.16 Glossary

A-label
The ASCII compatible encoded (ACE) representation of an internationalized (unicode) domain name. A-labels begin with the prefix xn--. To create an A-label from a unicode domain string use a library like idna.

authentication
The process of verifying that a message was created by a specific individual (or program). Like encryption, authentication can be either symmetric or asymmetric. Authentication is necessary for effective encryption.

bits
A bit is binary value – a value that has only two possible states. Typically binary values are represented visually as 0 or 1, but remember that their actual value is not a printable character. A byte on modern computers is 8 bits and represents 256 possible values. In cryptographic applications when you see something say it requires a 128 bit key, you can calculate the number of bytes by dividing by 8. 128 divided by 8 is 16, so a 128 bit key is a 16 byte key.

bytes-like
A bytes-like object contains binary data and supports the buffer protocol. This includes bytes, bytearray, and memoryview objects. It is unsafe to pass a mutable object (e.g., a bytearray or other implementor of the buffer protocol) and to mutate it concurrently with the operation it has been provided for.

ciphertext
The encoded data, it’s not user readable. Potential attackers are able to see this.

ciphertext indistinguishability
This is a property of encryption systems whereby two encrypted messages aren’t distinguishable without knowing the encryption key. This is considered a basic, necessary property for a working encryption system.

decryption
The process of converting ciphertext to plaintext.

encryption
The process of converting plaintext to ciphertext.

key
Secret data is encoded with a function using this key. Sometimes multiple keys are used. These must be kept secret, if a key is exposed to an attacker, any data encrypted with it will be exposed.

nonce
A nonce is a number used once. Nonces are used in many cryptographic protocols. Generally, a nonce does not have to be secret or unpredictable, but it must be unique. A nonce is often a random or pseudo-random number
(see Random number generation). Since a nonce does not have to be unpredictable, it can also take a form of a counter.

**opaque key**
An opaque key is a type of key that allows you to perform cryptographic operations such as encryption, decryption, signing, and verification, but does not allow access to the key itself. Typically an opaque key is loaded from a hardware security module (HSM).

**plaintext**
User-readable data you care about.

**private key**
This is one of two keys involved in public-key cryptography. It can be used to decrypt messages which were encrypted with the corresponding public key, as well as to create signatures, which can be verified with the corresponding public key. These must be kept secret, if they are exposed, all encrypted messages are compromised, and an attacker will be able to forge signatures.

**public key**
This is one of two keys involved in public-key cryptography. It can be used to encrypt messages for someone possessing the corresponding private key and to verify signatures created with the corresponding private key. This can be distributed publicly, hence the name.

**public-key cryptography**

**asymmetric cryptography**
Cryptographic operations where encryption and decryption use different keys. There are separate encryption and decryption keys. Typically encryption is performed using a public key, and it can then be decrypted using a private key. Asymmetric cryptography can also be used to create signatures, which can be generated with a private key and verified with a public key.

**symmetric cryptography**
Cryptographic operations where encryption and decryption use the same key.

**U-label**
The presentational unicode form of an internationalized domain name. U-labels use unicode characters outside the ASCII range and are encoded as A-labels when stored in certificates.

**unsafe**
This is a term used to describe an operation where the user must ensure that the input is correct. Failure to do so can result in crashes, hangs, and other security issues.

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**Note:** cryptography has not been subjected to an external audit of its code or documentation. If you’re interested in discussing an audit please get in touch.
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