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Internet X.509 Public Key Infrastructure -- Algorithm Identifiers for the Module-Lattice-Based Digital Signature Algorithm (ML-DSA)

Abstract

Digital signatures are used within X.509 certificates and Certificate Revocation Lists (CRLs), and to sign messages. This document specifies the conventions for using FIPS 204, the Module-Lattice-Based Digital Signature Algorithm (ML-DSA) in Internet X.509 certificates and CRLs. The conventions for the associated signatures, subject public keys, and private key are also described.

Status of This Memo

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Table of Contents

1. Introduction	3
1.1. Requirements Language	3
2. Identifiers	3
3. ML-DSA Signatures in PKIX	4
4. ML-DSA Public Keys in PKIX	6
5. Key Usage Bits	7
6. Private Key Format	8
7. IANA Considerations	11
8. Operational Considerations	11
8.1. Private Key Format	11
8.2. Private Key Consistency Testing	12
8.3. Rationale for Disallowing HashML-DSA	12
9. Security Considerations	13
10. References	14
10.1. Normative References	14
10.2. Informative References	14
Appendix A. ASN.1 Module	15
Appendix B. Security Strengths	18
Appendix C. Examples	18
C.1. Example Private Keys	19
C.1.1. ML-DSA-44 Private Key Examples	19
C.1.2. ML-DSA-65 Private Key Examples	27
C.1.3. ML-DSA-87 Private Key Examples	40
C.2. Example Public Keys	53
C.3. Example Certificates	61
C.4. Example Inconsistent Seed and Expanded Private Keys	83

Appendix D. Pre-Hashing (Externalμ-ML-DSA)	89
Acknowledgments	91
Authors' Addresses	91

1. Introduction

The Module-Lattice-Based Digital Signature Algorithm (ML-DSA) is a quantum-resistant digital signature scheme standardized by the US National Institute of Standards and Technology (NIST) PQC project [NIST-PQC] in [FIPS204]. This document specifies the use of the ML-DSA in Public Key Infrastructure X.509 (PKIX) certificates and Certificate Revocation Lists (CRLs) at three security levels: ML-DSA-44, ML-DSA-65, and ML-DSA-87.

[FIPS204] defines two variants of ML-DSA: pure and pre-hash. Only the former is specified in this document. See [Section 8.3](#) for the rationale. The pure variant of ML-DSA supports the typical pre-hash flow. Refer to [Appendix D](#) for more details.

Prior to standardization, ML-DSA was known as Dilithium. ML-DSA and Dilithium are not compatible.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Identifiers

The `AlgorithmIdentifier` type is defined in [RFC5912] as follows:

```
AlgorithmIdentifier{ALGORITHM-TYPE, ALGORITHM-TYPE:AlgorithmSet} ::=
  SEQUENCE {
    algorithm  ALGORITHM-TYPE.&id({AlgorithmSet}),
    parameters ALGORITHM-TYPE.
               &Params({AlgorithmSet}{@algorithm}) OPTIONAL
  }
```

NOTE: The above syntax is from [RFC5912] and is compatible with the 2021 ASN.1 syntax [X680]. See [RFC5280] for the 1988 ASN.1 syntax.

The fields in `AlgorithmIdentifier` have the following meanings:

- `algorithm` identifies the cryptographic algorithm with an object identifier (OID).

- parameters, which are optional, are the associated parameters for the algorithm identifier in the algorithm field.

The NIST-registered OIDs [[CSOR](#)] are:

```
id-ml-dsa-44 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
  country(16) us(840) organization(1) gov(101) csor(3)
  nistAlgorithm(4) sigAlgs(3) id-ml-dsa-44(17) }

id-ml-dsa-65 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
  country(16) us(840) organization(1) gov(101) csor(3)
  nistAlgorithm(4) sigAlgs(3) id-ml-dsa-65(18) }

id-ml-dsa-87 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
  country(16) us(840) organization(1) gov(101) csor(3)
  nistAlgorithm(4) sigAlgs(3) id-ml-dsa-87(19) }
```

The contents of the parameters component for each algorithm **MUST** be absent.

3. ML-DSA Signatures in PKIX

ML-DSA is a digital signature scheme built upon the Fiat-Shamir-with-aborts framework [[Fiat-Shamir](#)]. The security is based upon the hardness of lattice problems over module lattices [[Dilithium](#)]. ML-DSA provides three parameter sets for the NIST PQC security categories 2, 3, and 5.

Signatures are used in a number of different ASN.1 structures. As shown in the ASN.1 equivalent to that in [[RFC5280](#)] below, in an X.509 certificate, a signature is encoded with an algorithm identifier in the signatureAlgorithm attribute and a signatureValue attribute that contains the actual signature.

```
Certificate ::= SIGNED{ TBSCertificate }

SIGNED{ToBeSigned} ::= SEQUENCE {
  toBeSigned          ToBeSigned,
  algorithmIdentifier SEQUENCE {
    algorithm          SIGNATURE-ALGORITHM.
                      &id({SignatureAlgorithms}),
    parameters        SIGNATURE-ALGORITHM.
                      &Params({SignatureAlgorithms}
                              {@algorithmIdentifier.algorithm})
                      OPTIONAL
  },
  signature BIT STRING (CONTAINING SIGNATURE-ALGORITHM.&Value(
                              {SignatureAlgorithms}
                              {@algorithmIdentifier.algorithm}))
}
```

Signatures are also used in the CRL list ASN.1; the representation below is equivalent to that in [RFC5280]. In an X.509 CRL, a signature is encoded with an algorithm identifier in the `signatureAlgorithm` attribute and a `signatureValue` attribute that contains the actual signature.

```
CertificateList ::= SIGNED{ TBSCertList }
```

The following SIGNATURE-ALGORITHM ASN.1 classes are for ML-DSA-44, ML-DSA-65, and ML-DSA-87:

```
sa-ml-dsa-44 SIGNATURE-ALGORITHM ::= {  
  IDENTIFIER id-ml-dsa-44  
  PARAMS ARE absent  
  PUBLIC-KEYS { pk-ml-dsa-44 }  
  SMIME-CAPS { IDENTIFIED BY id-ml-dsa-44 }  
}  
  
sa-ml-dsa-65 SIGNATURE-ALGORITHM ::= {  
  IDENTIFIER id-ml-dsa-65  
  PARAMS ARE absent  
  PUBLIC-KEYS { pk-ml-dsa-65 }  
  SMIME-CAPS { IDENTIFIED BY id-ml-dsa-65 }  
}  
  
sa-ml-dsa-87 SIGNATURE-ALGORITHM ::= {  
  IDENTIFIER id-ml-dsa-87  
  PARAMS ARE absent  
  PUBLIC-KEYS { pk-ml-dsa-87 }  
  SMIME-CAPS { IDENTIFIED BY id-ml-dsa-87 }  
}
```

NOTE: The above syntax is from [RFC5912] and is compatible with the 2021 ASN.1 syntax [X680].

The identifiers defined in Section 2 can be used as the `AlgorithmIdentifier` in the `signatureAlgorithm` field in the sequence `Certificate/CertificateList` and in the `signature` field in the sequence `TBSCertificate/TBSCertList` in certificates and CRLs, respectively, [RFC5280]. The parameters of these signature algorithms **MUST** be absent, as explained in Section 2. That is, the `AlgorithmIdentifier` **SHALL** be a SEQUENCE of one component, the OID `id-ml-dsa-*`, where `*` is 44, 65, or 87 -- see Section 2.

The `signatureValue` field contains the corresponding ML-DSA signature computed upon the ASN.1 DER-encoded `TBSCertificate/TBSCertList` [RFC5280]. The optional context string (`ctx`) parameter as defined in Section 5.2 of [FIPS204] is left to its default value: the empty string.

Conforming Certification Authority (CA) implementations **MUST** specify the algorithms explicitly by using the OIDs specified in [Section 2](#) when encoding ML-DSA signatures in certificates and CRLs. Conforming client implementations that process certificates and CRLs using ML-DSA **MUST** recognize the corresponding OIDs. Encoding rules for ML-DSA signature values are specified in [Section 2](#).

4. ML-DSA Public Keys in PKIX

In the X.509 certificate, the `subjectPublicKeyInfo` field has the `SubjectPublicKeyInfo` type, which has the following ASN.1 syntax:

```
SubjectPublicKeyInfo {PUBLIC-KEY: IOSet} ::= SEQUENCE {
  algorithm      AlgorithmIdentifier {PUBLIC-KEY, {IOSet}},
  subjectPublicKey BIT STRING
}
```

NOTE: The above syntax is from [\[RFC5912\]](#) and is compatible with the 2021 ASN.1 syntax [\[X680\]](#). See [\[RFC5280\]](#) for the 1988 ASN.1 syntax.

The fields in `SubjectPublicKeyInfo` have the following meaning:

- `algorithm` is the algorithm identifier and parameters for the public key (see above).
- `subjectPublicKey` contains the public key.

Algorithm 22 in Section 7.2 of [\[FIPS204\]](#) defines the raw byte string encoding of an ML-DSA public key. When used in a `SubjectPublicKeyInfo` type, the `subjectPublicKey BIT STRING` contains this raw byte string encoding of the public key. When an ML-DSA public key appears outside of a `SubjectPublicKeyInfo` type in an environment that uses ASN.1 encoding, it could be encoded as an `OCTET STRING` by using the `ML-DSA-44-PublicKey`, `ML-DSA-65-PublicKey`, and `ML-DSA-87-PublicKey` types corresponding to the correct key size defined below.

The PUBLIC-KEY ASN.1 types for ML-DSA are defined here:

```
pk-ml-dsa-44 PUBLIC-KEY ::= {
  IDENTIFIER id-ml-dsa-44
  -- KEY no ASN.1 wrapping --
  CERT-KEY-USAGE
  { digitalSignature, nonRepudiation, keyCertSign, cRLSign }
  PRIVATE-KEY ML-DSA-44-PrivateKey } -- defined in Section 6

pk-ml-dsa-65 PUBLIC-KEY ::= {
  IDENTIFIER id-ml-dsa-65
  -- KEY no ASN.1 wrapping --
  CERT-KEY-USAGE
  { digitalSignature, nonRepudiation, keyCertSign, cRLSign }
  PRIVATE-KEY ML-DSA-65-PrivateKey } -- defined in Section 6

pk-ml-dsa-87 PUBLIC-KEY ::= {
  IDENTIFIER id-ml-dsa-87
  -- KEY no ASN.1 wrapping --
  CERT-KEY-USAGE
  { digitalSignature, nonRepudiation, keyCertSign, cRLSign }
  PRIVATE-KEY ML-DSA-87-PrivateKey } -- defined in Section 6

ML-DSA-44-PublicKey ::= OCTET STRING (SIZE (1312))

ML-DSA-65-PublicKey ::= OCTET STRING (SIZE (1952))

ML-DSA-87-PublicKey ::= OCTET STRING (SIZE (2592))
```

NOTE: The above syntax is from [\[RFC5912\]](#) and is compatible with the 2021 ASN.1 syntax [\[X680\]](#).

[\[RFC5958\]](#) specifies the Asymmetric Key Package's `OneAsymmetricKey` type for encoding asymmetric keypairs. When an ML-DSA private key or keypair is encoded as a `OneAsymmetricKey`, it follows the description in [Section 6](#).

When the ML-DSA private key appears outside of an Asymmetric Key Package in an environment that uses ASN.1 encoding, it can be encoded using one of the `ML-DSA-PrivateKey CHOICE` formats defined in [Section 6](#). The seed format is **RECOMMENDED** as it efficiently stores both the private and public key.

[Appendix C](#) contains example ML-DSA public keys encoded using the textual encoding defined in [\[RFC7468\]](#).

5. Key Usage Bits

The intended application for the key is indicated in the `keyUsage` certificate extension; see [Section 4.2.1.3](#) of [\[RFC5280\]](#). If the `keyUsage` extension is present in a certificate that includes `id-ml-dsa-*` (where `*` is 44, 65, or 87 -- see [Section 2](#)) in the `SubjectPublicKeyInfo`, then the subject public key can only be used for verifying digital signatures on certificates or CRLs, or those used in an entity authentication service, a data origin authentication service, an integrity

service, and/or a non-repudiation service that protects against the signing entity falsely denying some action. This means that the `keyUsage` extension **MUST** have at least one of the following bits set:

- `digitalSignature`
- `nonRepudiation`
- `keyCertSign`
- `cRLSign`

ML-DSA subject public keys cannot be used to establish keys or encrypt data, so the `keyUsage` extension **MUST NOT** have any of the following bits set:

- `keyEncipherment`
- `dataEncipherment`
- `keyAgreement`
- `encipherOnly`
- `decipherOnly`

Requirements about the `keyUsage` extension bits defined in [\[RFC5280\]](#) still apply.

6. Private Key Format

[\[FIPS204\]](#) specifies two formats for an ML-DSA private key: a 32-octet seed (ξ) (GREEK SMALL LETTER XI, U+03BE) and an (expanded) private key. The expanded private key (and public key) is computed from the seed using `ML-DSA.KeyGen_internal(ξ)` (algorithm 6).

"Asymmetric Key Packages" [\[RFC5958\]](#) specifies how to encode a private key in a structure that both identifies what algorithm the private key is for and allows for the public key and additional attributes about the key to be included as well. For illustration, the ASN.1 structure `OneAsymmetricKey` is replicated below.


```
OneAsymmetricKey ::= SEQUENCE {
  version          Version,
  privateKeyAlgorithm SEQUENCE {
    algorithm      PUBLIC-KEY.&id({PublicKeySet}),
    parameters     PUBLIC-KEY.&Params({PublicKeySet}
                          {@privateKeyAlgorithm.algorithm})
                          OPTIONAL}
  privateKey       OCTET STRING (CONTAINING
    PUBLIC-KEY.&PrivateKey({PublicKeySet}
                          {@privateKeyAlgorithm.algorithm})),
  attributes       [0] Attributes OPTIONAL,
  ...
  [[2: publicKey   [1] BIT STRING (CONTAINING
    PUBLIC-KEY.&Params({PublicKeySet}
                      {@privateKeyAlgorithm.algorithm})
    OPTIONAL ]],
  ...
}
```

NOTE: The above syntax is from [RFC5958](#) and is compatible with the 2021 ASN.1 syntax [X680](#).

For ML-DSA private keys, the `privateKey` field in `OneAsymmetricKey` contains one of the following DER-encoded CHOICE structures. The seed format is a fixed 32-byte OCTET STRING (34 bytes total with the 0x8020 tag and length) for all security levels, while the expandedKey and both formats vary in size by security level:

```
ML-DSA-44-PrivateKey ::= CHOICE {
  seed [0] OCTET STRING (SIZE (32)),
  expandedKey OCTET STRING (SIZE (2560)),
  both SEQUENCE {
    seed OCTET STRING (SIZE (32)),
    expandedKey OCTET STRING (SIZE (2560))
  }
}

ML-DSA-65-PrivateKey ::= CHOICE {
  seed [0] OCTET STRING (SIZE (32)),
  expandedKey OCTET STRING (SIZE (4032)),
  both SEQUENCE {
    seed OCTET STRING (SIZE (32)),
    expandedKey OCTET STRING (SIZE (4032))
  }
}

ML-DSA-87-PrivateKey ::= CHOICE {
  seed [0] OCTET STRING (SIZE (32)),
  expandedKey OCTET STRING (SIZE (4896)),
  both SEQUENCE {
    seed OCTET STRING (SIZE (32)),
    expandedKey OCTET STRING (SIZE (4896))
  }
}
```

NOTE: The above syntax is from [\[RFC5912\]](#) and is compatible with the 2021 ASN.1 syntax [\[X680\]](#).

The CHOICE allows three representations of the private key:

1. The seed format (tag [0]) contains just the 32-byte seed value (ξ) from which both the expanded private key and public key can be derived using `ML-DSA.KeyGen_internal(ξ)`.
2. The expandedKey format contains the expanded private key that was derived from the seed.
3. The both format contains both the seed and expanded private key, allowing for interoperability; some may want to use and retain the seed and others may only support expanded private keys.

When encoding an ML-DSA private key in a `OneAsymmetricKey` object, any of these three formats may be used, though the seed format is **RECOMMENDED** for storage efficiency.

The `privateKeyAlgorithm` field uses the `AlgorithmIdentifier` structure with the appropriate OID as defined in [Section 2](#). If present, the `publicKey` field will hold the encoded public key as defined in [Section 4](#).

NOTE: While the private key can be stored in multiple formats, the seed-only format is **RECOMMENDED** as it is the most compact representation. Both the expanded private key and the public key can be deterministically derived from the seed using `ML-DSA.KeyGen_internal(ξ)`. Alternatively, the public key can be generated from

the private key. While the `publicKey` field and `expandedKey` format are technically redundant when using the seed-only format, they **MAY** be included to enable keypair consistency checks during import operations.

When parsing the private key, the ASN.1 tag explicitly indicates which variant of CHOICE is present. Implementations should use the context-specific tag IMPLICIT [0] (raw value 0x80) for seed, OCTET STRING (0x04) for `expandedKey`, and SEQUENCE (0x30) for both to parse the private key, rather than any other heuristic like length of the enclosing OCTET STRING.

[Appendix C](#) contains example ML-DSA private keys encoded using the textual encoding defined in [\[RFC7468\]](#).

7. IANA Considerations

For the ASN.1 module in [Appendix A](#), IANA has assigned the following object identifier (OID) in the "SMI Security for PKIX Module Identifier" registry (1.3.6.1.5.5.7.0):

Decimal	Description	Reference
119	id-mod-x509-ml-dsa-2025	RFC 9881

Table 1: Registered ASN.1 Module

8. Operational Considerations

8.1. Private Key Format

An `ML-DSA.KeyGen seed` (ξ) represents the **RECOMMENDED** format for storing and transmitting ML-DSA private keys. This format is explicitly permitted by [\[FIPS204\]](#) as an acceptable representation of a keypair. In particular, generating the seed in one cryptographic module and then importing or exporting it into another cryptographic module is allowed. The internal key-generation function `ML-DSA.KeyGen_internal`(ξ) can be accessed for this purpose.

Note also that unlike other private key compression methods in other algorithms, expanding a private key from a seed is a one-way function, meaning that once a full key is expanded from seed and the seed discarded, the seed cannot be recreated, even if the full expanded private key is available. For this reason, it is **RECOMMENDED** that implementations retain and export the seed, even when also exporting the expanded private key. ML-DSA seed extraction can be implemented by including the seed ξ that is randomly generated at line 1 of Algorithm 1 `ML-DSA.KeyGen` in the returned output.

When encoding an ML-DSA private key in a `OneAsymmetricKey` object, any of these three formats may be used, though the seed format is **RECOMMENDED** for storage efficiency.

8.2. Private Key Consistency Testing

When receiving a private key that contains both the `seed` and the `expandedKey`, the recipient **SHOULD** perform a seed consistency check to ensure that the sender properly generated the private key. Recipients that do not perform this seed consistency check avoid keygen and compare operations, but are unable to ensure that the `seed` and `expandedKey` match.

If the check is done and the `seed` and the `expandedKey` are not consistent, the recipient **MUST** reject the private key as malformed.

The seed consistency check consists of regenerating the expanded form from the `seed` via `ML-DSA.KeyGen_internal`, and ensuring it is bitwise equal to the value presented in the private key.

[Appendix C.4](#) includes some examples of inconsistent seeds and expanded private keys.

8.3. Rationale for Disallowing HashML-DSA

The HashML-DSA mode defined in Section 5.4 of [\[FIPS204\]](#) **MUST NOT** be used; in other words, public keys identified by `id-hash-ml-dsa-44-with-sha512`, `id-hash-ml-dsa-65-with-sha512`, and `id-hash-ml-dsa-87-with-sha512` **MUST NOT** be in X.509 certificates used for CRLs, OCSP, certificate issuance, and related PKIX protocols. This restriction is primarily to increase interoperability.

ML-DSA and HashML-DSA are incompatible algorithms that require different `Verify()` routines. This introduces the complexity of informing the verifier whether to use `ML-DSA.Verify()` or `HashML-DSA.Verify()`. Additionally, since the same OIDs are used to identify the ML-DSA public keys and ML-DSA signature algorithms, an implementation would need to commit a given public key to be either of type ML-DSA or HashML-DSA at the time of certificate creation. This is anticipated to cause operational issues in contexts where the operator does not know whether the key will need to produce pure or pre-hashed signatures at key-generation time. The External "μ" (GREEK SMALL LETTER MU, U+03BC) mode described in [Appendix D](#) avoids all of these operational concerns.

A minor security reason for disallowing HashML-DSA is that the design of the ML-DSA algorithm provides enhanced resistance against collision attacks, compared with HashML-DSA or conventional RSA or ECDSA signature algorithms. Specifically, ML-DSA prepends the SHAKE256 hash of the public key (`tr`) to the message to-be-signed prior to hashing, as described in line 6 of Algorithm 7 of [\[FIPS204\]](#). This means that in the unlikely discovery of a collision attack against the SHA-3 family, an attacker would have to perform a public-key-specific collision search in order to find message pairs such that $H(tr || m1) = H(tr || m2)$, because a direct hash collision $H(m1) = H(m2)$ will not suffice. HashML-DSA removes this enhanced security property. In spite of its lack of targeted collision protection, the practical security risk of using HashML-DSA in X.509 signatures would be immaterial. This is because a hash of the issuing CA's public

key is already included in the Authority Key Identifier (AKI) extension, which is signed as part of the `TBSCertificate` structure. Even when it is a SHA-1 hash, general second pre-images against the AKI hash of existing issuing CAs would be impractical.

9. Security Considerations

The Security Considerations section of [\[RFC5280\]](#) applies to this specification as well.

The ML-DSA signature scheme is strongly unforgeable under chosen message attacks (SUF-CMA). For the purpose of estimating security strength, it has been assumed that the attacker has access to signatures for no more than 2^{64} chosen messages.

ML-DSA depends on high quality random numbers that are suitable for use in cryptography. The use of inadequate pseudo-random number generators (PRNGs) to generate such values can significantly undermine various security properties. For instance, using an inadequate PRNG for key generation might allow an attacker to efficiently recover the private key by trying a small set of possibilities, rather than brute-force searching the whole keyspace. The generation of random numbers of a sufficient level of quality for use in cryptography is difficult; see Section 3.6.1 of [\[FIPS204\]](#) for some additional information.

In the design of ML-DSA, care has been taken to make side-channel resilience easier to achieve. For instance, ML-DSA does not depend on Gaussian sampling. Implementations must still take great care not to leak information via various side channels. While deliberate design decisions such as these can help to deliver a secure implementation with greater ease -- particularly against side-channel attacks -- it does not necessarily provide resistance to more powerful attacks such as differential power analysis. Some amount of side-channel leakage has been demonstrated in parts of the signing algorithm (specifically the bit-unpacking function), from which a demonstration of key recovery has been made over a large sample of signatures. Masking countermeasures exist for ML-DSA, but comes with performance overhead.

ML-DSA offers both deterministic and randomized signing. Signatures generated with either mode are compatible and a verifier cannot tell them apart. In the deterministic case, a signature only depends on the private key and the message to be signed. This makes the implementation easier to test and does not require a randomness source during signing. In the randomized case, signing mixes in a 256-bit random string from an approved random bit generator (RBG). When randomized, ML-DSA is easier to harden against fault and hardware side-channel attacks.

A security property that is also associated with digital signatures is non-repudiation. Non-repudiation refers to the assurance that the owner of a signature keypair that was capable of generating an existing signature corresponding to certain data cannot convincingly deny having signed the data, unless its private key was compromised. The digital signature scheme ML-DSA possesses three security properties beyond unforgeability, that are associated with non-repudiation. These are exclusive ownership, message-bound signatures, and non-resignability. These properties are based tightly on the assumed collision resistance of the hash function used (in this case SHAKE-256). A full discussion of these properties in ML-DSA can be found at [\[CDFJ21\]](#).

10. References

10.1. Normative References

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- [FIPS204-ExternalMuFAQ]** NIST, "FIPS 204 Section 6 FAQ", 2025, <<https://csrc.nist.gov/csrc/media/Projects/post-quantum-cryptography/documents/faq/fips204-sec6-03192025.pdf>>.
- [NIST-PQC]** NIST, "Post-Quantum Cryptography (PQC)", 28 July 2025, <<https://csrc.nist.gov/Projects/post-quantum-cryptography>>.
- [RFC3647]** Chokhani, S., Ford, W., Sabett, R., Merrill, C., and S. Wu, "Internet X.509 Public Key Infrastructure Certificate Policy and Certification Practices Framework", RFC 3647, DOI 10.17487/RFC3647, November 2003, <<https://www.rfc-editor.org/info/rfc3647>>.
- [RFC7468]** Josefsson, S. and S. Leonard, "Textual Encodings of PKIX, PKCS, and CMS Structures", RFC 7468, DOI 10.17487/RFC7468, April 2015, <<https://www.rfc-editor.org/info/rfc7468>>.

Appendix A. ASN.1 Module

This appendix includes the ASN.1 module [X680] for the ML-DSA. Note that as per [RFC5280], certificates use the Distinguished Encoding Rules; see [X690]. This module imports objects from [RFC5912].

```
<CODE BEGINS>
X509-ML-DSA-2025
{ iso(1) identified-organization(3) dod(6)
  internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
  id-mod-x509-ml-dsa-2025(119) }

DEFINITIONS IMPLICIT TAGS ::= BEGIN

EXPORTS ALL;

IMPORTS

PUBLIC-KEY, SIGNATURE-ALGORITHM
FROM AlgorithmInformation-2009 -- [RFC 5912]
  { iso(1) identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) id-mod(0)
    id-mod-algorithmInformation-02(58) } ;

--
```

```
-- ML-DSA Identifiers
--
nistAlgorithms OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
  country(16) us(840) organization(1) gov(101) csor(3)
  nistAlgorithms(4) }

sigAlgs OBJECT IDENTIFIER ::= { nistAlgorithms 3 }

id-ml-dsa-44 OBJECT IDENTIFIER ::= { sigAlgs 17 }

id-ml-dsa-65 OBJECT IDENTIFIER ::= { sigAlgs 18 }

id-ml-dsa-87 OBJECT IDENTIFIER ::= { sigAlgs 19 }

--
-- Public Key Algorithms
--

PublicKeys PUBLIC-KEY ::= {
  -- This expands PublicKeys from [RFC 5912]
  pk-ml-dsa-44 |
  pk-ml-dsa-65 |
  pk-ml-dsa-87,
  ...
}

--
-- ML-DSA Public Keys
--

pk-ml-dsa-44 PUBLIC-KEY ::= {
  IDENTIFIER id-ml-dsa-44
  -- KEY no ASN.1 wrapping; 1312 octets --
  PARAMS ARE absent
  CERT-KEY-USAGE { digitalSignature, nonRepudiation,
                   keyCertSign, cRLSign }
  PRIVATE-KEY ML-DSA-44-PrivateKey
}

ML-DSA-44-PrivateKey ::= CHOICE {
  seed [0] OCTET STRING (SIZE (32)),
  expandedKey OCTET STRING (SIZE (2560)),
  both SEQUENCE {
    seed OCTET STRING (SIZE (32)),
    expandedKey OCTET STRING (SIZE (2560))
  }
}

pk-ml-dsa-65 PUBLIC-KEY ::= {
  IDENTIFIER id-ml-dsa-65
  -- KEY no ASN.1 wrapping; 1952 octets --
  PARAMS ARE absent
  CERT-KEY-USAGE { digitalSignature, nonRepudiation,
                   keyCertSign, cRLSign }
  PRIVATE-KEY ML-DSA-65-PrivateKey
}
```



```
ML-DSA-65-PrivateKey ::= CHOICE {
  seed [0] OCTET STRING (SIZE (32)),
  expandedKey OCTET STRING (SIZE (4032)),
  both SEQUENCE {
    seed OCTET STRING (SIZE (32)),
    expandedKey OCTET STRING (SIZE (4032))
  }
}

pk-ml-dsa-87 PUBLIC-KEY ::= {
  IDENTIFIER id-ml-dsa-87
  -- KEY no ASN.1 wrapping; 2592 octets --
  PARAMS ARE absent
  CERT-KEY-USAGE { digitalSignature, nonRepudiation,
    keyCertSign, cRLSign }
  PRIVATE-KEY ML-DSA-87-PrivateKey
}

ML-DSA-87-PrivateKey ::= CHOICE {
  seed [0] OCTET STRING (SIZE (32)),
  expandedKey OCTET STRING (SIZE (4896)),
  both SEQUENCE {
    seed OCTET STRING (SIZE (32)),
    expandedKey OCTET STRING (SIZE (4896))
  }
}

ML-DSA-44-PublicKey ::= OCTET STRING (SIZE (1312))
ML-DSA-65-PublicKey ::= OCTET STRING (SIZE (1952))
ML-DSA-87-PublicKey ::= OCTET STRING (SIZE (2602))

--
-- Signature Algorithms
--

SignatureAlgorithms SIGNATURE-ALGORITHM ::= {
  -- This expands SignatureAlgorithms from [RFC 5912]
  sa-ml-dsa-44 |
  sa-ml-dsa-65 |
  sa-ml-dsa-87,
  ... }

--
-- ML-DSA Signature Algorithm Identifiers
--

sa-ml-dsa-44 SIGNATURE-ALGORITHM ::= {
  IDENTIFIER id-ml-dsa-44
  PARAMS ARE absent
  PUBLIC-KEYS { pk-ml-dsa-44 }
  SMIME-CAPS { IDENTIFIED BY id-ml-dsa-44 }
}

sa-ml-dsa-65 SIGNATURE-ALGORITHM ::= {
  IDENTIFIER id-ml-dsa-65
  PARAMS ARE absent
```

```

PUBLIC-KEYS { pk-ml-dsa-65 }
SMIME-CAPS { IDENTIFIED BY id-ml-dsa-65 }
}

sa-ml-dsa-87 SIGNATURE-ALGORITHM ::= {
  IDENTIFIER id-ml-dsa-87
  PARAMS ARE absent
  PUBLIC-KEYS { pk-ml-dsa-87 }
  SMIME-CAPS { IDENTIFIED BY id-ml-dsa-87 }
}
END
<CODE ENDS>

```

Appendix B. Security Strengths

Instead of defining the strength of a quantum algorithm using the common but imprecise notion of bits of security, NIST has instead elected to define security levels by picking a reference scheme, which NIST expects to offer notable levels of resistance to both quantum and classical attacks. To wit, an algorithm that achieves NIST PQC security level 1 must require computational resources to break the relevant security property, which are greater than those required for a brute-force key search on AES-128. Levels 3 and 5 use AES-192 and AES-256 as references, respectively. Levels 2 and 4 use collision search for SHA-256 and SHA-384 as references.

The parameter sets defined for NIST security levels 2, 3, and 5 are listed in [Table 2](#), along with the resulting signature size, public key, and private key sizes in bytes. Note that these are the sizes of the raw keys, not including ASN.1 encoding overhead from `OneAsymmetricKey` and `SubjectPublicKeyInfo` wrappers. Private key sizes are shown for both the seed format and expanded format.

Level	(k,l)	eta	Sig. (B)	Public Key(B)	Private Seed(B)	Private Expand(B)
2	(4,4)	2	2420	1312	32	2560
3	(6,5)	4	3309	1952	32	4032
5	(8,7)	2	4627	2592	32	4896

Table 2: ML-DSA Parameters

Appendix C. Examples

This appendix contains examples of ML-DSA private keys, public keys, certificates, and inconsistent seed and expanded private keys.

C.1. Example Private Keys

The following examples show ML-DSA private keys in different formats, all derived from the same seed `000102...1e1f`. For each security level, we show the seed-only format (using a context-specific `[0]` primitive tag with an implicit encoding of `OCTET STRING`), the expanded format, and both formats together.

NOTE: All examples use the same seed value, showing how the same seed produces different expanded private keys for each security level.

C.1.1. ML-DSA-44 Private Key Examples

Each of the examples includes the textual encoding [RFC7468] followed by the so-called "pretty print"; the private keys are the same.

C.1.1.1. Seed Format

```
-----BEGIN PRIVATE KEY-----
MDQCAQAwCwYJYIZIAWUDBAMRBCkAIAABAgMEBQYHCAkKCwwNDg8QERITFBUWFxgZ
GhscHR4f
-----END PRIVATE KEY-----
```

```
SEQUENCE {
  INTEGER { 0 }
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
  }
  OCTET_STRING {
    [0 PRIMITIVE] { `000102030405060708090a0b0c0d0e0f10111213141
5161718191a1b1c1d1e1f` }
  }
}
```

C.1.1.2. Expanded Format

```

-----BEGIN PRIVATE KEY-----
MIIKGAIBADALBgIghkgBZQMEAxEEggoEBIIKANeytHJUquDbReeTDUqY0s19jx0X
0Xidr6FwJLmW6b7J0c4Pf3f421Z3No2a/5HNL2V9DX/mmE6pUqkHCxpTAQymgex
+rtI9SownxGhiY+EjiMi/+Yj7IENs77jNoWFsogmnaMg1RIL/P6JoY4w9xFNg6pA
SmRrbJlziYYNElIu4ABuI4SBkYZhmyYNEYZk1KYoiHhEgkAomBRhSKZhTEJIozII
wjgpUSRICKElwggxCMRxIBQJFINsGKeAhBBuycBwIrVvKCLBhDacEmBJEUYhpWQBG
IpMgQQYuQrZMARZJfChMQahRgEYKURZRWgggAiJE3JhJ0TJR4TbL08CFkqhREqFk
ADkiCUZiHMcM2Qht0AYmUkCFgEQwkQYsUmGJMMWEGpZtSpqsmQZtpEQyIKdkWjJu
EbVwIJJhJB00BIUsCkhyyKBR0wgqmSCAWCQgJAd0WRSIEKRkYMBt4LKNgXkJIDQi
wCRBcUNxciEgYaIBUiJSG4CAmjQAE5NN0zIpIhcKmJjPghRRICchnMagYqKBSBhp
GoVNg0RpWyBBaxJCyxhGAakNDaIxg7AhWiJKyJIF2ZBpBDBqSwZK0rIBHEBAGUIy
UjJyVKZAWhgQDDISksKAUhJiXIIoC7RsA0KNUxAMFAE04TZSiIQkQIKY0YmIAYp
EcIo0CBIArNsojYJWoZiY7Rhi0ZixECCGokJEAJNLJFIBILJMKFiCiMycBNWUgi
CiduwTRkTJBgW0RQgoZJQ4gEQ7KMYDCAoogthKRtjKYp0MaEQgZGiYhRAkMNAUmN
5DgNpAaN05RxQrJsGoRhG6MoQrQoCKBxGsUx4KBMATdLJChIFciQCRBh2UaIGzNg
CQKS0CSBIAQISRhEoyItXIhEFJgIPEZhAZVkcZkKDJRQykbq0rIgwDgBgjCOE7kI
kYCEF IgpwBiRejUNoCQi4gQG2cKFBCgSHMmJGAJy0kApwggS2AYqmZRxm7hoI4Qp
GiKJFEUR3IJEUJZFDESEwLIEmqYFQ4YsRDJuiEQhIKhMmjBw47gtYyaIAyVJA00M
SKgJyhRyUzROEkMIG6cEWTAi2ZSA4jQigUISnDAqLDQmYQRfJCYoE0YJSjJtESgJ
GLg1YigRE0ENQbIRkIRMIxISosaIycAwIgyG0hi0hIYwkERSEogx2SBxE8UoQwY0
AzBgZkaEWCZSTIGBhvclYshf+k0s+kkhfysXLXu8FGIObZgKcaq73wxF6aIG7LFC
P+4V3swXYBMAFJ2SI81ubG4fq0Qfx8ZJOKtokF/T3NpQ2HCC59DXHRVJsrhMhVI8
qP5srSlK340+FbEI/3IdDMh7w906dZAYSw6EVm0pH8nhw8U6YdhnQgsE8JI1V108
ZaBjaP1BKV/QmSQLG+R9nlkUJnSnJcNDkUxM7PWMB0vK9FWM1795EeB6ptCTjy
7iuzwajFldY16ENC/eoB3CSyEa0vwoHPd+WREMerxUvwyG1IC5vidkcdydYDzumM
/as+n8+3A3k1YfSepEUpp7M/uRacRLTSX7nEV/SXkc09oD6slglYE8EFEyzNp0Y+
SSKM0j2KHzeFbxQt7kNsJ+Cr4kljG0quAR6gMA2yTV+ogRvjcyY1TwxSlfNCu0F9
PP6wsf0zYiwp4Uy72S4TY8ZevUUEt1Ejkb1nDjLhssZ6V0fxpV+Ln56gToyjpwXm
KjxeY3N0r7eutt3qYSzeKPAaIC16pONHItJ90/m4mJTQGF1dTXEZ7+Ny07oQTLi7
CYHgdN46/iANqq6tgmzEXyRNv0Ma+rNO+994JHTS/VcRj2RiFJNO2Zy60wA+jWej
g29vGfxBkQzlfj7jrpnrhNUU63YeY2h0pW+XkdLdSquYWi5SMgX91oiKss0jNwD
zEr+j2cvfho203+u/58XK5iRNnfFod0IXp7kwiBSwa9YGTEWZz3NO/xfNLhV3MbH
eIVknp5x9D1K6g9Lcsp+2gV4uhPTGmWNLQYKmb/ae0b5516L7HScj04+b+r4Y+0
ezzakG50m16ULI6uspYHDr/TZJR6lAzJeL7Wazd0nm1dzXvoxJREDiuEzs/vuYwL
7fs8QeM1nSzXGX++cgxIqmXRZGXB7mPjVpwq3HREkTcLf3gm/gt3odGdZBAduYR
gQa0LS73N0f1YB/kuLDyPt5SHwMagX0VKUpDci6DeHhLbbDPG6norpEdkgG5zpzD
AZxvXCfLmNomFEtkIlp8kysw92Hni1Zodi4PsY0Si9t1H52VwbQC/SnmqSbDup
HYEsjyx5erF5Zwnl0WhWd4KTUp8ChtAVw7U51h1kKjM+n1k9bj9TU51CCOnmozKF
HX91JSKpKlKX4n4tbUITff4uv6b7HGeybAJUoaf9+vb4xWmjgotp2noqfQtPmAA
fHEzCSaywAetgrU5P0e2HLM0ZciAdKwJ/NUwSLTDNeLwddA/sy8b8KgRGxuM0rF
H1ppCYqi1EfyCFt0TkuSZmJpIdLeR4UYzQkM4meuotJ621f9iLSXbYn7hdzc0mn
bKJnnmgBv6f7AxIW+1BilwS5kj2u13ThTERICrfsRmV5ZtzA0z2ftA6uBOGdkjQ
JYKAh+lJqa/Ra5XXLZmx7coleqWTL/t6Bwmu1anA/wX7Dyu/KECe7XtfWAG+lktz
AZ4ct4Ud0FHxApBnThn/sAizAcSs9kGiuxQhbh1pyr9Ste8idJaw8weZqFXRF/rT
dEpvozUD6nmLUt3X71QmYJ2/zT8ME7Fk1sBR9+1KEZcZpxLjinMoQCCB/xNUTVTS
wjev7TsVHEuo6fS964SZowZuJrvGnorwid7HFzHR3FKeqxfvc3RzTA/kdU1Mg4Nr
3TSg05vImRRxYGG/uY7G5hw+1E003K81JDxkcIa56nAYsNmoolAM7LAKveJJjWnC
M2EBp3LL5PVxUj9RvQWILN81i4ScwUCqH68iQjoshRzg4z/UiXWk1Z+1xf5BjJ0Q
gZGrbnQbd7/gLL1pjueVxGbwFWGGeZEE4LG6sAYN06atzzqgLvInceNqRvXm2+C+J
l4XWhwDTk+Z1wiJNa3oa0hMgSVZ5ra7XAWe1CGZx01MQnbe299gTBOzf2Dsxxm7y
SDBrRa0p593Mhj2sVgSLXWnqF1AR92FMAKhqhjzeGHKokyh4uax+GsW9pJl7cgZP
DNdfTIF0A03hGsuQE89+qSa05+qs4HDHuiGI760uQx4SI9Rd0FxnHAPC5FzuZBPs
vnUn6HPkVcTmEKYY0arMC9VtJIPnjymLZqR46y9VjLr8qGv0R7rrAsWyFsJNiP6k
3ySbCeZwogcDq6wksKkavEpWRmAUQroQvs/TCZOIAFHQf1agWpN556jmvv7j8i+q
EGOY93BgBuQum+HvidJcJy8RqVCVxYfXE3MihN6dvTxyF7BonihY6w/2lmg=
-----END PRIVATE KEY-----

```

```
SEQUENCE {
  INTEGER { 0 }
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
  }
  OCTET_STRING {
    OCTET_STRING { `d7b2b47254aae0db45e7930d4a98d2c97d8f1397d178
9dafa17024b316e9bec939ce0f7f77f8db5644dcda366bfe4734bd95f435ff9a
613aa54aa41c2c694c04329a07b1fabb48f52a309f11a1898f848e2322ffe623
ec810db3bee33685854a88269da320d5120bfcfe89a18e30f7114d83aa404a64
6b6c997389860d12522ee0006e2384819186619b260d118664d4a62822184482
402898146148a6614c4248a19208c2382951244808a125c2083108c471201409
14836c18a78084106ec9c07022b56408b0610c07049812445188695900462293
2041062e42b64c01164914284c41a85180460a5116515a0820022244dc9849d1
3251e13065d3c08592a85112a1640039220946621cc70cd9086dd00626524085
80443091062c50c80924c5841a966d4a982c99066da4443220a7645a326e11b5
7020926124138e04852c0a4872c8a051d3082a99208058242024074e59148810
a46460c06de0b28d1b1909203422c024410943710a212061a2015222521b8080
9a340013934dd3322922170a9892691a14512027219cc02062a2814818691a85
4d8344695b2041031242cb184601a90d0c023183b0215a224ac89205d9906904
306a4b064ad2b2011c404081423252327254a6405a18100c321292c280521262
5c82280bb46c03428d53100c14010ee1365288842491020a63462620062911c2
28d0204802b36ca236095a8648cbb4618b4662c440821a890910024d24b24520
122524c90588288cc9c04d5948220a276ec134644c90605b4450828649438804
43b28c603080a2882d84a46d8ca629d0c68442064689885100a98d01498de438
0da4068dd3947142b26c1a84611ba32842b42808a0711ac531e0a04c01376524
2862142890091061d940221b3360090292d02481200408491844a3222d5c8844
149808a446610195640b390a0c9450ca406ad2b220c0380182308e13b9089180
84148829c0189112350da02422e20406d9c2850428121cc989180272d24029c2
0812d8062a9994719bb8682384291a2289144511dc82445096450c4484c0b204
9aa60543862c44326e88442120a84c9a3070e3b82d63268803254903438c48a8
09ca147253344e1243081ba704593022d99480e234228142129c302a94342661
04452426281346094a326d11280918b82562281113410d41b21190844c8b1212
a2c688c9c030220606d2188e848630904452128831d9207113c52843060e0330
60cca6845826524c88011ef72562c85ffa43acfa49217f2b172d7bbc14620e6d
980a71aabdbf0c45e9a206ecb1423fee15decc17601300149d9223cd6e6c6e1f
a8e41fc7c64938ab68905fd3dcda50d87082e7d0d71d1bc9b2b84c85523ca8fe
6cad294adf83be15b108ff721d0cc87bc3dd3a7590184b0e845663a91fc9e1c3
c53a61d867420b04f092355753bc65a06368fd41295fd09924132c6f91f67964
c142674a725c343914c4cecf58c074bcfa4558c97bf7911e07aa6d0938f2ee2b
b3c1a8c595d635e84342fdea01dc24b211ad2fc281cf77e59110c7abc54bf0c8
6d480b9be276471dc9d603cee98cfdab3e9fcfb703793560549ea4450fa7b33f
b9169c44b4d25fb9c457f49791cd3da03eac96095813c105132ccda4e63e4922
8cd23d8a1f37856f142d93b90db09f82af89258c63aab8047a80c036c9357ea2
046f8dc6354f0c5295f342bb417d3cf0b1fd33622c29e14cbbd92e1363c65e
bd4504b7512329b9670e32e1b2c67a54e7f1a55f8b9f9ea04e8ca3a705e62a3c
5e637374afb7aeb6ddea612cde28f01a202d7aa4e34722d27dd3f9b89894d019
fd5d4d7119efe3723bba104cb8bb0981e074de3afe200daaaead826cc45f244d
bf431afab34efbdf782474d2fd57118f646214934ed99cba3b003e8d67a3836f
6f19fc41910ce5163ee3ae99eb84d514eb761e63684ea56f9791d2dd4aac6e61
68b948c817f75a222acb0e8cdc03cc4afe8f67157e1a363b7faeff9f172b9891
3677c5a1dd085e9ee4c22052c1af58193116673dcd3bfc5f34b855dcc6c77885
649e9e71f43d4aea0f4b72ca7eda0578ba13d31a658d2d060a9a66ff69ed1be7
997a2fb1d2723d38f9bfabe18f8e7b3cda906e4e9b5e942c8eae296070ebfd3
64947a940cc978bed66b37749e6d5dcd7be8c494440e2b84cecfefb98c0bedfb
3c41e3359d2cd7197f7be720c48aa6c6b6465c1ee63e3569c2adc744491370b7f
7826fe0b77a1d19d64101d032b918106b42d2ef73747e5601fe4ba50f23ede52
```

```
1f031a817d15294a43722e8378784b6db0cf1ba9e8ae911d9201b9ce9cc3019c
6f5c27cb98da26144b64225a7c932b30f761e78a2d59a1d8b83ec6344a2f6dd4
7e765706d00bf4a79a6a926c3ba91d812c8f2c797ab1796709e5d16856778293
529f0286d015c3b5399619642a333e9e593d6e3f5353994208e9e6a332851d7f
652522a928b917e27e2d6d42137dfe2ebfa6fb1c67b26c0254528685f7ebdbe3
15a68eaa2da769e8a9f42d3e60007c71330926b2c0012d83ead4e4fd1ed872cc
d1972201d2b027f3545ac2d30cd78bc1d740feccbc6fc2a0446c6e30eac51f5a
69098aa2d447f2085b4e4e4b92ccc26921d2de478518cd090ce267aea2d27ada
57fd88b4976d89fb843cdccf49a76ca2679e6801bfa7fb031896fb50629704b9
923936bb5dd385311121cadfb11995e59b73034cf67ed03ab813867648d02582
8087e949a9afd16b95d72d99b1edca257aac132ffb7a0709aed5a9c0ff05fb0f
2bbf28409eed7b5f5801be964ced019e1cb7851d3851f10290674e19fffb008b3
01c4acf641a2bb14216e1d69cabf52b5ef227496b0f30799a855d117fad3744a
6fa33503ea798b52ddd7ee5426609dbfcd3f0c13b164d6c051f7ed4a119719a7
12e388d328402081fff1354b554d2c237afed3b151c4ba8e9f4bdeb8499a3066e
26bbc69e8af089dec71731d1dc529eab17ef7374734c0fe475494c83836bdd34
a03b9bc89914716061bfb98ec6e61c3ed4438edcaf25243c647086b9ea7018b0
d9a8a0b00cecb00abde2498d69c2336101a772cbe4f571523f51bd05882cdf35
8b849cc140aa1faf22423a12851ce0e33fd48975a4959fa5c5fe418c93908191
ab6e741b77bfe02cbd698ee795c466d615619e6441382c6eac01834ee9ab73ce
a80bbe235c78da91bd79b6f82f899785d68700d393e675c2224d6b7a1ad21320
495679adaed70167b50866713a53109db7b6f7d81304ecdffd83b319b1ef24830
6b45ad29e7ddcc863dac56048b5d69ea175011f7614c00a86a863cde1872a893
2878b9ac7e1ac5bda4997b72064f0cd75f4c814e034de11acb9013cf7ea926b4
e7eaace070c7ba2188efad2e431e1223d45dd05c4d8403c2e45cee6413ecbe75
27e873e455c4e610a61839aacc0bd56d2483e78f298b66a478eb2f558cbafca8
6be847baeb02c5b216c8cd88fea4df249b09e670a20703abac24b0a91abc4a56
46601442ba10becfd30993880051d07f56a05a9379e7a8e6befee3f22faa1063
98f7706006e42e9be1ef89d25c272f11a95095c587d713732284de9dbd3c7217
b0689e21d8eb0ff69668` }
}
}
```

C.1.1.3. Both Format


```

-----BEGIN PRIVATE KEY-----
MIIKPGIBADALBg1ghkgBZQMEAxEEggoqMIIKJgQgAAECAwQFBgcICQoLDA00DxAR
EhMUFERYXGBkaGxwdHh8EggoA17K0c1Sq4NtF55MNSpjSyX2PE5fReJ2voXAKsxbp
vsk5zg9/d/jbVktC2jZr/kc0vZX0Nf+aYTq1SqQcLGLMBDKaB7H6u0j1KjCfEaGJ
j4S0IyL/5iPsgQ2zvum2hYVKiCadoyDVEgv8/omhjjD3EU2DqkBKZGtsmX0Jhg0S
Ui7gAG4jhIGRhmGbJg0RhmTUpigiGESCQCiYFGFIpmFMQkihkgjCOC1RJEgIoSXC
CDEIxHEgFAkUg2wYp4CEEG7JwHAitWQIsGEMBwSYEKRRiG1ZAEYikyBBBi5CtkwB
FkkUKExBqFGARgpRf1FaCCACIkTcmEnRM1HhMGXTwIWSqFESoWQAOSIJRmIcxwzZ
CG3QBIZSQIWARDCRBixQyAkKxYQa1m1KmCyZBm2kRDIgp2RaMm4RtXAgkmEkE44E
hSwKSHLIoFHTCCqZIIIBYJCAkBO5ZF IgQpGRGwG3gso0bGQkGNCLAJEEJQ3EKISBh
ogFSI1IbgICaNAATk03TMikiFwqYkmaFFEGjYgCwCBiooFIGGkahU2DRG1bIEED
EkLLGEYBqQ0MAjGdsCFaIkrIkgXZkGkEMGpLBkrSsgEcQECBQjJSMnJUpkBaGBAM
MhKSwoBSEmJcigLtgWdQo1TEAwUAQ7hN1KIhCSRAGpjRiYgBikRwIjQIEgCs2yi
NglahkjLtgGLRmLEQIIaiQkQak0kskUgEiUkyQWIKIzJwE1ZSCIKJ27BNGRMGbBb
RFCCk1DiARDsoxgMICiic2EpG2MpinQxorCBkaJiFEaqY0BSY3k0A2kBo3T1HFC
smwahGEboyhCtCgIoHEaxTHgoEwBN2UkKGIUKAJAJEGHZQCIbM2AJApLQJIEgBAhJ
GESjIi1ciEQUmAikRmEBLWQLOQoM1FDKQGrSsiDA0AGCMI4TuQiRgIQUiCnAGJES
NQ2gJCLiBAbZwoUEKBIcyYkYAnLSQCnCCBLyBiqZlHGbuGgjhCkaIokURRHcgkRQ
lkUMRITAsgSapgVDhixEMm6IRCEggqEyaMHDjuC1jJogDJUkDQ4xIqAnKFHJTNE4S
shggbpwrZMCLZ1IDiNCKBQhKcMCqUNCzhBEUKjigTRglKmm0RKAKYucVikBETQQ1B
wGQhEylEhKixojJwDAiBgbSGI6EhjCQRFISiDZHETxShDbG4DMGDMpoRYJLJM
iAEe9yViyF/6Q6z6SSf/Kxcte7wUYg5tmApxqrvfDEXpogbssUI/7hXezBdEwAU
nZiJzW5sbh+o5B/Hxkk4q2iQX9Pc2lDYcILn0NcdG8myuEyFUjyo/mytKUrfg74V
sQj/ch0MyHvD3Tp1kBlLDoRWY6kfyehDxTph2GdCCwTwkVjVXU7x1oGN0/UEpX9CZ
JBMSb5H2eWTBQmdKc1w0ORTEzs9YwHS8r0VYyXv3kR4Hqm0JOPLuK7PBqMwV1jXo
Q0L96gHcJLIRrS/Cgc935ZEQx6vFS/DiB UgLm+J2Rx3J1gP06Yz9qz6fz7cDeTVg
VJ6kRQn+nsz+5FpxEtNjFucRX9JeRzT2gPqyWCVgTwQUTLM2k5j5JIoZSPYofN4Vv
FC2TuQ2wn4KviSWMY6q4BHqAwDbJNX6iBG+NxjVPDFKV80K7QX08/rCx/TNiLCnh
TLvLhNjx169RQX3USmpuWc0MuGyxnpU5/G1X4ufnqB0jK0nBeYqPF5jc3Svt662
3ephLN4o8BogLXqk40ci0n3T+biY1NAZ/V1NcRnv43I7uhBMuLsJgeB03jr+IA2q
rq2CbMRfJE2/Qxr6s07733gkdNL9VxGPZGIUK07ZnLo7AD6NZ60Db28Z/EGRD0UW
Pu0umeuE1Rtrdh5jaE61b5eR0t1KrG5haLlIyBf3WiIqyw6M3APMSv6PzXv+GjY7
f67/nxcrmJE2d8Wh3QhenuTCIFLBr1gZMRZnPC07/F80uFXcxs4hWSennH0PURq
D0tyyn7aBXi6E9MaZY0tBgqaZv9p7RvnmXovsdJyPTj5v6vhj457PNqQbk6bXpQs
jq6y1gc0v9Nk1HqUDM14vtZrN3SebV3Ne+jE1EQ0K4T0z++5jAvt+zxB4zWdLncZ
f75yDEiqbGtKzChuY+NwNcRcdESRnwt/eCb+C3eh0Z1kEB0DK5GBBRQtLvc3R+Vg
H+S6UPI+3lIfAxqBfRUpSkNyLoN4eEttsM8bqeiukR2SAbn0nMMbnG9cJ8uY2iYU
S2QiWnyTKzD3YeeKLVmh2Lg+xjRKL23UfnZXBtAL9KeaapJs06kdGsyPLH16sXln
CeXRaFZ3gpNSnwKG0BXDtTmWGWQqMz6eWT1uP1NTmUII6eajMoUdf2UliqkouRfi
fi1tQhN9/i6/pvscZ7JsAlRShoX369vjFaa0qi2naeip9C0+YAB8cTMJJrLAAS2D
6tTk/R7YcszRlyIB0rAn81RawtMM14vB10D+zLxvwqBEbG4w6sUfWmkJiqLUR/II
W050S5LMwmkh0t5HhRjNCQziZ66i0nraV/2ItJdtifuEPNzPSadsomeeaAG/p/sD
GJb7UGKXBLmS0Ta7Xd0FMREhyt+xGZXlM3MDTPZ+0Dq4E4Z2SNA1goCH6Umpr9Fr
ldctmbHtyiV6rBMv+3oHca7VqcD/BfsPK78oQJ7te19YAb6WT00Bnh3hR04UfEC
kGd0Gf+wCLMBxKz2QaK7FCFuHwnKv1K17yJ0lRdzB5moVdEX+tN0Sm+jNQpqeYtS
3dfuVCZgnb/NPwwTsWTWwFH37UoRlXmnEu0I0yhAIIH/E1S1VNLCN6/t0xUcS6jp
9L3rhJmjBm4mu8aeivCJ3scXMDhCUp6rF+9zdHNMD+R1SUyDg2vdNKA7m8iZFFHg
Yb+5jSbmHD7UQ47cYUkPGRwhrnqcbiw2aigsAzssAq94kmNacIzYQGncsvk9XFS
P1G9BYgs3zWLhJzBQKofryJC0hKFH0DjP9SjdaSVn6XF/kGMk5CBkatudBt3v+As
vWm055XEZtYVYZ5kQTgsbqWBg07pq3P0qAu+I1x42pG9ebb4L4mXhdaHAN0T5nXC
Ik1rehrSEyBJVnmtrtcBZ7UIZnE6UxCdt7b32BME7N/Y0zGbhVJIMGtFrSnn3cyG
PaxWBItdaeoXUBH3YUwAqGqGPN4YcqiTKHi5rH4axb2kmXtyBk8M119MgU4DTeEa
y5ATz36pJrTn6qzgcMe6IYjvrS5DhHij1F3QXE2EA8LkX05kE+y+dSfoc+RVx0YQ
phg5qswL1W0kg+ePKYtmpHjrL1Wmuvyoa+hHuusCxbIWyM2I/qTfJJJs5nCiBw0r
rCSwqRq8S1ZGYBRcuhC+z9MJk4gAUdB/VqBak3nnq0a+/uPyL6oQY5j3cGAG5C6b
4e+J0lwnLxGpUJXFh9cTcyKE3p29PHIXSgieIdjrd/aWaA==
-----END PRIVATE KEY-----

```

```
SEQUENCE {
  INTEGER { 0 }
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
  }
  OCTET_STRING {
    SEQUENCE {
      OCTET_STRING { `000102030405060708090a0b0c0d0e0f1011121314
15161718191a1b1c1d1e1f` }
      OCTET_STRING { `d7b2b47254aae0db45e7930d4a98d2c97d8f1397d1
789dafa17024b316e9bec939ce0f7f77f8db5644dcda366bfe4734bd95f435ff
9a613aa54aa41c2c694c04329a07b1fab48f52a309f11a1898f848e2322ffe6
23ec810db3bee33685854a88269da320d5120bfcfe89a18e30f7114d83aa404a
646b6c997389860d12522ee0006e2384819186619b260d118664d4a628221844
82402898146148a6614c4248a19208c2382951244808a125c2083108c4712014
0914836c18a78084106ec9c07022b56408b0610c070498124451886959004622
932041062e42b64c01164914284c41a85180460a5116515a0820022244dc9849
d13251e13065d3c08592a85112a1640039220946621cc70cd9086dd006265240
8580443091062c50c80924c5841a966d4a982c99066da4443220a7645a326e11
b57020926124138e04852c0a4872c8a051d3082a99208058242024074e591488
10a46460c06de0b28d1b1909203422c024410943710a212061a2015222521b80
809a340013934dd3322922170a9892691a14512027219cc02062a2814818691a
854d8344695b2041031242cb184601a90d0c023183b0215a224ac89205d99069
04306a4b064ad2b2011c404081423252327254a6405a18100c321292c2805212
625c82280bb46c03428d53100c14010ee1365288842491020a63462620062911
c228d0204802b36ca236095a8648cbb4618b4662c440821a890910024d24b245
20122524c90588288cc9c04d5948220a276ec134644c90605b44508286494388
0443b28c603080a2882d84a46d8ca629d0c68442064689885100a98d01498de4
380da4068dd3947142b26c1a84611ba32842b42808a0711ac531e0a04c013765
242862142890091061d940221b3360090292d02481200408491844a3222d5c88
44149808a446610195640b390a0c9450ca406ad2b220c0380182308e13b90891
8084148829c0189112350da02422e20406d9c2850428121cc989180272d24029
c20812d8062a9994719bb8682384291a2289144511dc82445096450c4484c0b2
049aa60543862c44326e88442120a84c9a3070e3b82d63268803254903438c48
a809ca147253344e1243081ba704593022d99480e234228142129c302a943426
6104452426281346094a326d11280918b82562281113410d41b21190844c8b12
12a2c688c9c030220606d2188e848630904452128831d9207113c52843060e03
3060cca6845826524c88011ef72562c85ffa43acfa49217f2b172d7bbc14620e
6d980a71aabbdf0c45e9a206ecb1423fee15decc17601300149d9223cd6e6c6e
1fa8e41fc7c64938ab68905fd3dcda50d87082e7d0d71d1bc9b2b84c85523ca8
fe6cad294adf83be15b108ff721d0cc87bc3dd3a7590184b0e845663a91fc9e1
c3c53a61d867420b04f092355753bc65a06368fd41295fd09924132c6f91f679
64c142674a725c343914c4cec58c074bcacf4558c97bf7911e07aa6d0938f2ee
2bb3c1a8c595d635e84342fdea01dc24b211ad2fc281cf77e59110c7abc54bf0
c86d480b9be276471dc9d603cee98cfdb3e9fcfb703793560549ea4450fa7b3
3fb9169c44b4d25fb9c457f49791cd3da03eac96095813c105132ccda4e63e49
228cd23d8a1f37856f142d93b90db09f82af89258c63aab8047a80c036c9357e
a2046f8dc6354f0c5295f342bb417d3cfeb0b1fd33622c29e14cbbd92e1363c6
5ebd4504b7512329b9670e32e1b2c67a54e7f1a55f8b9f9ea04e8ca3a705e62a
3c5e637374afb7aeb6ddea612cde28f01a202d7aa4e34722d27dd3f9b89894d0
19fd5d4d7119efe3723bba104cb8bb0981e074de3afe200daaaead826cc45f24
4dbf431afab34efbdf782474d2fd57118f646214934ed99cba3b003e8d67a383
6f6f19fc41910ce5163ee3ae99eb84d514eb761e63684ea56f9791d2dd4aac6e
6168b948c817f75a222acb0e8cdc03cc4afe8f67157e1a363b7faeff9f172b98
913677c5a1dd085e9ee4c22052c1af58193116673dcd3bfc5f34b855dcc6c778
85649e9e71f43d4aea0f4b72ca7eda0578ba13d31a658d2d060a9a66ff69ed1b
e7997a2fb1d2723d38f9bfabe18f8e7b3cda906e4e9b5e942c8eae296070ebf
```

```

d364947a940cc978bed66b37749e6d5dcd7be8c494440e2b84cecfefb98c0bed
fb3c41e3359d2cd7197f7be720c48aa6c6b6465c1ee63e3569c2adc744491370b
7f7826fe0b77a1d19d64101d032b918106b42d2ef73747e5601fe4ba50f23ede
521f031a817d15294a43722e8378784b6db0cf1ba9e8ae911d9201b9ce9cc301
9c6f5c27cb98da26144b64225a7c932b30f761e78a2d59a1d8b83ec6344a2f6d
d47e765706d00bf4a79a6a926c3ba91d812c8f2c797ab1796709e5d168567782
93529f0286d015c3b5399619642a333e9e593d6e3f5353994208e9e6a332851d
7f652522a928b917e27e2d6d42137dfe2ebfa6fb1c67b26c0254528685f7ebdb
e315a68eaa2da769e8a9f42d3e60007c71330926b2c0012d83ead4e4fd1ed872
ccd1972201d2b027f3545ac2d30cd78bc1d740fecbcb6fc2a0446c6e30eac51f
5a69098aa2d447f2085b4e4e4b92ccc26921d2de478518cd090ce267aea2d27a
da57fd88b4976d89fb843cdccf49a76ca2679e6801bfa7fb031896fb50629704
b9923936bb5dd385311121cadfb11995e59b73034cf67ed03ab813867648d025
828087e949a9afd16b95d72d99b1edca257aac132ffb7a0709aed5a9c0ff05fb
0f2bbf28409eed7b5f5801be964ced019e1cb7851d3851f10290674e19fffb008
b301c4acf641a2bb14216e1d69cabf52b5ef227496b0f30799a855d117fad374
4a6fa33503ea798b52ddd7ee5426609dbfcd3f0c13b164d6c051f7ed4a119719
a712e388d328402081ff1354b554d2c237afed3b151c4ba8e9f4bdeb8499a306
6e26bbc69e8af089dec71731d1dc529eab17ef7374734c0fe475494c83836bdd
34a03b9bc89914716061bfb98ec6e61c3ed4438edcaf25243c647086b9ea7018
b0d9a8a0b00cecb00abde2498d69c2336101a772cbe4f571523f51bd05882cdf
358b849cc140aa1faf22423a12851ce0e33fd48975a4959fa5c5fe418c939081
91ab6e741b77bfe02cbd698ee795c466d615619e6441382c6eac01834ee9ab73
cea80bbe235c78da91bd79b6f82f899785d68700d393e675c2224d6b7a1ad213
20495679adaed70167b50866713a53109db7b6f7d81304ecdfd83b319b1ef248
306b45ad29e7ddcc863dac56048b5d69ea175011f7614c00a86a863cde1872a8
932878b9ac7e1ac5bda4997b72064f0cd75f4c814e034de11acb9013cf7ea926
b4e7eaace070c7ba2188efad2e431e1223d45dd05c4d8403c2e45cee6413ecbe
7527e873e455c4e610a61839aacc0bd56d2483e78f298b66a478eb2f558cbafc
a86be847baeb02c5b216c8cd88fea4df249b09e670a20703abac24b0a91abc4a
5646601442ba10becfd30993880051d07f56a05a9379e7a8e6bfee3f22faa10
6398f7706006e42e9be1ef89d25c272f11a95095c587d713732284de9dbd3c72
17b0689e21d8eb0ff69668` }
    }
}

```

C.1.2. ML-DSA-65 Private Key Examples

Each of the examples includes the textual encoding [RFC7468] followed by the so-called "pretty print"; the private keys are the same.

C.1.2.1. Seed Format

```

-----BEGIN PRIVATE KEY-----
MDQCAQAwCwYJYIZIAWUDBAMSBCAIAABAgMEBQYHCAkKCwwNDg8QERITFBUWFxgZ
GhscHR4f
-----END PRIVATE KEY-----

```

```
SEQUENCE {  
  INTEGER { 0 }  
  SEQUENCE {  
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.18 }  
  }  
  OCTET_STRING {  
    [0 PRIMITIVE] { `000102030405060708090a0b0c0d0e0f10111213141  
5161718191a1b1c1d1e1f` }  
  }  
}
```

C.1.2.2. Expanded Format

```

-----BEGIN PRIVATE KEY-----
MIIP2AIBADALBg1ghkgBZQMEAxIEgg/EBIIPwEhoPZGXj jHrPd24sEc0gtK4i19i
WUn9j1i1YeaWvUwn2FP6abgZkCPOzWeN2fq/kEdkb/0Ms8x/eVgFpx5w0jcbBWPj
zTNGFJyMnrzyOwp0WpA06pxlYnkKfGPjhmPaot3bbkgNxAWh5wGUi3SEHvXMHD8r
8yeXlpUQUQzVN17MCFVvdxGHIiGGI4EABCR3gGFHUAdQFxcDVQRRUSVHGDgEYXVy
IkQqiGhghkYBJ0dWcYCHBmaGQzJEQSIENjhmDKCNjQkQyIFc2QQZFVUdyJ1VoFD
NhRiVQggZDdoVGh1Q1N1EGhxgzOAVHUFJYB1KBiE0BEIcmAgIAhYgwGDYROCghIG
FxFXh2h4iHhkN1RgFlcVUIRxiGYHJzKIBmR0GFZ2IYAxgnZkFXgkUCVkJZkMRNQQ2
R4ASZnMUMBfMBlWGRxg2iGNQOEeGEQEGI1YRYTeGB4UyEkAHVHiCMENmYRZgQ1VB
goVgU2d4VjhdRDBjJhB3BzF4QnIUERZTA4UnaGdGAVCCNzUyB2YQdQRoEkGZgMD
JlIxJEVAiAAxgIh2chcwcYJHIVEngBF1RHSGYXIjM4CGYGRGg1IVhCA2gBGAIRgY
MxdzVFNIGQBEh1NnQ3BXCliDNGA4QjKfAaBAGBCYEJYRWAjVoIFGDhjhdJCEiQkVv
WfhncUVyYhQR4hxcYBhiDYIaGQVZQgRZQJkZwBggmYic4MXJAc1cwBycohiBmdYho
JgcGQCAzA0NmMVVGQkU0VmcYc0V1g3AiUIRoViiAcDZwhGI3FxAAGVxdYR3hwhlVT
eCI1FEZ3KFzZayKHABQzIGFxWEVSzjJQJlEzR3c4A1UWQxNHNRBmJ1F1dAJGiFw
Z0NGgYYBdlJFMzCHIQQ0NAEDIodjUVUmUIEwd0VEQWgVQYNjZBEgQCaHMENndxKA
iEY1VFMAYkWBFBf2USSEJ4A0UWzjWEN4VgFGURV0IyFDZoUiR3cxNFAXg2JCBVAA
ZIRHEjRAiABgRzVAV4MzYwghBhUiUgckiFE0hjcGdiJYhXEmVnNHaBZGRoQ1hwgS
JwVQCDgyACMggGY0UzYAM0aFckcGNVQANXcSJ1IwcUJTaHQ3RXAFZkMiRIKFIHIY
MzAgUzCzQHcnfU1MGNSUEBnM0YTGAcobXckg3djRXMYWFFgIzNENiUWQzGwCFh3
NGJCiDAHA2Wfn1UAADVIXUDcCEyRjBdcIaAY2FQMDAENY1cIAHEGZHNGNSJiAzBD
gCEIUodXgyEHiGdICFY0dDZzQoQFhGaEFDcAVRCHNCZEdyESc4RzZSZHJXcUrwQX
hkQmAkcRrh0CBIhZgWecXgTcGdoCBcFgYVYVHE2NCEHVYAWNYNYUYRA0EcRazh0Ji
gkd0E2VUQnBzRjV3dQBmJWJoQgISRo0GRhZkYDEiU4iEVACEVzRGR1RHJWBUYWaE
ZjCIBjgnFWMocY0EB1IkdoEWMITAzAYaAKAE4RjBQVlCjh1g2VyMjBogEYSJgZl
FnVXBTJBMidnNRcIAVMAFihGATSIidwERiBVXExVGQxFwRzKIKFY2gjRVUEGGJ2Vj
ERFodQUQQLRBRCEfiHEXF4gVNoUvDcWYLU2VYNjAlA0vXaHUycTcQnYNwVxR2Fx
NlGEEKI2ZERmQUNSBSEIUvCdM2OGAlhCZigUgRBUymgXMDh1ZDMhZyHWhmNjKBNA
YlQBIECIZUeIYXf1diNyYjSGcDARURVjIFB1NQISIqhcZTFDvWcRFSvYaqAFnjAV
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}
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C.1.2.3. Both Format

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ca2af75ccce734fd191c50089dad53982fddae02531ff93e1f21ff395fc0a128
74edf06b6f9647e95a7324586c71dfd91d901d621858190fecdd0ccd110bbac5
9f96cb884c3c93994748a56f41283bfc41fb89052153a894588c3cb9017f3d66
326c985637e575acb812346342654025d602de3ba940c19ac1a633dfda977b5
29b8013e19c1d6d0680f4dae62c924450ae66aab82f21473061dab3d62b247f9
07e3551939ad3f5465e9d08a82bfea17eea1b6b2b923757477f993000b2f43b7
0f28aaab1fe9a26ad1fd3361616c0b0e242fe76604b7033a1f30e97e28f526ca
3c880fe2b8d9d1b0c9ff188b31cb9d97425acab9b216d98a6ae355e583da71e8
864ee3d16b0759796190ef545c1e62bfef92af6ca147b13244d6c892fc8ef223
ab3f43f924c2f466097ee8` }
    }
  }
}

```

C.1.3. ML-DSA-87 Private Key Examples

Each of the examples includes the textual encoding [RFC7468] followed by the so-called "pretty print"; the private keys are the same.

C.1.3.1. Seed Format

```

-----BEGIN PRIVATE KEY-----
MDQCAQAwCwYJYIZIAWUDBAMTBCKAIAABAgMEBQYHCAkKCwwNDg8QERITFBUWFxgZ
GhscHR4f
-----END PRIVATE KEY-----

```

```

SEQUENCE {
  INTEGER { 0 }
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
  }
  OCTET_STRING {
    [0 PRIMITIVE] { `000102030405060708090a0b0c0d0e0f10111213141
5161718191a1b1c1d1e1f` }
  }
}

```


C.1.3.2. Expanded Format

```

-----BEGIN PRIVATE KEY-----
MIITOAIBADALBgIghkgBZQMEAxMEghMkBIITIJesV0wvJDBoaol8zzwvX/Z153HX
q0G5A1jPp+k0yXEk20nuTpChbGAvXsm8OFF9wn4ynVqydn09hftJSDAPd20JiGdQ
tXwk2z/AEUYe3111Mzc3T6cSSZFUmVJDSW0GN8s74FpZSCNb95h1+JbY/gyrMMhJ
SNtNYxWqrxYKxiQ2ZCIBSBYRCREs1AKJIKUsYrhFAEUqCJZwkBJuFJNw1EYQhERR
WJaRDkKpgrJBByQhxxChoBJaJSECFmyJtHChkWRJBNLiRhASJRJAFyzRioIaQQCaS
IJKpEwVpXDRopDKOGSAsWUYQCaRJI0JNEjZhWBB1ASiQGjNmMYx06JJCyl1QxQo
wDiBAXVNWyIGCIDiIzFSlCilw8BNpJghmEAg0UKGy0BwW7BxnJYswRIGU0YJDEUC
FEZukbQhVLCM5EZCmiCMASE1E0EFWkAiE8kMoBhAUswIwyzQsS8hoG6RgSYSEYzAp
SqBpW4AE0jgKFCZM4rJEi6IRJEZJxBRSC0JxA7IQkiiAASSI4wgRCgUoGcSBACai
3ERoQHiiRAAqySZqDIcx4MBEmRSEGDYNETdCIhiMY7KRDJgIoaABCJJEbBmKXJhx
goRxdJSubAxnEIuGqgoAgIRAcCJC8cFiiRIIsJkTIiRXIJoE6VkUCCGIQCKZRE
SCiWijlKApiECaKIGRkpREiMIpUMoQRyBIIdwEieQQGaEG0mFiQZK0zYI28BAWLZR
DKcJjCRhmZBkjmKQWysQEKNJAYvhQzKKEZHEyLiGBDhBEEcsGcZEHCUsBIgw2UZp
myAAG0aCwQSAW6BJGJAlACaC8IxWkByVMYgwbAxJLFNEJUoFAAKoMhNVKKIi5iB
YJAEAhYsEyFAkYaNCMKRkrQm0LQMCcZgUUQuBBEmAcKrk8IIY6QxIgaowRQIDEAs
QRQGNcByVICGiwhNoUhpEDBBHChJRBiOzJZI2UJQGwZJDEWIIwQNIDAuI4UsFAcw
QLaFTMAgRIYgQGBsVAJIZIhsWQYySRSEBMDQE0ko5AYJ08YQyChMIz1EUQRkzKhJ
RDgyComEADQsIoWNEDEJCTJlHImMQEApIYUACaFthMBk4gItSARAEgm04EIuk0QI
EhBqAYQFkjCKyzS0oiYuXIYRCzUIGBAAAjQmJC0J0YQAJEZge7JJChGGAJxoDiQ
iLRG05YtoxAIychwBhQq8gEQUKNXCZBRKJtSBI0QDILCxSCckguy4KIA6NgGyUm
jLggJLCFmAQhCkcsghzkhVdKJAQQBI0mEApVp0ARNE6QMkUYNYZSAKDhFXMZQARcg
U8YomxgQQRJokBIhwBCEQhaSU4IppSZJ2KQFmiYkJAMP4EAm0gJIESRoEZmJmBSF
ySANUBKMHAgQAhaAAJUowSiQWbSF0xRlCkBuESl1GMJMITR12DBpEDBSGTFmjBiK
yMAITJgw06YgQRYiGAUuIiUqZLg1CrMBYyCECYAJGSg0AheBo5QR45hsWCAhCUEQ
YDYiCAZxEsKFWqCFwMaEXDgGy7ZpFIEUyKCoaZaZiYAxCYioKgImDRy1CBBQ8SQ
SBZoGxZSGjcCUCBCSEiKIBFB4gBswMIMFAZJETFNGQYKiUYJG4FIRMgAggZwABZy
zCRQikKJnJaQZChwkrJomCziYZRAwRaJ2EJkGiFOYpBkIcgkiyhtXEKSoMZNDIWA
zIhN1EKNojSKCwRRryaGJCWBEjUGoEQEYJSBW7QxHAgGXCQIAydqIMI14YCQGRt
o0YMSxhgUMYsG5ItERUEogAEIUgu2BYG0hCkG6ILCDENCThr2UhJcXZMIz1lGRkC
SkQJ0bIhC4MsIyWfKxaFRKBEG4NQAiJySwSamxRlIZNgGBMK2UYNIkVhyLRAoUit
ArgJABREm7YRC5eMQBBKghRq2pAFHAKODBlYo7SNJDBQEYcJZMYo5BiSmLrsYRZR
QEYOHdJI2iBRiDaKI7EhgpAoGhUy4hHHkgSOE7aQExNoyYRoTEbtCzMAgUZN0jgM
BJaBpIhQAPCFIRAE06Rxo0AQypZAUaZBpIQo4AhSCzCM0jgKDC1Rw4IJyiCR2DaS
o6YokkIiohYBGjSGN9mmWRaYgewhz0gRhp0dfx0fBTfPbxGEWFQF/ReAivHgYjnT
s05ayovxNpZ3tEescYrEfYUMTXewjHcn1C00XjyQnSrAYX3J6vf9Z9EkDcb8EYQ
42TmTsh1750g3JQHfh4WYyeobirUWFgsqP3dDe5s8x9F66t3ITbYnRqNawJb3gv
YqfWgqbWaT3uyQsjxmmFoCMH4KHK5ZimcyTboPUvIkMidekyVwZc035eHP4d/U0N
8IbfISQFKLSfiAjCoKb50tMgsFtNfeLD14gzLgAHS7ZGEvqxfUyJccto5e2rA2
nxFxs0aavY0E4tLVPxt454bh7p0LmNOfg8zs830evTqdY67HZhZKEBcaT9jGPa8Y
LEISWMX1KapVy3664uFlIxXh9x6KdBMUENAYR+3hHTTbkfbwiqJHj9eJZ5wE1J9x
vAFx4H46i7V1PbvapBGmNQq0bu+/hvXVHCnv5M3XZ1c9sPbItD03eWZhURZ2X8g
33RVvfnWoZjQ9+ttNBEfyUCyXAVDt4jt2p0mgQ6sPWzJxRMnws+D6IfUCJ4ZaV4R
rdg39vRAzDYPk/Mv7oqWY3Esa704yEq3tUg7DY+t+QutZ/B/OYPvVUwez7IX9na
8yBte0s5F/HIt6kuPGfYmID98uR/WgyZRZXFwR0G6v1o1tNwcQt1qnbJx52TeL7
AVpJqFDhkZvkaAajNuLjJf3l0sWZVU0KfeTvRexAw51rr/MRvu512J4CrTh0vkvS
CukZT17d2qZ1B3YRbp8nD3dxSteo6Jr090t/99jb7Cf4AgqYUKfizazvSJSk1ouj
fKkS1r5zUByzUYHl1t3cjNQs2Mdo3AOE/02bhMb8Gs262sDRQkyCfCnv+uH92HwW
BofBFjw1PX0yQk3s06Xjpl4Ia3JZiIC70iaF+e7Za4X2DuQ275qUBp0E0W+50W1
tTry5bo9HvP04FrfCzpm8uUwNg/uZJKZArVx9v0uMFZSpMsBD3n4FeGPK7uMyJ+m
/Hb3fInik88XWgsZWAD+ctLM3X115b2QvGrENDakQ0+FLpocjFPeA78ZM2XXNary
nFFiphfjZ0f5RbaND7SP70BVj0VC18w91QhmLPI/uI4ZVKpF0cXhFbzDbwWz4JjV
VSIPQL4mKbNFB7hGTFTCe13seNqPImUFFHl6+Go1Ery34pIzee9tc8E3AGwb0PUe
N/k1heKQqAPk469GAHzh04tfexfv119VmjKJ7y+fsHXxAjAVKSMGueXv5msvI0m
B1IpNf1mXqeCLZMPI+q/9407I2l1aeIEuUMUHGDaiBCVa+BSU2Xbq1TtSMt21kzN
9cvTrucoLUoAANJ4TXuPqxay9/DVIlcyse+8TrHP7etD/eebaezA++qh5rQHKGc7
1LLpig1KjwL4U5UHMPKNNesS/MeXalJhjkvaDlijMaL3HXzMLUUBMrHGXDQz0fu

```

```
UTsh1UxBwAyHOHLu1M8U9GA3Q1Nh9L21SCH3EUYM666MB1CKkhn4j6a+2qZ47tUB
1EoWrm97W7ei4eNX5w17mEYaLHHLd6di1q2YJAgdN/KS/UvouEw2EQ3HRDYCAB7r
4L1snQXoaSVtL/P5lRe379KjN3QFbLVnFnWotJLp9fJiDrjvk4HT0d8Zk4t7X/qs
WbyBEPqHuo16PQF1+0Qd0PgE8Rud7Q81K114NdBjB6jgXu9NIZBDOeHPRYKjo+ie
A12UU0c2bALz3WNo10R+hdPSqXBb1X1hhS5aV5+TscUUXTn0nqEWOipJ0w78tH9H
SPapnhC/cHgoLkr0GBNuKos+4K0A3NOz7z514bgVconWJGetSIug0SsukKHt7cvc
kx3BcpjM73ZkXH0zCgXCzkD4m4VGjzV6IXdR4VRjEwTsTgS7RbNniQnHSvUc43A2
TY9PfrHmHgAodCnJlh3oMiypomKbEwnYA0krwdxQVdzH1/M4ZusM/Y1JA1DUj/yo
Ai9JKQ4tU3YWL7qpgtFkU8gls19lFWNeqSvqcjZ7q1TeP56uppVCqBpBJ/ccuqJX
8yT+/vFPCPvWWgSc0vs2JZSo4j/xomF9tbFY9vAc9Qqw7ZXG5wmEEWQqiwbtAqw
qxHECDAdPZ20pp6WipYAs9F/OAEc4oB04sLhC/YZfGAtjQzn06PvLYli08nxLqM4
eR6SZruM4CsSTGx5KbrqatJECYRUoIDrdSPH07G3xbZ3X6urq76Qdf5Wh6pFE5e7
nPzNBRJD6b9a7yQGLTnd5fziTp3b3hGRBS2Aw235+ENIcvJ37U9aH0jr07lggkp0
TxABsEy2hfm+5NDdsMVxWYrCAhpmBv0jNFxvu4TzwgX+UnNFibewfGOI0605kxi/
ATFQsqnfuvVI+dMqnNTGiTuksRMwot0q0+0qWJZuuwE0R11UP9d5evVJ9Wjq6+lX
9k/shUZ0kCuXVYdWmG1G6jq3o1HLvqEaaHvUP10L2JzSyrph1SGDdJk06LkiGe0l
3KARxoqXV8ATvYN7Ldc043UfZPy0s3Na8V+pWf1cW4XNnJEDr4ja7Iq1T53J1aV
bnZAE//SwySQdUqipXJSnUyS8eunx2tTQNVl98xypEBvfga6pSK7c8heqj8zXoH
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sNE81Gw1fjjmnh7pRa3RmSkypbHlxWkcn0j3ZhhT2gB4fJ14+5JVU78HpQ3Vudk1
hTQg5NGnGuYv+Qyhk83WwvS+0mNBWq+aNq1LwqIuKmY8dkUAHNGQt7wXx1/q346H
z1wkt202WE7TLnGwJoFC6j7WiYFXv5I76/AZLRv17jCn01FjSmC1BN3jii4RT3rp
vxdtShi6KJWnu0tHREqbqNu0wSTNQBuzL0vLHeSMSrtrBgegAbWgALukNhi2wZ5D
UXtFtCQFKotnxx0IGFI606Q1EcJxb/nNMyA0tnK1L/FmEIBc2+dUSoqEtm4cdfpz
wba82l1t3uVHzbA96U3Lenl0fm7zeiEPGkJAC3aSHXmdXGvC+xYGFbDLAnCQ0Zk52
H1fNDY3Ipxy5GKv2LREShc2LVhPdvQygisA0Kyve44+W+nVlSrCHF5wRPJOYaoED
VuuUVAuTy53sSqkpD/EuwaouZWyb49WQdTw2bGAUBsBhvCID0h/R90ERHQ0biB05
g8tQbD6n/zBXmD6L8BaC+7APQwBTE8gsE5KRimFloTM4/+EamSwfs9EDKqZ5pBjI
uk+KC8GZ4Qz2vXehT91qBgk1FDS00o10Q0roo2djaca+LPk0Zys0P84ErGsi4M9H
VovEXXCmjmjGSaSDCuIYWQwaQ356I6V0/kT2cIbraXufpXg18Lj3DwqSkibvszba
4hgzoCghjNY3MgKpHfmLRQduoGFT3DaaNr/SoTLbed5JU6K1+c1ZTdK9Akq8Fy9
Z1Svw/1y8K4jJpXLZmjQ/sxAab2Qu1KLg++i+829k7KJkpYh7XTYCHOPwQPusQVR
CFH8kxnxceoM7QuXtbn7XvmFGGvFIJj560dvZ7fMdmXUdYeXXLRaUPxkEAcZv3Y0
Xw/fHgnv6fuADcEU5Gvgh5oZXMBoc0I9JjHa5xw5lEgch2HEDQfFv8qV5xi3siWF
rwPtNBdaRtV681G0Mqf8GqRIJzKoGof3JPjS54Czo51FGjgPdcLWgMxyE+qx1KWd
OUrjgQockIGNUvk/sgPi2LG1+o9gstWF2RNdZiH8Tt4aVMkLSux8uzf0JtN52UY
F7jk5ksZPxqsUjqt8nSKndj/vCn01Fe2+XgbCKZ6GXXQMczXFUXAA3Q0BWwknNE+
bEvuv0b8EiIsCy7M1hWdWuq0VU16CWUrBr98ppmNZ5xbQXdVTBBqPKzA9I2qbq6
r7n6Uo8oosoq4C5QDg8CZqmWgB0uD/R8Lxbe15Gw15Ug4s8vPyV+H8dRxs7qJRD
T6WJUv3Ld/FhNyaTMG26To8hbRyOxK/w/oNgrRxdgJZEFp/caoJn8uP5CaYbKmeL
zmrpBA0nRgnt+jNi1TDcIep4URG2V5pCNLU2/zGU+Av33cfcBp5ueWibtCpR4Qg
cP01cBdCIRIZ52F2LDfw0KHRuXUP7ld+EggRXGasB+wJHmo/xKpqJTvLqGjt0xVN
yvUWL2FehUkKbKNC80xDrGGj6mv+79hQ4ZDrHY2k0otezusWeMAKM+zV1Is1NkBC
V+jKe+9YVfK4E+0vTECURaMxfJvho1ri+00rh5IbkeVywU21FM7gRSUC/CdjdnSV
yZ3qFazeGXutSSYjjm2Moe+uGdoZaqjutG004yrFcvyekmHWeMgOr82npckLwsB
VBSfFKwjPntzoit/uPCTJb8qzo07a124oSGitoIummkTHMz1IimECxE/x7C8xYQF
v+h/H5X/wu1vxV1lZ+1DZN+qbZ1abrma5N30JA==
-----END PRIVATE KEY-----
```

```
SEQUENCE {
  INTEGER { 0 }
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
  }
  OCTET_STRING {
    OCTET_STRING { `9792bcec2f2430686a82fccf3c2f5ff665e771d7ab41
b90258cfa7e90ec97124d8e9ee4e90a16c602f5ec9bc38517dc30e329d5ab276
73bd85f4c9b0300f776389886750b57c24db3fc012e61ede59753337374fa712
4991549af243496d0637cb3be05a5948235bf79875f896d8fe0cab30c84948db
4d6315aaaf160ac6243664220148161109112c94028922452c62b84500452a08
967090126e149370d446108444515896910ca92982b241c90871c42868049689
4840859b226d1c28645912419cb891840489449005cb3462a086904026922099
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c3c04da49821984020d14286cb40705bb0719c962cc112065346090c45021446
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59b485d314650a406e11296518c24c213465d830691030521931668c188ac8c0
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1101a39411e3986c58202109411060362208067112c2855aa085c0c6845c3806
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681b16521a370250204248488a201141e2006cc0c20c14064911314d19060a89
46091b816544c800820670001672cc24508a42899c969064287092b268982662
619440c11689d842641a214e62906421c8248b286d5c4292a0c64d0c8580cc88
4dd4428d42348a0b0451c32686242581123506a04404c894815bb4311c08065c
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21482ed81606d2108a83a22508310d093851d948490b164c2332251919024a44
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130ad9460d224561c8b440a1422d02b8090014449bb6110b978c40104a82146a
da90051c028e0c1972a3b48d24305011870964c628e4189298b46c6116514046
0e1c3248da205188368a23b1218290281a1532e2186192048e13b690131368c9
84684c406d0b330081464dd2380c049681a4885002908522b004d3a471d28010
ca964051a641a48428e008520b308cd2380a0c2951c38209ca2091d83692a3a6
28924222a216011a348637d9a659169881ec21cf4811869d1d7f139f0537e96f
1184585405fd17808af1e06239d3b34e5aca8bf1369677b447ac718ac47d850c
```

4d77b0be31dc9f508e3978f24274ab0185f727abdf59f4490371bf04610e364
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aeaddc84db62746a35ac096f782f62a7f01aa6d6693deec90b23c66985a02307
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1258c5f529aa55cb7ebae2e1652315e1f71e8a74131410d03247ede11d34db91
f6f08aa2478fd789679c04949f71bc0171e07e3a8bb5753dbbdaa411a6350ab4
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55bdf356a198d0f7eb6d34111fc940b25c0543b788edda9d26810eac3d6cc9c5
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C.1.3.3. Both Format

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6M2LVMNwh6nhREbZXmkI0u7b/MZT4C/fdx9wGnm55aJu0K1HhCBw87VvF0IhEhnn
YXYsN/DQodG5dQ/uV34SCBfcZqwh7Akeaj/Eqmol08uoa03TFU3K9RYvYV6FSQps
o0LzTEOsYaPqa/7v2FDhk0sdjaTSi1706xZ4wCQz7NXUiyU2QEJX6Mp771hV8rgT
7S9MQJRFozF8m+GjWuL7TSuHkhuQS/LBTbUuZuBFJRz8J2N02xxXJneoVrN4ZfG61
JJi00bYyh764Z2h1qq060bQ7jKsVy/J6SYdZ4yA6vzaelyQvCwFUFJ8UrCM8230i
K3+48Jm1vyr0g7trXbihIaK2ghSaaRMcz0UiKYQLET/HsLzFhAW/6H8f1f/C6W/F
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-----END PRIVATE KEY-----

```

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  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
  }
  OCTET_STRING {
    SEQUENCE {
      OCTET_STRING { `000102030405060708090a0b0c0d0e0f1011121314
15161718191a1b1c1d1e1f` }
      OCTET_STRING { `9792bcec2f2430686a82fccf3c2f5ff665e771d7ab
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7673bd85f4c9b0300f776389886750b57c24db3fc012e61ede59753337374fa7
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5c240803276a20c225e1809019b46da3460c4b186050c62c1b922d111504a200
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18130ad9460d224561c8b440a1422d02b8090014449bb6110b978c40104a8214
6ada90051c028e0c1972a3b48d24305011870964c628e4189298b46c61165140
460e1c3248da205188368a23b1218290281a1532e2186192048e13b690131368
c984684c406d0b330081464dd2380c049681a4885002908522b004d3a471d280
```

10ca964051a641a48428e008520b308cd2380a0c2951c38209ca2091d83692a3
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6f1184585405fd17808af1e06239d3b34e5aca8bf1369677b447ac718ac47d85
0c4d77b0be31dc9f508e3978f24274ab0185f727abdf59f4490371bf04610e3
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2c6bbd38c84ab7b54823ec363eb7e42eb59fc1fce60fbd55307b3ec85fd9daf3
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fa754bb2b087179c113c93986a810356eb94540b93cb9dec4aa9290ff12ec1aa
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ffe11a992c1fb3d1032aa679a418c8ba4f8a0bc199e10cf6bd77a14fdd6a0609
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1ccce52229840b113fc7b0bcc58405bfe87f1f95ffc2e96fc5596567e94364df
aa6d9d5a6eb99ae4ddf424` }
}
}
```

C.2. Example Public Keys

The following is the ML-DSA-44 public key corresponding to the private key in the previous section. The textual encoding [RFC7468] is followed by the so-called "pretty print"; the public keys are the same.

```
-----BEGIN PUBLIC KEY-----
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GYRsrBjIqpdORME0VWuiFbWnGeWdDgsq1tOYWQcf3MLN51JKe+2uV0hbMY6FTo/i
svPt+s1xkSgnCq/R5QRM0k/a/Z/zH5B4S46ORZYUSg2vWGUR09mWK56pWvGXtOX8
YPKx7RXe01vvX4m9x52RBR2bKBbnT6VfMe/cHL501EiFf0drzVjyHAt10zt2p0B2
plWamCcYVvzGP3SfMqurk18C0GHKjND3utsocfZ9VTJtdFETWtRfShumKj7ssiJ
DuyTku8/l3Bmya3VxxDMZHsVFNIx2VjHAXw+kP0gwE5nS5BIbpNwoxoAHTL0c5ee
SQZ0nn5Hf6C3RQj4pfi3gxK4PCW90IygsP/3R4uvQrcWZ+2qyXxGs1kP1huWwVa
DCEZRTzTbmbd7Vhg+gQqMV2YJhZNapI3w1pFv0lUkKW9TfJIuVxKrneEtgVnMWas
QkW1tLCCoJ6TI+YvIHjFt2eDRG3v1zat0jcC1JsImESQcMGDM5e8RBmzDXqXoLOH
wZEUdMTUG1PjKpd6y280p122W70eWecB52lX3vby1EVZwXP3EitSB001whnxaIsU
7QvAuAGz5ugtZUPpw0n0F0TNmBW9G8iCDYuxI/BPrNGxt0XdWisbjbvz7ZM2cPCV
oYC08ZLQixC4+rVfzCskUY4y7qC14MkEyoRHgAg/OwzS0Li2r2e8NVuU1AJdx7Cn
j6g00i2/61EyiFHWB4GY6Uk2Ua54fsA1H5Irow6fUd9iptcNhM890gU5MXbfoyS1
Er2U1wo23TS1FKhkfDrNvAUWwmrZGUbSgMTsplhGiocSIkWJ1mHaKMRQC6RENI
bfUVIqH0iLMJhcIW+0btF43VZ7MEoNtk+6iCooNC8Xqaomr1jbYwCD0sNY/fVmw/
XWkkKFZ7yeqM6VYqDzVHsWv6jz0aJQq0388gg76077wQVeGP4VNw7ssmBwBYP/Br
IRquxDyim1TM0A+IFaJGXvC0ZRXmfkHZEK8J7/9zkwmrWlKaFFmgC85Q00k4yWeP
cus0TuX9quZtn4Vz/Jf8QrSVn0v4th14Qz6GsDNdbpGRxNi/SHs5BcEiZ9asJLD0
t9y3z1H4TQ7Wh71errHFM8BvDZcCPZKnCCWDe1m6bLfU5WsKh8IDhiro8xW6WSXo
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-----END PUBLIC KEY-----
```

```

SEQUENCE {
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
  }
  BIT_STRING { `00` `d7b2b47254aae0db45e7930d4a98d2c97d8f1397d17
89dafa17024b316e9bec94fc9946d42f19b79a7413bbaa33e7149cb42ed51156
93ac041facb988adeb5fe0e1d8631184995b592c397d2294e2e14f90aa414ba3
826899ac43f4cccacbc26e9a832b95118d5cb433cbef9660b00138e0817f61e7
62ca274c36ad554eb22aac1162e4ab01acba1e38c4efd8f80b65b333d0f72e55
dfe71ce9c1ebb9889e7c56106c0fd73803a2aecfeafded7aa3cb2ceda54d12bd
8cd36a78cf975943b47abd25e880ac452e5742ed1e8d1a82afa86e590c758c15
ae4d2840d92bca1a5090f40496597fca7d8b9513f1a1bda6e950aaa98de46750
7d4a4f5a4f0599216582c3572f62eda8905ab3581670c4a02777a33e0ca7295f
d8f4ff6d1a0a3a7683d65f5f5f7fc60da023e826c5f92144c02f7d1ba1075987
553ea9367fcd76d990b7fa99cd45afdb8836d43e459f5187df058479709a01ea
6835935fa70460990cd3dc1ba401ba94bab1dde41ac67ab3319dcaca06048d4c
4eef27ee13a9c17d0538f430f2d642dc2415660de78877d8d8abc72523978c04
2e4285f4319846c44126242976844c10e556ba215b5a719e59d0c6b2a96d3985
9071fdcc2cde7524a7bedae54e85b318e854e8fe2b2f3edfac9719128270aafd
1e5044c3a4fdafd9ff31f90784b8e8e4596144a0daf586511d3d9962b9ea95af
197b4e5fc60f2b1ed15de3a5bef5f89bdc79d91051d9b2816e74fa54531efdc1
cbe74d448857f476bcd58f21c0b653b3b76a4e076a6559a302718555cc63f748
59aabab925f023861ca8cd0f7badb2871f67d55326d7451135ad45f4a1ba6911
8fbb2c8a30eec9392ef3f977066c9add5c710cc647b1514d217d958c7017c3e9
0fd20c04e674b90486e9370a31a001d32f473979e4906749e7e477fa0b74508f
8a5f2378312b83c25bd388ca0b0fff7478baf42b71667edaac97c46b129643e5
86e5b055a0c211946d4f36e675bed5860fa042a315d9826164d6a9237c35a5fb
f495490a5bd4df248b95c4aae7784b605673166ac4245b5b4b082a09e9323e62
f2078c5b76783446defd736ad3a3702d49b089844900a61833397bc4419b30d7
a97a0b387c1911474c4d41b53e32a977acb6f0ea75db65bb39e59e701e76957d
ef6f2d44559c31a77122b5204e3b5c219f1688b14ed0bc0b801b3e6e82dcd43e
9c0e9f41744cd9815bd1bc8820d8bb123f04facd1b1b685dd5a2b1b8dbbf3ed9
33670f095a180b4f192d08b10b8fabdbfcc2b24518e32eea0a5e0c904ca84478
0083f3b0cd2d0b8b6af67bc355b9494025dc7b0a78fa80e3a2dbfeb51328851d
6078198e9493651ae787ec0251f922ba30e9f51df62a6d72784cf3dd20539317
6dfa324a512bd94970a36dd34a514a86791f0eb36f0145b09ab64651b4a0313b
299611a2a1c48891627598768a3114060ba4443486df51522a1ce88b30985c21
6f8e6ed178dd567b304a0d4cafba882a28342f17a9aa26ae58db630083d2c358
fdf566c3f5d62a428567bc9ea8ce95caa0f35474b0bfa8f339a250ab4dfcf208
3be8eefbc1055e18fe15370eeeb260566d83ff06b211aaec43ca29b54ccd00f8
815a2465ef0b46515cc7e41f3124f09efff739309ab58b29a1459a00bce5038e
938c9678f72eb0e4ee5fdaae66d9f8573fc97fc42b4959f4bf8b61d78433e86b
0335d6e9191c4d8bf487b3905c108cfd6ac24b0ceb7dcb7cf51f84d0ed687b95
eaeb1c533c06f0d97023d92a70825837b59ba6cb7d4e56b0a87c203862ae8f31
5ba5925e8edefa679369a2202766151f16a965f9f81ece76cc070b55869e4db9
784cf05c830b3242c8312` }
}

```

The following is the ML-DSA-65 public key corresponding to the private key in the previous section. The textual encoding [RFC7468] is followed by the so-called "pretty print"; the public keys are the same.

```
-----BEGIN PUBLIC KEY-----
MIIHsjALBgIghkgBZQMEAxIDggehAEhoPZGXjjHrPd24sEc0gtK4i19iWUn9j1i1
YeaWvUwn0Fs427Lt8B5mTv2Bvh6ok2iM5oqi1RxZWPi7xut0ie5n0sAyCVTVchLK
xyKf8dbq8DKovVFRH42I2EdzbH3icw1Ze0VBBxMWCXiGdxG/VTmgv8TDUMK+Vyuv
DuLi+xbM/qCAKNmaxJrrt1k33c4RHNq2L/886ouIz0eVvvFxaHnJt5j+t0q8Bax
GRd/o9lXotkncXP85VtndFrwt8IdWX2+uT5qMvNBxJpai+noJQiNHYqkUVXWyK4V
Nn50sA04/feFEHGULzn5//CQI+r0UQTsqEpFkG7tRnGkTcKNJ5h7tV32np6FYfYa
gKcmmVA4Zf7Zt+5yq0F6GcQIFE9LKa/vcDHDpthXFhC0LJ9CEKWoJx1+FoErAxFZ
tluWh+Wz6TTFILrpinm6c9Kzmdc1EO/60Z5TuEUPC6j84QEv2Y0mCnSqqhP64kmg
BrHDT1uguILyY3giL7NvIoPCQ/D/618btBSgpw1V49QKVrbLyIrh8Dt7KILZje6i
jhRcne39jq8c7y7ZSOSFD4lk9G0eoNDCpD4N2mGCrB9PbtF1tnQiV4Wb8i86QX7P
H52JMXteU51YevFrnhMT4EUU/6ZLqLP/K4Mh+IEcs/sCLI9kTnCkuAovv+5gSrtz
eQkeqObF038AoNma0DAeThwAoIEoTa/Xa1WjreY00kDi9sMEeA0ReeEFLUGnHXP
KKXgHHeZ2VghDdvLIm5Rr++fHer7Bzhz1tP5dFa+3ghQgudKKYss1I9LMJMVXzZs
j6YBxq+FjfoyrISRsqKYh/kDNZSaXW7apnmIKjqV1r9tIwoiH0udPYy/OEr4GqyV
4rMpTgR4msg3J6XcBFwflq9B2KBTUW/u7rxSdG62qygZ4JEIcQ2DXwEfpjB1hyrT
NNXN/7KyMQUH6S/Jk64xfal/TzCc2vD2ftmdkCFVdgg4Sf1TskbX/ts/22dnmFC1
rUB0ZBR/t89Pau3dBa+0uDSWjR/ogBSWdc5d1CI2Um4SpHjWn1++aXAczCMBORQ
GM/HsqtDCh0msax7sCzMuZ2RGsLxEGhhP74Cm/30As9c041Q7XLIOUTt+8dWfa+H
+GTAUfPFVfBFQShjpAwG0dq1Yr3/BXG4080Re70wCIC7pemYI5uV+pG31kFtZmL
0tvNMJg+01krTZ731CNv0A9Q2Yq10iNaxBcnIPd91hcmcpGM/o/3pacCeD7cK6Mb
I1kBWHEvx/RoqL5RkA5AC0w72eLTLeyvBFiFr96mnwYug03tY/QdRXTEVBj02FL
56B+dEMAdQ3x0sWHUziQWer8PXhczdMcB2SL7cA6XDuK1G0GTvNBpVc3Ryn8Ti1T
YuK1GRIEUwQovBUir6KP9f4WVeMEy1vIwnrQ4MajndTfKJVsfLOMyTaCzv5AK71e
gtKcRk5E6103tI/FaN/gzG60FrrqBeUTVZDxkpTnPoNnsCFtu4FQMLneVZE/CA0c
QjUcWeVRXdWvjgiaFeY16Pbe5jk4bEZJfXomMoh3TeWBp96WKbQbRCQUH5ePuDMS
C0/ew8bg3jm8VwY/Pc1sRwNzWiR6inLx8xtZIO4iJCDrOhqp7UbHCz+birRjZf0
NvvFbqVrpfmp6wRSGRHjDZt8eux57EakJhQT9WXW98fSdxwActjwX0anSY/utQH
P2qfbCuK9LTDmQEDoM/6Xe6y0GLKPCFf02ACa+ffFk9KRCTvdJSIBNzvrKh3Mgg
LH1UeGR7TqcdYnwIYCTMo1SkHwh3s48Zs3dK0glcjaU7Bp4hx2ri0gB+Fnge1ACA
0zT321Lp9aWZBDnK8IOpW4M/Aq0QoIwabQ8mDABYhb1KL0dw01rvR1KH010xisI1
FDfiEP9WaBSxD4eik9bxmdPD1ZmQ0MEmi09Q1fn877vyN70MKLgBgtZ110HxTxC/
uyG7oSq2IKojlvVsBoa06pAXmQIKIwsv6K12xKkUju+ahqNjWmqne8Hc+2+6Wad9
/am3Uw3AyoZiYnlzc44Burjwi0kF6EqkZBvWAKEM2XUgJl8vIx8rNeFesvoE0r2U
1ad6uvHg4WEBCpkAh/W0bqmIsrwFEv2g+pI9rdbEXFMB0JSDZzJl1tasuEPS6Ug9r
utVkpCPV4nvbCA99IOEylqMYGVTDnGSc1D6+F99cH3quCo/hJsR3WFpdTWSKDQCL
avXozTG+aaKpbU8/017YbyIeS5P2X1kp1nUzYkuSNXUMMHB1ULWFNtEJpxMcWlu+
SlcVVnwSU0rsdmB2Huu5+uKJHHdfibgOVmrVV93vc2cZa3In6phw7wnd/seda5MZ
poebUgXXa/erpazz0vtZ0X/FTmg4PWv1oI6bZtpT3N4Ai7KUuFgr0TLNzEmVn9vC
H1JyGIDIrQNSx58DpDu9hMTN/cbFKQBeHnzZo0mnFoo1Vpu13qgY1o1akUZr1uZ0
IL9iQXGYr8ToHCjdd+1AKCMjmlUvvehryE9HW5AWcQziqrwRoGtNuskB7BbPNlyj
8tU4E5SKaToPk+ecRspdWm3KPSjKUK0YvRP8pVBZ3ZsYX3n5xHGWP0gbIQS8RgoF
HgLy6ERP
-----END PUBLIC KEY-----
```

```
SEQUENCE {
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.18 }
  }
  BIT_STRING { `00` `48683d91978e31eb3dddb8b0473482d2b88a5f62594
9fd8f58a561e696bd4c27d05b38dbb2edf01e664efd81be1ea893688ce68aa2d
51c5958f8bbc6eb4e89ee67d2c0320954d57212cac7229fff1d6eaf03928bd515
11f8d88d847736c7de2730d5978e5410713160978867711bf5539a0bfc4c350c
2be572baf0ee2e2fb16ccfea08028d99ac49aebb75937ddce111cdab62fff3ce
a8ba2233d1e56fbc5c5a1e726de63fadd2af016b119177fa3d971a2d9277173f
ce55b67745af0b7c21d597dbeb93e6a32f341c49a5a8be9e825088d1f2aa4515
5d6c8ae15367e4eb003b8fdf7851071949739f9ffff09023eaf45104d2a84a459
06eed4671a44dc28d27987bb55df69e9e8561f61a80a72699503865fed9b7ee7
2a8e17a19c408144f4b29afef7031c3a6d8571610b42c9f421245a88f197e168
12b031159b65b9687e5b3e934c5225ae98a79ba73d2b399d73510effad19e53b
8450f0ba8f0e1012fd98d260a74aaaa13fae249a006b1c34f5ba0b882f263782
22fb36f2283c243f0fffeb5f1bb414a0a70d55e3d40a56b6cbc88ae1f03b7b288
2d98deea28e145c9dedfd8eaf1cef2ed9a48b050f8964f46d1ea0d0c2a43e0dd
a6182adb4f6ed175b6742257859bf22f3a417ecf1f9d89317b5e539d587af16
b9e1313e04514ffa64ba8b3ff2b8321f8811cb3fb022c8f644e70a4b80a2fbfe
e604abb7379091ea8e6c5c74dfc0283666b40c0793870028204a136bf5da9568
eb798d349038bdb0c11e03445e7847cb5069c75cf28ac601c7799d958210ddbc
b226e51afef9f1de47b073873d6d3f97456bede085082e74a298b2cd48f4b309
3155f366c8fa601c6af858dfa32c08491b2a29887f90335949a5d6edaa679882
a3a95d6bf6d970a221f4b9d3d8cbf384af81aac95e2b3294e04789ac83727a5d
c04559f96af41d8a053516feeeebc52746eb6ab2819e09108710d835f011fa63
065872ad334d5cdfb2b2310507e92fc993ae317da97f4f309cdf0f67ed99d9
0215576083849f953b246d7fedb3fdb67679850a5ad404e64147fb7cf4f6aedd
d05afb4b834968d1fe88014960dce5d942236526e12a478d69e5f6e6970310b3
08c06845018cfc7b2ab430a13a6b1ac7bb02cccbb3d911ac2f11068613f6e029
bfdce02cf5cd38950ed72c83944edfbc75615af87f864c051f3c55456c541286
3a40c06d1dab562bdf0571b8d3c3917bbd300880bba5e998239b95fa91b7d64
16d4f398b3adbc30983ed3592b4d9ef7d4236fd00f50d98aa53a235ac417272
0f77d96172672980cfe8ff7a5a702783edc2ba31b2259015a112fc7f468a9c2f
9464039002d30ef678b4cb798bc116216bf7a9a7c18ba03b7b58fd07515d3115
049d3614be7a07e744300750df1d2c58753389059eafc3d785ccdd31c07648be
dc03a5c3b8ad46d064d59c13d57374729fc4e295362e2a5191204530428bc152
2afa28ff5fe1655e304ca5bc8c27ad0e0c6a39dd4df28956c14b38cc93682cef
e402bbd5e82d29c464e44eb5d37b48fc568dfe0cc6e8e16baea05e5135590f19
294e73e8367b0216dbb815030b9de55913f08039c42351c59e5515dd5af8e089
a15e625e8f6dee639386c46497d7a263288774de581a7de9629b41b4424141f9
78fb8331208efdec3c6e0de39bc57063f3dcd6c470373c08891ea29cbc7cc6d6
483b8889083ace86aa7b51b1c2cfe6e2ad18d97ce36fbc56ea42fae97e6a7ac1
14864478c366df1ebb1e7b11a9098504fd5975bdf1f49dc70002b63c1739a9d2
63fbad4073f6a9f6c2b8af4b4c332a103a0cffa5deeb2d062ca3c215fd360026
be7c5164f4a4424ef74948804d66f46487732c8202c795478647b4ea71d627c0
86024cca354a41f0877b38f19b3774ad2095c8da53b069e21c76ae2d2007e167
19ed40080d334f7da52e9f5a5990439caf083a95b833f02ad10a08c1a6d0f260
c007285bd4a2f47703a5aef465287d253b18ac22514316210ff566814b10f87a
293d6f199d3c3959990d0c1268b4f50d5f9fcefbbf237bd0c28b80182d665974
1f14f10bfbb21bba12ab620aa2396f56c0686b4ea9017990224216b2fe8ad76c
4a9148ee9a86a3635a6aa77bc1dcfb6fba59a77dfda9b7530dc0ca8648c8d97
3738e01bab8f08b4905e84aa4641bd602410cd97520265f2f231f2b35e15eb2f
a04d2bd94d5a77abaf1e0e161010a990087f5b46ea988b2bc0512fda0fa923da
dd6c45c5301d09483673265b5ab2e10f4ba520f6bbad564a5c3d5e27bdb080f7
d20e13296a3181954c39c649c943ebe17df5c1f7aae0a8fe126c477585a5d4d6
48a0d008b6af5e8cd31be69a9296d4f3fd25ed86f221e4b93f65f59299675336
```



```
24b9235750c30707550b58536d109a7131c5a5bbe4a5715567c12534aec76607
61eebb9fae2891c774589b80e566ad557ddef7367196b7227ea9870ef09ddfec
79d6b9319a6879b5205d76bf7aba5acf33afb59d17fc54e68383d6be5a08e9b6
6da53dcde008bb294b8582bd132cdcc49959fdb21e52721880c8ad0352c79f0
3a43bbd84c4cdfdc6c529005e1e7cd9a349a7168a35569ba5dea818968d5a914
66bd6e64e20bf62417198afc4e81c28dd77ed4028232398b52fbde86bc84f475
b9016710ce2aabc11a06b4dbac901ec16cf365ca3f2d53813948a693a0f93e79
c46ca5d5a6dca3d28ca50ad18bd13fca55059dd9b185f79f9c47196a4e81b210
4bc460a051e02f2e8444f` }
}
```

The following is the ML-DSA-87 public key corresponding to the private key in the previous section. The textual encoding [RFC7468] is followed by the so-called "pretty print"; the public keys are the same.

```

-----BEGIN PUBLIC KEY-----
MIIKmjALBg1ghkgBZQMEAxMDggohAJeSv0wvJDBoaoL8zzwvX/Z153HXq0G5A1jP
p+kOyXEkpzsY05uiGrZNdnpDP1pShv/hj4bkahiJUUsRGfgSLcp5/xNEV5+SNOY1t
X+EZsQ3N3vYssweVQHS0IzblKDbeYdqUH4036misgQb6vkhHBnmvYAhTcSD3B504
6pzA5ue3tMmlx0IcYPJEUboekz2xou4Wx5VZ8hs9G4MFhQqkKvuxPx9NW59InfnY
ffzrFi009Kf9xMuhdDzRyHu0ln2hbMh2S2Vp3471vcv/6aTgV0jm/fI1r55063dz
ti6Phfm1a1SJRUVYRPvYmAakrDab7S01YQD2iKatXgpwmCbcREnPHiPFUG5kI2Hv
WjE3EvebxLMYaGHKhaS6sX5/LD0bijM6o6584WtEDWAY+eBNr1c1x/GpP60aWie2
eJW9JJqpFoXeIK8yyLfiaMf5aHfQyFABE1pPCo8bgmT6br5aNJ2K7K0aFimczy/Z
x7hbr0L006oSdrph7njtfl1y1tnzdRYqTVAM0aru6v1agojFv7J26g7UdQv0xZ/Hg
+QhV1cZ1CbIQJ13B5U7ES006fPmu8Ri0TYCRL0dRZqZ1HhFs6+SSKacGLAMTH3Gr
0ik/dvfvvyFbqXGA35Y5HC9u7Q8GwQ56vecVNk7RkrJ7+n74VGHTPsqZMvuKMxM
D+d3X12HDxwC5bLjxQBmMv8kybd5y3U6J300cf1CXra8LKVs4SnbUfcHQPMeY5dr
UMcxLpeX14xbGsJKX6NHZJFuCoP1w7Z1zTC4Hj+hC5NETgc5dXHM6Yso2lHbkFa8
coxbCxB4vvTh7THmrG1/v70NxZ693LdrRrTDmC21pZ0nrFz7GMVCRFwAno6te
9qoSnlHyVye5NYooUB1x0nLz8dsxcUKG+bZAgB0vBgRddVkvwLfdR8c+2cdbEenX
xp98rfwygKkGLFJzxDvhw0+HRIhkzqe1yX1tMvWb1fJThGU7tcT6pFvqi41AKEPm
Rba5Jp4r2YjdrLazMo/7BgRQ998IAFPmlpslHodezsMs/FkoQNaatpp14Gs3nFNd
lSZrCC9PCckxYrM7DZ9zB6Tqq1IQRdf+1m+04+q71F1nslqBM/SWRotSuv/b+tk+
7xqYGLXkLscieIo9jTUp/Hd9K6VwgB364B7IgwKDFB+54DVXJ2Re4QRsP5Ffaugt
rU+2sDVqR1GP/INBvc00/m2vpsyKXM9TzxoISdjUT33PcnV0cOG337RHu070nRpx
j2Fxu84gCVDgzpJhBrFRo+hX1c5JcxvWZQqbDKly2hxfE21Egg6mODwI870EzyM4
54nFE/YYzFaUpvD04QRRHh7XxfI6Hr/YoNuEJFUyQBvtv2IoMbDGQ9HFUbbz96mN
KbhcleBaZfphXu4WSVvZBzdnIRW1PpHF2QAozz8ak5U6FT3100QITpzP9rc2aTkm
2u/rstd6pa1om5LzFoZmnfFtFxxMWPeiz7ct0aUekvglmTp0Aivn6etgVGVEVw1N
FJKPICFeeyIqxWtRrb7I2L22mD15p+0iG0S10VGMqX0LUZX1HtaiQ1DI10fh7epR
tEj6RRwVM6SeHPJDb0U2GiI4H3/F3WT1veeFSMCIErrA74jhq8+JAeL0CixaJ9e
FHyFRSyM6wLsWcydtjoDV2zur+mCOQI419oCNmMKU8Def0NaGYaXkvqzbnueY1dg
8JBp5kMucAA1rCoCh5//Ch4b7FIgRkx910td8e/VPuoRRMp41AhS9eyXJ5BLNm7e
T14tMx+tX8K6ixH6SMUJ3HD3XWoc1dIfe+Z5fg0nZ7WI8F10CiIXr+CwHqA1UcW
s8PCvb4unwqbuq6+tNUpNodkBvXADo5LvQpewFeX5iB8WrbIjxpohCG9BaEU9Nfe
KsJB+g6L7f9H92Ldy+qpEAT40x6FCVvBBUmUrTgm40S61gQIEPwLktheSM+t4ALG
LlpJoHmas4NEvBY23xa/YH1WhV5W1oQAPHGOS62eWgmZefzd7rHEp3ds03o0F8s0
GE4p75vA6HR1umY74J4Aq1Yut8D3F1+WmptCQUGYzPG/8qLI1omkFOznZiknZ1aJ
6U25YeuxWFcvBp41caFGslhQy/xEY1GB9Mu+dxzLVEz0+S000MN3qeE7Ki+R+dB
vpwZYx3EcKUu9NwTpPnjP9Q014fBcJd7QX31m0HQ3eUGu3HW8LwX7HDjsDzcGWXL
Npk/YzsEcuUNCS0sbG698dPmRzZBIfd1+U0J6dvPXWk0Iym40KC6y3xjJrsmUKQw
jNFxtoVRJtHaZypu2FqNeMKG+1b0qz0hSXUoBFxjJiyKQq8vmALF03u4vijnj+C1
zkX7t6GvGjsoqN1LeJDjyILjm8mOnwrXYCW/DdLwApjnFBoiaz187kFPYE0eC6VN
EdX+WLz0pq13rS6MHKRPmkWQFL5EAGx76itFypSP7jjZbV3Ehv5/Yiixgwh6CHX
tqy0elqZkDKztXCI7j+beXhjp0uWJOu/rt6rn/xoUYmDi8RDpOVKCE6ACWjjsea
q8hhs168UJpGdMEyqqy34BRvFO/RHPyvTKpPd1pxb0M14KQ1pNNJ1yC88TdfCvxF
BG/Bofg6nTKXd6cITkqtrnEizpcAWTBSjrPH9/ESmzcoh6NxFVo7ogGiXL8dy2Tn
ze4JLDFB+1VQ/j0N2C6HD1eLK0ZQCbgR0491aXc8Z30FtppCt33Lp6z/2V/URS4j
qqHTfh2iFR6mWNQKNZayesn4Ep3GzwZDdyYktZ9PRhIw30ccomCHw5QtXGaH32CC
g1k1o/h8t2Kww7HQ3aSmUz11vvG3uCuKjUwBTQkP7YV8RMGDnG1MCMtj+tkKEfU0
citu4VdPLhSdVddE3kiHAK4IURQxwGJ1DhbHSrnzJC8ts/+xKo1hB/qiKdb2NzsH
8205Mr09sEwZ3WTq3X+Tw8Vkw1ihyB3PHJwx5bBlapL1RMF9wVaYxcs4mDqa/EJ4
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kWewE9BCM5Xuaaqu4yBhSafVUNZ/xf3+SopcNdJRC2ZDeauPcoVaKvR6v0KmMgSO
r4nly0qI3rxTpZUQ0szk8c/xis/wev4etXFqoeQLYxNM0jrpV5+of1Fb4JPC0p22
1rZck2YeAGNRWScE0JPMZxbCNC6xhT1IyFxrIooVEYse3fn470erFvKKP+qALXT
SfilR62HW5aowrKRDJMBMJo/kTilaTER9Vs8AJypR80d/ILZjrHKpKnL6IX3hvqG

```

```
5VvgYiIvi6kKl0BzMmsxISrs4KNKYA==  
-----END PUBLIC KEY-----
```

```
SEQUENCE {
  SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
  }
  BIT_STRING { `00` `9792bcec2f2430686a82fccf3c2f5ff665e771d7ab4
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1743cd1c87bb4967da16cc8764b6569df8ee5bdcbbffe9a4e05748e6fdf225af9
e4eeb7773b62e8f85f9b56b548945551844fbd89806a4ac369bed2d256100f68
8a6ad5e0a709826dc4449e91e23c5506e642361ef5a313712f79bc4b3186861c
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d1a5a27b67895bd249aa91685de20af32c8b7e268c7f96877d0c85001135a4f0
a8f1b8264fa6ebe5a349d8aead1a16299ccf2fd9c7b85bace2ced3aa1276ba6
1ee78ed7e5ca5b67cdd458a9354030e6abbbabf56a0a2316fec9dba83b51d42f
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736693926daefeb2d77aa5ad689b92f31686669df16d1715cc58f7a2cfb72dd
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db63a03576ceafe98239023897da0236630a53c0de7f435a19869792fab36e7
b9e635760f09069e6432e700035ac2a02879ffff0a1e1bec522047193d94eb5df
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05797e6207c5ab6c88f1a688421bd05a114f4d7de2ac241fa0e8bedff47f762d
dcbeaa91004f8d31e85095c81054994ad3826e344ba96040810fc0b2ad1de48c
fade002c62e5a49a0731ab38344bc1636df16bf607d56855e56d684003c718e4
bad9e5a099979fcddeeb1c4a7776cd37a3417cb0e184e29ef9bc0e87475ba663
be09e00ab562eb7c0f7165f969a9b42414198ccf1bfff2a2c8d689a414ece7662
927665689e94db961ebaec5615cbc1a7895c6851ac961432ff1118d4607d32ef
9dc732d51333be4b4d0e30dde784eca8be47e741be9c19631dc470a52ef4dc1
3a4f3633fd434d787c170977b417df598e1d0dde506bb71d6f0bc17ec70e3b03
cdc1965cb36993f633b0472e50d0923ac6c66fdf1d3e6459cc121f0f5f94d09e
```

```

9dbc5f5d690e23233838a0bacb7c638d1b2650a4308cd171b6855126d1da672a6
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ab9f3242f2db3fffb12a8d6107faa229d6f6373b07f36d3932b3bdb04c19dd64e
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a9afc42783faa773a52c9d8260690be9e3156aa5bc1509dea3f69587695cd6ff
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c1fc856d1802762840ebc72d7988bde75cbca70d319d32ce0cc0253bb2ad4557
23ee0c7f4736ce6e6665c5aca32a481c53839bc259167b013d0423395eeb9aaa
ee3206149a7d550d67fc5fdfe4a8a5c35d2510b664379ab8f72855a2af47abce
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4d093cc6716c2342eb1853d48c85c63ac8a2854462c7b77e7e3bd1eac5bca28f
faa00b5d349f8a547ad875b96a8c2b2910c9301309a3f9138a5693111f55b3c0
09ca947c39dfc82d98eb1caa4a9cbe885f786fa86e55be062222f8ba90a97407
3326b31212aece0a34a60` }
}

```

C.3. Example Certificates

NOTE: The example certificates in this section have key usage bits set to digitalSignature, keyCertSign, and cRLSign to lessen the number of examples, i.e., brevity. Certificate Policies (CPs) [RFC3647] for production CAs should consider whether this combination is appropriate.

The following is a self-signed certificate for the ML-DSA-44 public key in the previous section. The textual encoding [RFC7468] is followed by the so-called "pretty print"; the certificates are the same.

```

-----BEGIN CERTIFICATE-----
MIIP1DCCBgqgAwIBAgIUfZ/+byL9XMQsUk32/V4o0N44804wCwYJYIZIAWUDBAMR
MCIxDTALBgNVBAoTBELFVEYxETAPBgNVBAMTCExBTVBTIFdHMB4XDTIwMDIwMzA0
MzIxMFoXDQwMDEyOTA0MzIxMFowIjENMAsgA1UEChMESUVURjERMA8GA1UEAxMI
TEFNUFMgV0cwggUyMASGCGSADF1AwQDEQ0CBSEA17K0c1Sq4NtF55MNSpjSyX2P
E5fReJ2voXAKsxbpvs1PyZRtQvGbeadBO7qjPnFJy0LtURVp0sBB+suYit61/g4d
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F/YediyidMNq1VTrIqrBFi5KsBrLoeOMTv2PgLZbMz0PcuVd/nHOnB67mInnxWEG
wP1zgd0q7P6v3teqPLL021TRK9jNNqem+XWU00er016ICsRS5XQu0ejRqCr6huWQ
x1jBWuTShA2SvKGLCQ9ASWWX/KfYuVE/GhvabpUKqpjeRnUH1KT1pPBZkhZYLdVY
9i7aiQwRNYFnDEoCd3oz4Mpy1f2PT/bRoK0naD119fX3/GDaAj6CbF+SFEwC99G6

```

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 6FsxjoV0j+Ky8+36yXGRKCCr9H1BEw6T9r9n/MfkHhLjo5F1hRKDa9YZRHT2ZYr
 nqla8Ze05fxg8rHtFd46W+9fib3HnZEFHZsoFudPpUUX79wcvnTUSIV/R2vNWPIC
 C2U703ak4HamVZowJxhVXMY/dIWAq6uSXwI4YcqM0Pe62yhX9n1VMm10URNa1F9K
 G6aRGPuyyKM07JOS7z+XcGbJrdXHEMxkexUU0hfZWMcBfD6Q/SDATmdLkEhuk3Cj
 GgAdMvRz155JBnSefkd/oLdFCP1l8jeDErg8Jb04jKCw//dHi69CtXzn7arJfEax
 KWQ+WG5bBVoMIR1G1PNuZ1vtWGD6BCoxXZgmFk1qkjfdWl+/SVSQpb1N8ki5XEqu
 d4S2BWcxZqxCRbW0sIKgnpMj5i8geMW3Z4NEbe/XNq06NwLUmwiYRJAkYYMz17xE
 GbMNepegs4fBkRR0xNQB+Mq13rLbw6nXbZbs55Z5wHnaVfe9vLURVnDgncSK1IE
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 s2oY1scn3JsCexJ5R50kjHq2bt9XrBgRORTADQoRt1pL1L0d3Eze/dDZm/Klby90R
 Ia4HUL7FWtWoy86Y5TiuUj1H1pKZdjMPyj/JXAHQRDtJ5cuoGBL0N1DdATEJNCee
 zQfMqzTCyjCn091QkuFjDhQjzJ+sQ6G02w491w8Kpm1ASuh7BLTPcuz7Z+rLpNjN
 jmw67rR6+hHMK474mSKIZnu03vVKnidntjLhSYc1soxvYPCLWWn14m3XyjlrlnzD
 4Soec2I2AjKNZKC09KKA81cRzIcNjJc7sbnrLv/hKXNUTESn4s3yAyRPU7N6bVIy
 N9ifBvb1U07WMPRI8A7/f9zVCaLYx87ym9P7GGpMjDYrPUQp0aKQdu4ycWuPrIEA
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```
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lgZHnqFyebeC1uDw8r/wGtYmI2EC53+F10F5AFcH+3Lz0bZzerqwr4UM0A+B5c
QMU5vDv1LFcWLzvJHMXJfCHL5nVSukXCMawr+DbeKjrkseG0UX0gpUbQy0vHIH1K
2geD2xy13TJ8jCaK0xb/Hu+KfkvtOCsh07TA+cnTV1WHR77svUcMErzHXWOFm8+U
omIXAL01EiDbpu38gERRLkC84eMhRBQjKcdmlcBFsmilt3cfIofypuhMRiIFjIke
00y2GEdQVsZGA/LX1HILqD4dEFDDQI2LPvCG5qe28HTfWspzsqK94IRESzm+Vmdp
IjNzkTyrPI06yMvxaHGajwUtLWCREJOG/uXhswbX7EviVYyqCR4vzDLDVXAulxo/
OsHaQhMX8xYOLXontx7SNcBlU/EEBww5Qk1KUlDgd5igr7bDxsvZ6vHy/wcNIzY3
RUdidnuDkpSm1hIoLz4/SW2Tm6C2u9La5evu7xAfIy1u18LE3/P0AAAAAAAAAAAA
AAAAABcmOEM=
-----END CERTIFICATE-----
```

```

SEQUENCE {
  SEQUENCE {
    [0] {
      INTEGER { 2 }
    }
    INTEGER { `159ffe6f22fd5cc42c524df6fd5e28d0de38f34e` }
    SEQUENCE {
      OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
    }
  }
  SEQUENCE {
    SET {
      SEQUENCE {
        # organizationName
        OBJECT_IDENTIFIER { 2.5.4.10 }
        PrintableString { "IETF" }
      }
    }
    SET {
      SEQUENCE {
        # commonName
        OBJECT_IDENTIFIER { 2.5.4.3 }
        PrintableString { "LAMPS WG" }
      }
    }
  }
  SEQUENCE {
    UTCTime { "200203043210Z" }
    UTCTime { "400129043210Z" }
  }
  SEQUENCE {
    SET {
      SEQUENCE {
        # organizationName
        OBJECT_IDENTIFIER { 2.5.4.10 }
        PrintableString { "IETF" }
      }
    }
    SET {
      SEQUENCE {
        # commonName
        OBJECT_IDENTIFIER { 2.5.4.3 }
        PrintableString { "LAMPS WG" }
      }
    }
  }
  SEQUENCE {
    SEQUENCE {
      OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
    }
    BIT_STRING { `00` `d7b2b47254aae0db45e7930d4a98d2c97d8f139
7d1789dafa17024b316e9bec94fc9946d42f19b79a7413bbaa33e7149cb42ed5
115693ac041facb988adeb5fe0e1d8631184995b592c397d2294e2e14f90aa41
4ba3826899ac43f4cccacbc26e9a832b95118d5cb433cbef96660b00138e0817f
61e762ca274c36ad554eb22aac1162e4ab01acba1e38c4efd8f80b65b333d0f7
2e55dfe71ce9c1ebb9889e7c56106c0fd73803a2aecfeafded7aa3cb2ceda54d
12bd8cd36a78cf975943b47abd25e880ac452e5742ed1e8d1a82afa86e590c75
8c15ae4d2840d92bca1a5090f40496597fca7d8b9513f1a1bda6e950aaa98de4

```



```

67507d4a4f5a4f0599216582c3572f62eda8905ab3581670c4a02777a33e0ca7
295fd8f4fff6d1a0a3a7683d65f5f5f7fc60da023e826c5f92144c02f7d1ba107
5987553ea9367fcd76d990b7fa99cd45afdb8836d43e459f5187df058479709a
01ea6835935fa70460990cd3dc1ba401ba94bab1dde41ac67ab3319dcaca0604
8d4c4eef27ee13a9c17d0538f430f2d642dc2415660de78877d8d8abc7252397
8c042e4285f4319846c44126242976844c10e556ba215b5a719e59d0c6b2a96d
39859071fdcc2cde7524a7bedae54e85b318e854e8fe2b2f3edfac9719128270
aafd1e5044c3a4fdafdf9ff31f90784b8e8e4596144a0daf586511d3d9962b9ea
95af197b4e5fc60f2b1ed15de3a5bef5f89bdc79d91051d9b2816e74fa54531e
fdc1cbe74d448857f476bcd58f21c0b653b3b76a4e076a6559a302718555cc63
f74859aabab925f023861ca8cd0f7badb2871f67d55326d7451135ad45f4a1ba
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c3e90fd20c04e674b90486e9370a31a001d32f473979e4906749e7e477fa0b74
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a5fbf495490a5bd4df248b95c4aae7784b605673166ac4245b5b4b082a09e932
3e62f2078c5b76783446defd736ad3a3702d49b089844900a61833397bc4419b
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957def6f2d44559c31a77122b5204e3b5c219f1688b14ed0bc0b801b3e6e82dc
d43e9c0e9f41744cd9815bd1bc8820d8bb123f04facd1b1b685dd5a2b1b8dbbf
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5c216f8e6ed178dd567b304a0d4cafba882a28342f17a9aa26ae58db630083d2
c358fdf566c3f5d62a428567bc9ea8ce95caa0f35474b0bfa8f339a250ab4dfc
f2083be8eefbc1055e18fe15370eeccb260566d83ff06b211aaec43ca29b54ccd
00f8815a2465ef0b46515cc7e41f3124f09efff739309ab58b29a1459a00bce5
038e938c9678f72eb0e4ee5fdaae66d9f8573fc97fc42b4959f4bf8b61d78433
e86b0335d6e9191c4d8bf487b3905c108cfd6ac24b0ceb7dcb7cf51f84d0ed68
7b95eae1c533c06f0d97023d92a70825837b59ba6cb7d4e56b0a87c203862ae
8f315ba5925e8edefa679369a2202766151f16a965f9f81ece76cc070b55869e
4db9784cf05c830b3242c8312` }
}
[3] {
  SEQUENCE {
    SEQUENCE {
      # keyUsage
      OBJECT_IDENTIFIER { 2.5.29.15 }
      BOOLEAN { TRUE }
      OCTET_STRING {
        BIT_STRING { b`1000011` }
      }
    }
    SEQUENCE {
      # basicConstraints
      OBJECT_IDENTIFIER { 2.5.29.19 }
      BOOLEAN { TRUE }
      OCTET_STRING {
        SEQUENCE {
          BOOLEAN { TRUE }
        }
      }
    }
  }
  SEQUENCE {
    # subjectKeyIdentifier
    OBJECT_IDENTIFIER { 2.5.29.14 }
  }
}

```

```
OCTET_STRING {
  OCTET_STRING { `329a07b1fabb48f52a309f11a1898f848e23
22ff` }
}
}
}
}
}
SEQUENCE {
  OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.17 }
}
BIT_STRING { `00` `67a8951fc308e12f6867611fdc254bf4bcb514f7f5f
2fdeb72fa8e1a030061677b84cd275597d83154195966b141670cb0e88113460
d978a1a7a3895c11ca41995775c09d64ddeb47bc87c4e8bf1c9327fc4afd5c37
86553e17d629b0f27142765481432b5e7ccd0ba61e51cad3dd8f95938c235ebe
ceef8b16ae3366f300c5358ec7be9eb23a1ea1a3da58686704f0483f968a6e4
b1f89670a0134b36a18d6c727dc9b027b12794793a48c7ab66edf57ac1811391
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d01310934279ecd07ccab34c2ca30a7d3dd5092e1630e1423cc9fac43a1b4db0
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b8ef8992288667b8edef54a9e2767b632e1498735b28c6f60f08b5969e5e26dd
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9eb2effe12973544c44a7e2cdf203244f53b37a6d523237d89f06f6f5534ed63
113c8f00eff7fdcd509a2d8c7cef29bd3fb186a4c8c362b3d442939a29076ee3
2716b8fae5100d81a07215cdb1c79bddfbdc14f52e37318d1e526db84d160fb8
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9e86294c0c3b51ce77e6dfb6f6722e68f4c3ff2eb4c346931506e743bb021998
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78ce402d5082c3e0572c2322cc20996ca968da35d7b2edbc0623be6165090120
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f81399e6ca969b111b6c7b6fce549e6b4d89d459381ea9166e9bb3072089db94
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f2c3b3bc49f8b7e048c0ce2734830b48a79d35fcc5a62a9454800a30f4b3eb7a
268bab64c12100d712151bf5f12163bed029e8abf1ca6e7b7b1286a733f532da
e511091aab0fffcfd4464ee5663888f9859b44ba765360ffff434f12af1fc6bc
cdb5a71947149dc7689dff24d6ba6b63e6cc23140e32934b6e9da765b4332011
8b8a811f89c3d1b7fff21530e77a91cae3557ac7c784fff8263500bc82560030d6
c6e74eee817fc2c63402752e59ef43916d3d83c21686436e9034dda6c974f210
8b174eaa1f73121c9add500cecd8618b302bedad72b62f793bd0f70ba8c5e16c
```

```
f4abeddd51196816d019517d1e25fb62c9f79d9232fdf1ceec604f8dda5f7145
541c5793b9c5ae1589588a49a6e6174614ea012933a192b3b084725b465bb1a2
2ccb4b60cf3ca142f7683a8267fb6b0a8dc0b3a5f63ab60443f6c7ee70e9b5b0
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d5f62c7e876b57f40f262e6a3e6be91ed0af7c8b5b74b160f3c661d735799d5f
b47685135c5551f69a09444f5f01295f539a8227d271e4849fbc8906cf57e67e
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25c689fcb1687acb444b533d4c4da9846192825c03d9cc9a1685bcdd367b3f41
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7c017d4f1467f3ad0e41e31c4ff351b14f59ffc9d19f3dca6c0b8c4d8b10eaa6
e3b8b4c3c1f17d0786f86140d0476db3f3097308d2f3830165192235db185fdd
e8d19708c664927fd75529e2911e8114bf73e2e2d8e52f42bf49c62f17188744
2596354fca15a730c97f70b6f60a40456483017ac59f49606479ea17279b782d
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850c380f81e5c40c539bc3bf52c57162f3bc91cc5c97c21cbe67552ba45c231a
c2bf836de2a3ae4b1e1b4517d20a546d0cb4bc7207d4ada0783db1ca5dd327c8
c268a3b16ff1eef8a7e4bed382b21d3b4c0f9c9d357558747beecbd470c12bcc
75d63859bcf94a2621700b3b51220dba6edfc8044512e40bce1e32144142329c
76695c045b268a5b7771f2287f2a6e84c4622058c891ed34cb618475056c6460
3f2d7d4720ba83e1d1050c3408d8b3ef086e6a7b6f074df5aca73b2a2bde0844
44b39be566769223373913cab3c8d3ac8cbf168719a8f052d2d6091789386fee
5e1b306d7ec4be2558caa091e2fcc32c355702e971a3f3ac1da421317f3160e2
d7a27b71ed2342065bbf104070c3942494a5257607798a0afb6c3c6cbd9eaf1f
2ff070d233637454762767b839294a6d612282f3e3f496d939ba0b6bbd2dae5e
beef101f232d6e97c2c4dff3f4000000000000000000000000000000000000017263843` }
}
```

The following is a self-signed certificate for the ML-DSA-65 public key in the previous section. The textual encoding [RFC7468] is followed by the so-called "pretty print"; the certificates are the same.

```
-----BEGIN CERTIFICATE-----
MIIVjTCCCIqgAwIBAgIUfZ/+byL9XMqUk32/V4o0N44804wCwYJYIZIAWUDBAMS
MCIXDTALBgNVBAoTBELFVEYxETAPBgNVBAMTCEExBTBTIFdHMB4XDTEwMDIwMzA0
MzIxMFOxDTQwMDEyOTA0MzIxMFowIjENMAsGA1UEChMESAUVURjERMA8GA1UEAxMI
TEFNUFMcwgggMAsGCGSAFlAwQDEgOCB6EASGg9kZe0Mes93biwRzSC0riK
X2JZSf2PWKVh5pa9TCfQWzjbsu3wHmZO/YG+HqiTaIzmiqLVHF1Y+LvG606J7mfs
wDIJVNvyEsRHip/x1urw0Si9UVEfjYjYR3NsfeJzDV145UEHEXYJeIZ3Eb9V0aC/
xMNQwr5XK6804uL7Fsz+oIAo2ZrEmuu3WTFdzhEc2rYv/zzqi6IjPR5W+8XFoecm
3mP63SrwFrEZf3+j2XGi2Sdxc/zlW2d0WvC3wh1Zfb65Pmoy80HEmlqL6eglCI0f
KqRRVdbIrhU2fk6wA7j994UqcZSX0fn/8JAj6vRRBNKoSkWQbu1GcaRNwo0nmHu1
XfaenoVh9hqApyaZUDh1/tm37nKo4XoZxAgUT0spr+9wMcm2FcWELQsn0ISRaiP
GX4WgSsDEVm2W5aH5bPpNMUiWumKebpz0r0Z1zUQ7/rRn104RQ8LqPzhAS/ZjSYK
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hZvyLzpBfs8fnYkxe15TnVh68WueExpGRRT/pkuos/8rgyH4gRyz+wIsj2R0cKS4
Ci+/7mBKu3N5CR6o5sXHTfwCg2ZrQMB50HACggShNr9dqVa0t5jTSQOL2wwR4DRF
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jL84SvgarJXisyl0BHiayDcnpdwEVZ+Wr0HYoFNRb+7uvFJ0brarKBngkQhxDYnf
AR+mMGWHkTm01c3/srIxBQfpL8mTrjF9qX9PMJza8PZ+2Z2QIVV2CDhJ+V0yRtf+
2z/bZ2eYUKWtQE5kFH+3z09q7d0Fr7S4NJaNH+iAFJYNz12UIjZSbhKkeNaeX75p
```

cDELMiWghFAYz8eyq0MKE6axrHuwLMy7PZEawvEQaGE/vgKb/c4Cz1zTiVDtcsG5
R037x1YVr4f4ZMBR88VUVsVBKGOkDABR2rVivf8FcbjTw5F7vTAIgLul6Zgjm5X6
kbfWQW1POys6280wmd7TWstNnvfUI2/QD1DZiqU6I1rEFycg932WFyZymAz+j/e1
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FdMRUENtYUvnoH50QwB1DfHSxYdTOJBZ6vw9eFzN0xwHZIvtwDpc04rUbQZNwCE9
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NoLo/kArvV6C0pxGTkTrXTe0j8Vo3+DMbo4Wuuof5RNvkPGS10c+g2ewIW27gVAw
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1m9GSHcyyCAsEVR4Zht0px1ifAhgJMyjvKQfChezjxmzd0rSCVyNpTsGniHHauLS
AH4WcZ7UAIDTNPfaUun1pZkeOcrwg61bgz8CrRCgjbptDyYMAHKFvUovR3A6Wu9G
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1mWXQfPEL+7IbuhKrYgqi0W9WwGhrTqkBeZAIQhay/orXbEqRS075qGo2Naaqd7
wdz7b7pZp339qbdTDcDKhkjI2XNzjgG6uPCLSQXoSqRkG9YCQZzdsAmXy8jHys1
4V6y+gTsvZTVp3q68eDhYQEKmQCH9bRuqYiyvAUS/aD6kj2t1sRcUwHQlINmMw1
qy4Q9LpSD2u61WSlw9Xie9sID30g4TKWoxgZVM0cZJyUPr4X31wfeq4Kj+EmxHdY
W11NZiONAIItq9ejNmB5ppS1tTz/SXthvIh5Lk/ZfWsmWdTNiS5I1dQwwcHVQtYU2
0QmnExxaW75KVxVwFBjTSux2YHYe67n64okcd0WJuA5WatVX3e9zZx1rcifqMHdV
Cd3+x51rKxmmh5tSBddr96ulrPM6+1nRf8V0aDg9a+Wgjptm21Pc3gCLspS4WcVr
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```

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IA==
-----END CERTIFICATE-----

```

```

SEQUENCE {
  SEQUENCE {
    [0] {
      INTEGER { 2 }
    }
    INTEGER { `159ffe6f22fd5cc42c524df6fd5e28d0de38f34e` }
    SEQUENCE {
      OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.18 }
    }
  }
  SEQUENCE {
    SET {
      SEQUENCE {
        # organizationName
        OBJECT_IDENTIFIER { 2.5.4.10 }
        PrintableString { "IETF" }
      }
    }
    SET {
      SEQUENCE {
        # commonName
        OBJECT_IDENTIFIER { 2.5.4.3 }
        PrintableString { "LAMPS WG" }
      }
    }
  }
  SEQUENCE {
    UTCTime { "200203043210Z" }
    UTCTime { "400129043210Z" }
  }
  SEQUENCE {
    SET {
      SEQUENCE {
        # organizationName
        OBJECT_IDENTIFIER { 2.5.4.10 }
        PrintableString { "IETF" }
      }
    }
    SET {
      SEQUENCE {
        # commonName
        OBJECT_IDENTIFIER { 2.5.4.3 }
        PrintableString { "LAMPS WG" }
      }
    }
  }
  SEQUENCE {
    SEQUENCE {
      OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.18 }
    }
    BIT_STRING { `00` `48683d91978e31eb3dddb8b0473482d2b88a5f6
25949fd8f58a561e696bd4c27d05b38dbb2edf01e664efd81be1ea893688ce68
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45155d6c8ae15367e4eb003b8fdf7851071949739f9fff09023eaf45104d2a84` }
  }
}

```

```

a45906eed4671a44dc28d27987bb55df69e9e8561f61a80a72699503865fed9b
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3e79c46ca5d5a6dca3d28ca50ad18bd13fca55059dd9b185f79f9c47196a4e81
b2104bc460a051e02f2e8444f` }
}
[3] {
    SEQUENCE {
        SEQUENCE {

```

```

    # keyUsage
    OBJECT_IDENTIFIER { 2.5.29.15 }
    BOOLEAN { TRUE }
    OCTET_STRING {
        BIT_STRING { b`1000011` }
    }
}
SEQUENCE {
    # basicConstraints
    OBJECT_IDENTIFIER { 2.5.29.19 }
    BOOLEAN { TRUE }
    OCTET_STRING {
        SEQUENCE {
            BOOLEAN { TRUE }
        }
    }
}
SEQUENCE {
    # subjectKeyIdentifier
    OBJECT_IDENTIFIER { 2.5.29.14 }
    OCTET_STRING {
        OCTET_STRING { `1b0563e3cd3346149c8c9ebcf23b0a4e5a90
0eea` }
    }
}
}
}
}
SEQUENCE {
    OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.18 }
}
    BIT_STRING { `00` `11816868a90c66934bdbb1d19c53a6a5dc30535ff6d
cc8669b24284ae9310e9a57c7918702b5fa49c633be475d5492d9d7eea391426
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```


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rnVLSdqKkbgKCwwRPEiw8SU8WZu5zwG9ygURLGN4obLeSQU8UHyCteEbbpGrstXp
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
-----END CERTIFICATE-----
```

```

SEQUENCE {
  SEQUENCE {
    [0] {
      INTEGER { 2 }
    }
    INTEGER { `159ffe6f22fd5cc42c524df6fd5e28d0de38f34e` }
    SEQUENCE {
      OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
    }
  }
  SEQUENCE {
    SET {
      SEQUENCE {
        # organizationName
        OBJECT_IDENTIFIER { 2.5.4.10 }
        PrintableString { "IETF" }
      }
    }
    SET {
      SEQUENCE {
        # commonName
        OBJECT_IDENTIFIER { 2.5.4.3 }
        PrintableString { "LAMPS WG" }
      }
    }
  }
  SEQUENCE {
    UTCTime { "200203043210Z" }
    UTCTime { "400129043210Z" }
  }
  SEQUENCE {
    SET {
      SEQUENCE {
        # organizationName
        OBJECT_IDENTIFIER { 2.5.4.10 }
        PrintableString { "IETF" }
      }
    }
    SET {
      SEQUENCE {
        # commonName
        OBJECT_IDENTIFIER { 2.5.4.3 }
        PrintableString { "LAMPS WG" }
      }
    }
  }
  SEQUENCE {
    SEQUENCE {
      OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
    }
    BIT_STRING { `00` `9792bcec2f2430686a82fccf3c2f5ff665e771d
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37120f70793b8ea9cc0e6e7b7b4c9a5c7421c60f24451ba1e933db1a2ee16c79
559f21b3d1b8305850aa42afbb13f1f4d5b9f4835f9d87dfceb162d0ef4a7fdc
4cba1743cd1c87bb4967da16cc8764b6569df8ee5bdcbffe9a4e05748e6dfd22
5af9e4eeb7773b62e8f85f9b56b548945551844fbd89806a4ac369bed2d25610` }
  }
}

```

0f688a6ad5e0a709826dc4449e91e23c5506e642361ef5a313712f79bc4b3186
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```

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b3c009ca947c39dfc82d98eb1caa4a9cbe885f786fa86e55be062222f8ba90a9
74073326b31212aece0a34a60` }
}
[3] {
  SEQUENCE {
    SEQUENCE {
      # keyUsage
      OBJECT_IDENTIFIER { 2.5.29.15 }
      BOOLEAN { TRUE }
      OCTET_STRING {
        BIT_STRING { b`1000011` }
      }
    }
    SEQUENCE {
      # basicConstraints
      OBJECT_IDENTIFIER { 2.5.29.19 }
      BOOLEAN { TRUE }
      OCTET_STRING {
        SEQUENCE {
          BOOLEAN { TRUE }
        }
      }
    }
    SEQUENCE {
      # subjectKeyIdentifier
      OBJECT_IDENTIFIER { 2.5.29.14 }
      OCTET_STRING {
        OCTET_STRING { `89886750b57c24db3fc012e61ede59753337
374f` }
      }
    }
  }
}
}
SEQUENCE {
  OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.3.19 }
}
BIT_STRING { `00` `08783d565efc7b97440f8bd9818b466be538dbccedb
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```


be65614181a51ff7ddbc14e47087af78483bb2f056124ecf1922fb6841380a6c
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37abdea5af4b4a3a7f1e8a3e8cfff1026ddefc29bae39e75249364a953ec52231
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a15840e92822b7166c8611d464af2e8d1baa5bcacf1c1649589a7eb16b889b54e
0b7ced0ba25a51e34f4d0f152fbeb9e1f43682d81a5de05f89628b1b5ef10032
7e4b4fb3a02385762b4ab1e721da7ff61733c41d7071e819ec44c03311474330
e97a6c0248d1dd99419feb83980f2422a9e7c9065469c4103d76bdb7b8524c4e
21914095fe25eea171d88dce27d96f7649a717d9415ba05138b6a26a685fb768
f75564884fa38cc9bade16b94db62d1f9da3ce294f3e917301855676a7ee7b3f
77bd07c7fb8b53de30082bbacdf34f19e1db5aaff7a3188ef408c6a9c906b42b4
1193003d273a5a69b0ca5844bbbcb8c7812330aa3f93e155b8681f9edfba2ddb
b011cae933e72b34d1117d26d665b195322dca63429bde4183c02255ccf0c595
873d25c4c73db307d3165e2c0be0a6016c8785a4e83d581ec3eb0f59ed7a3832
3d9772fdf36818aed3b485c38203fb1b019fbeb0ada9099543291f106f6d2d057
8c53734d101938945284ce689a35b3ff93fe2d40e07e31310e55d21c09cbd0db
44a64ea3f16ed2ddc243ef5d6e5ceb4b0a81dc0564ab21e9d81cbc16c5683bad
d91125d8b4d551f3091be2115ea121b21438033786c5b76bfc8c0e0721d0fbd7
090541d3bdb8e99cb029a135e2ed1f6c490572e625ebce83c7fa02df21d16b0f
b93db803cf65ebfb1380b1ba584717b6cb65fe6236adb3613d4a2b0443254dec
83c9679ad84e2609cd475f2d9cb98a06fdfdcc73a88be0fac78c6a42e351b698
bdc31172568deaec20964d5bc529612d580ba0a7bbcb425bffe1bf3ef1a40eb7
504d046ba213e00a0714d11950e94b0e249e3ee6e0b6c6db4ea32b4024011a68e
51160a133b25f99034273255916a92ea3a94fb2bcfafcc0a2e9e9dc2f8c3195d
d0ee7c704b8bcd5d8960f2bd2160f7fd304c107d27b3b0984f50deb813a467b0
73e6347149a1cf4b5332289d635d5d23c2730b30368a5ce3cceb6155347f0df
21f611044505bce3806bd8edba86324637c6a9210830b636602a83527b41eee6
0f2d2df4c7c6a571ee8514848a47beb0a7203f8e4b91e4fa67ea3022fe9d9f94
14884016e66fe48536167e12f0dc550e801004c11a86c5b798e26ca9b1f25841
624ad2327137908dd23ba5f65eeb107b8bf1e4f45218e44f15e75dae8df9e78b
edf5e65cb12278f1524d4597c037d40aa1222ad514046393d5f7e29759e61087
bf1f1d3907d2d2b6f21bb8a1a7098c533a897cbcb8891b56a1bc65ab8625bab6
6f36e2afc6eb084cdb2159be5437e5c437a738ef80ada9eb1d08b173d22a3a6e
4eae6b29b329a93c2dc6b47993606e7ecff40431831e83aa7c64a09e7eb291b1

```
a9f671c14ff8517251b0419b517095b97fd7010ac59063be3652d27414262ecd
c2f9b91a8a46fa583bb4588365c4942dd8243268fc9f5fa3343cbe17fc3539d2
4341d582e0a463539412e793507e4be487ebf9cc7e26476bf5e68eec99e6280f
eeaecf057f2d3600890dab50bb7f859b209857d67830e06a66b535ca763bac9
79b9eed31e2b9b3095ab64ab961c57f6a6660cb172aedeb3d85bc9bf3b9fa8fc
4673de2813d138ef85e0d456e501e59dbade75add36acf197baf472f6351f23e
780214dbc6947aabb673e033d61aa61f9a87285f8afbc5bf879c91bea9692fa9
33f7010116f028b32de397100350f5808e1761a61f08361a2dc8c3cf0aaf111
cf44dfdf1088e428866be3a58b5f638c5c762fb2790ade914be0cf612b6b3bde
c6b88accf6d1b3d78c410c05ae5117ca1025d32cc03a016f330236018d6579cd
0b9930b317a2ecaa2b41491b826a7d259226ff83bc3bc67660a4c5c0620f33ba
c03196a4517ae45f33ef01ca53b54ccc96b72d68e57ce9489fb7dea6fb8dc88f
8f2bd532bd7d1a9bb476f5bc4dc824cd24742e549bfddd6ae89095fb20739a65
7c98ed3e1b323cb0d3232c58e6a7cc3ca1d32ece1a10e05e2252e36cb65d4d14
1ff24618465b6651297cd34d38f61c62f31fb8e970c30653225eed4ad93a9340
2d67beed1e6c368aee7bdf4ca85e54eb2b17bbda501d0d096f5cb4e47575f0fa
8c60f8ed3bf2766de6374342014c5d8c72a9a9d981ce6c7069f75f843fb97819
d104a584f12b1a3b480b9fd774052b698259368ea5bb7af675809421fa3ac6e9
feebe427a13ece5e96fe85cd382b2e10607ab911877ad07e74a200621d3cc2d9
02dca836e92b8ae754b483a8a91b80a0b0c113c48b0f1253c599bb9cf01bdca0
5112c6378a1b2de49053c507c82b5e11b6e91abb2d5e900000000000000000
00000000000000000000000000000000000040c12151d1e252c` }
}
```

C.4. Example Inconsistent Seed and Expanded Private Keys

WARNING: These private keys are purposely bad; do not use them in production systems.

The following examples demonstrate inconsistent seed and expanded private keys.

Three ML-DSA-44-PrivateKey examples of inconsistent seed and expanded private keys follow:

1. The first ML-DSA-PrivateKey example includes the both CHOICE , i.e., both seed and expandedKey are included. The seed and expandedKey values can be checked for inconsistencies.
2. The second ML-DSA-PrivateKey example includes only expandedKey. The public key fails to match the tr hash value in the private key.
3. The third ML-DSA-PrivateKey example also includes only expandedKey. The private s_1 and s_2 vectors imply a t vector whose private low bits do not match the t_0 vector portion of the private key (its high bits t_1 are the primary content of the public key).

The second and third examples would not be detected by implementations that do not regenerate the public key from the private key or, when they do, they neglect to check consistency of tr and t_0.

The following is the first example:

```

-----BEGIN PRIVATE KEY-----
MIIKPGIBADALBg1ghkgBZQMEAxEEggoqMIIKJgQgAAECAwQFBgcICQoLDA00DxAR
EhMUFpRyXGBkaGxwdHh8EggoAUQyb/R3XN090iucd1YKBEGqTQS7Y+jv/dLU0Z7L
GSHTp1/J04jvDMqbhRvs7BmZm+qQaMhZ1t8RXGCMFQEXDrbAVcIvY1WSSXbYlaX1
TSw4WWxAPM72+XPiKl+MfCuoNjNecJcniyK7Qc/e2vvLLt7PkHDM5hLkKrCh8T65
3DwUkDGJwoHgsDHa1ISCEgijTDDSKEoEByDDRELgQC5EoHEBqSwDjMqSQSQYMiQA
Ii5K1mALGZAIMyBShkUbCEyTGIQZAG1TgAwQpChQBgogBgwJETLSxEDSEgIENIYj
lQygtkxbSJGMEoQgGQKRGIEKJRACoG1gkCgDxjCTBJARuJAERTLBIezawpDZiCwY
RiTksAUjsWyKEIwEgXDLpDDYRmLBxhDIyEXBlgwEEgrkKGYcJXCcsohigGxi0EWE
gEyoA0jBw7IRiAk1SkkRgVICHATIUXghCGQsg3QNoAZgE0b1mEUEIUaJkCcwIij
GBADAiGSM1GYCDiI0YpAEm4MJkEYGU4iAmTCMBFCFhJjFiwRo4TigCXSRmKakgAR
uA2LhgBRlnHIRiQIiUEDFUCHIm4kNwMAJC7CiIUEMYxawILCRI1YxgCZMpIbISDL
Am4YGXDYxiRBNnIZkGVYOG4IIAwCFcpjFoUBtCVQwmGJGVAisk3DGCokGCKbRmgQ
NUIgNmLbNAWLSmxIEI0yByI0hMA6MFCZCJAQLN4xDBiLCSiBYGIXIpAQUtjHRNgwi
gykAok1cuA1kiEXIAEGU0ExiomjUBi7ZAg3MthFh0GTIMpJRyElSgAHgwDEAIgrB
RGaAtIRQCDASxiikCGBKsGHKxkESyGhSsHGbaAwIR2ZhGGxRFImBRoYJOUSDAJEK
kWhIIFZrKGiBjLaBnCMZCZiJi3akpDBACDasGWCJDKDRIVcxGwAQyKJxhCjBABh
hCSjQBjRIA0YMoBBNirIsCkgRwgaEKDtpEiKYzYmmbD1hBiJnIbRWXDpmXZwGAU
EAjQxG1JMoXQBg0RJEZjtAABqUAM4BCMGBKgEmCNCBDGAgSBiaSRILKMAHhNo5b
IiIkBwZUEiLlOEGYRgpMFEoKNIQgI07AFgUDRIyAtkEUkzHLJgARmG0KEg7YEGKQ
NgwUAXGJBirIJmZSBFhkBkDckiHIEHFkGC7kuABSkiLqChLJEKRJoGZiJFUNG0K
mIG8aRx5dr9/gBkPfhwZrwn4DSmTPR/Vn01JddemyttdtkeLCZ4DW7+Gkb7Z8S4f
HY7JlsvtetEEMyRAS8/INLbzTBrgWIRQqWxf3YcrxGG51ND01vdrYH7wnyS0ku6m
N12BMMwLEfKkm0SU747o81iHE+wiM2bPH+rG7eP6rIrB7NRY67odfeBGboLHeSdf
79U3GOWczZiFB5wtZGzNoVpiExABNAydQC40JIPvpxR0ULrErVz9y33/zj9KIZJy
+saqdCSsuX3kbavVhZQz7eytus2Aji7uSWgPb4M7FqBoFcpobHX/jVvHD8oaBt2
T0jtuObFuJQUndcztr62etukrM+iwyyLR4WCpFev9qGM+ZP9TCsLbEDu/rVMVS81
dnKlkkYhy/pUgsGU2jg1bTD83Wib8laA1kZgXsQLbsyP2hpmU66+mX/2gQR9rCzh
gJSDFfiIGPo1nU2ye1QMj8Y0niHNv8I5ZRkylmRFpDZo+QPVoXMnwTg0eF/c3UC0
PTc59SF1UpXMSPTtjYLHENPlqJnHLb/PZMwLqfd+FE+i4GFhFKDH6RF3NUjPF0Jx
I1EJ51/HxG+zK4c1abd6LU4fMGnnKrNK1NSF5yoq8b68GIspz/Mni13Z8++arXx/
hzMVayoTe6vtL0ZtyByyV26jjrx0EMpf0ZLzjkWB+Q9a+Z6QxEcttpVls0hnxB9w
cWFz1hzd0z1ZaMv89k3iYgajdmNIHeUQdz8wWC1621onspo5Y1zuruFSorrzz/Ru
yyg3iHNFmRv2SCNuWcziaFTSd8HBTInzNWmeqBeF7HW1hsCpRoR02ZV4iM+REFrj
qPVHh3zqURGGSDu1y29uK6M2vjUp0w8NfyuvzbHIy2hJz3Py9kiZotFF4k0gU25D
11b+/IcaVavqBxCUAz9N4c29aBGZ08reC+X9kPWuNE8NY7e3j4YmPcWppZGfXnY9
PNV0pLylhLeifev2Wk1ahcLVYLE6l/cFE6qxmThkD8uTrZ7h75JmUqDmKNVjtJW5N
YS5XSZQz4bFhsdXvpED5F5jwr2NUPpZDKjuEKXu811114F4wx98g776d6LI/zTY
a06arDBhDhmeyDQZFhMtlu575XeFZGdP11IVo4UPSCQKzc/AMx1rjNrQw2wNZJ+t
6JDEJq75MS7q5C7gvPpBd3qdmBnQwLFvYcJ8ohXcpqc1Lgw12BFntm5L2JXXle/7
QmhVrMEkSwJznkd+b0qky9uPbI1Nr1fw0+NJBeqCJtxVvjngV3rE97E1RqzHFxaH
QQvju+iK/j03mKXQes6be6UWIrYz8+RhZ4jw1K2nPDk1HM0+0p2sN1ha3BY1+Fob
uXxZug5ze+Lor7aiIiy18xn64MxZ4QB3pFpKeW3YJKoLcJSexuJlKJ8Ky5WjnJ+
skZeuWRgmW/0YyRcKyyy1rgnWv0A2oyBqe8ujjv5MD20i10q/mxtA+a8IAQ0oq0L
F00uc91QcXXoUdXnQ+ZCCeNIUg1shMyx+2v6smyMLuSFEQ3R17Br1Sgw6lu2gD0S
XMYOX6h8w0Ww9m11Huth5xm21mYiPLiejT3vPoyWrJNQ7pg4l/0VGBTG+1zaN5fo
paZzqkJijn+EH7d+G8RVLGHU0gkbp1rNqDAIHAIcn076b3CuBam2ngtjQzBPULSU
AqXPtG17rJg2B+fzGPKAgh8vuZLEaXP7/XeNMwNe6QsNuU9gfln7Tt+pqYpwm1gH
Wkqor1xYXy+1md2Ct3tLbznuPLFIQ3NVBkeDW+NVvpPvC+CF/NefkSuz0aBP1Ta
itxMHENeGFxR5cf0Sp43j59iGkdWBtJBCV8uWf4qRgRG8fdbfQ+l1qAJEx4v8r4H
2Hsm6eS/CeZ1Epe9fnobwS1BBNoczKSL+noqpxcmgAjbcEtZtsBXSJVBSj40Cdt3
fA/6IfpWRsNBIVR1aD2p/a0U/RH3FCZKdhwF2ZhBLEHEWWQOCr1v0W68/r1lFuIW
Ycyq00jDEup7oFhc0k4aUwdv50HJAWk3ehaPvBp+z1z84DmyVMQjXYJ19gZShi+9
tFV4KJ8aZz/kCdufmWwtLJKHIBuVkX/hqbY08Xg4XyWv2pZpZIGeW77918wQE1MI
2Yt6grThI3sytb+dM3JvqUW79clVJ288BqRZMJSN02vUIo4vPqyM/Wcuy465qS0V

```

```
ns+zr0zC2uo3z3LqK57arYABNRm8CV2Vxa0qH61GvYyUrA==  
-----END PRIVATE KEY-----
```

The following is the second example:

```

-----BEGIN PRIVATE KEY-----
MIIKGAIBADALBgIghkgBZQMEAxEEggoEBIIKANeytHJUquDbReeTDUqY0s19jx0X
0Xidr6FwJLMW6b7J0c4Pf3f421ZE3No2a/5HNL2V9DX/mmE6pUqkHCxpTAQzmgex
+rtI9SownxGhiY+EjiMi/+Yj7IENs77jNoWFsogmnaMg1RIL/P6JoY4w9xFNg6pA
SmRrbJlziYYNElIu4ABuI4SBkYzhmyYNEYZk1KYoiHhEgkAomBRhSKZhTEJIozII
wjgpUSRICKElwggxCMRxIBQJFINSgKeAhBBuycBwIrVvKCLBhDacEmBJEUYhpWQBG
IpMgQQYUqRZMARZJfChMQahRgEYKURZRWgggAiJE3JhJ0TJR4TbL08CFkqhREqFk
ADkiCUZiHMcM2Qht0AYmUkCFgEQwkQYsUmGJMMWEGpZtSpqsmQZtpEQyIKdkWjJu
EbVwIJJhJB00BIUsCkhyyKBR0wgqmSCAWCQgJAd0WRSIEKRkYMBt4LKNgXkJIDQi
wCRBcUNxCiEgYaIBUiJSG4CAmJQAE5NN0zIpIhcKmJpGhRRICchnMagYqKBSBhp
GoVNg0RpWyBBaxJCyxhGAakNDaIxg7AhWiJKyJIF2ZBpBDBqSwZK0rIBHEBAGUIy
UjJyVKZAWhgQDDISksKAUhJiXIIoC7RsA0KNUxAMFAE04TZSiIQkkQIKY0YmIAYp
EcIo0CBIArNsojYJWoZiY7Rhi0ZixECCGokJEAJNjLJFIBILJMKFiCiMycBNWUgi
CiduwTRkTJBgW0RQgoZJQ4gEQ7KMYDCAoogthKRtjKYp0MaEQgZGiYhRAkMNAUmN
5DgNpAaN05RxQrJsGoRhG6MoQrQoCKBxGsUx4KBMATdLJChIFciQCRBh2UAiGzNg
CQKS0CSBIAQISRhEoyItXIhEFJgIPEZHAZVkcZkKDJRQykbq0rIgwDgBgjCOE7kI
kYCEFgIgpwBiRejUNoCQi4gQG2cKFBCgSHMmJGAJy0kApwggS2AYqmZRxm7hoI4Qp
GiKJFEUR3IJEUJZFDESEwLIEmqYFQ4YsRDJuiEQhIKhMmjBw47gtYyaIAyVJA00M
SKgJyhRyUzROEkMIG6cEWTAi2ZSA4jQigUISnDAqLDQmYQRfJCYoE0YJSjJtESgJ
GLg1YigRE0ENQbIRkIRMIxISosaIycAwIgyG0hi0hIYwkERSEogx2SBxE8UoQwY0
AzBgZkaEWCZSTIGBhvclYshf+k0s+kkhfysXLXu8FGIObZgKcaq73wxF6aIG7LFC
P+4V3swXYBMAFJ2SI81ubG4fQ0Qfx8ZJOKtokF/T3NpQ2HCC59DXHRVJsrhMhVI8
qP5srSlK340+FbEI/3IdDMh7w906dZAYSw6EVm0pH8nhw8U6YdhnQgsE8JI1V108
ZaBjaP1BKV/QmSQLG+R9nlkUJnSnJcNDkUxM7PWMB0vK9FWM1795EeB6ptCTjy
7iuzwajfLdY16ENC/eoB3CSyEa0vwoHPd+WREMerxUvwyG1IC5vidkcdydYDzumM
/as+n8+3A3k1YfSepEUpp7M/uRacRLTSX7nEV/SXkc09oD6slglYE8EFEyzNp0Y+
SSKM0j2KHzeFbxQt7kNsJ+Cr4kljG0quAR6gMA2yTV+ogRvjcyY1TwxSlfNCu0F9
PP6wsf0zYiwp4Uy72S4TY8ZevUUEt1Ejkb1nDjLhssZ6V0fxpV+Ln56gToyjpwXm
KjxeY3N0r7eutt3qYSzeKPAaIC16pONHItJ90/m4mJTQGF1dTXEZ7+Ny07oQTLi7
CYHgdN46/iANqq6tgmzEXyRNv0Ma+rNO+994JHTS/VcRj2RiFJNO2Zy60wA+jWej
g29vGfxBkQzlfj7jrpnrhNUU63YeY2h0pW+XkdLdSquYWi5SMgX91oiKss0jNwD
zEr+j2cvfho203+u/58XK5iRNnfFod0IXp7kwiBSwa9YGTEWZz3NO/xfNLhV3MbH
eIVknp5x9D1K6g9Lcsp+2gV4uhPTGmWNLQYKmb/ae0b5516L7HScj04+b+r4Y+0
ezzakG50m16ULI6uspYHDr/TZJR6lAzJeL7Wazd0nm1dzXvoxJREDiuEzs/vuYwL
7fs8QeM1nSzXGX++cgxIqmXRZGXB7mPjVpwq3HREkTcLf3gm/gt3odGdZBAduYR
gQa0LS73N0f1YB/kuLDyPt5SHwMagX0VKUpDci6DeHhLbbDPG6norpEdkgG5zpzD
AZxvXCfLmNomFEtkIlp8kysw92Hni1Zodi4PsY0Si9t1H52VwbQC/SnmqSbDup
HYEsjyx5erF5Zwnl0WhWd4KTUp8ChtAVw7U51h1kKjM+n1k9bj9TU51CCOnmozKF
HX91JSKpKlKX4n4tbUITff4uv6b7HGeybAJUoaf9+vb4xWmjgotp2noqfQtPmAA
fHEZCSaywAetgrU5P0e2HLM0ZciAdKwJ/NUwSLTDNeLwddA/sy8b8KgRGxuM0rF
H1ppCYqi1EfyCFt0TkuSZmJpIdLeR4UYzQkM4meuotJ621f9iLSXbYn7hDzCz0mn
bKJnnmgBv6f7AxIW+1BilwS5kj2u13ThTERICrfsRmV5ZtzA0z2ftA6uBOGdkjQ
JYKAh+lJqa/Ra5XXLZmx7coleqWTL/t6Bwmu1anA/wX7Dyu/KECe7XtfWAG+lKzt
AZ4ct4Ud0FHxApBnThn/sAizAcSs9kGiuxQhbh1pyr9Ste8idJaw8weZqFXRF/rT
dEpvozUD6nmLUt3X71QmYJ2/zT8ME7Fk1sBR9+1KEZcZpxLjinMoQCCB/xNUTVTS
wjev7TsVHEuo6fS964SZowZuJrvGnorwid7HFzHR3FKeqxfvc3RzTA/kdU1Mg4Nr
3TSg05vImRRxYGG/uY7G5hw+1E003K81JDxkcIa56nAYsNmoolAM7LAKveJJjWnC
M2EBp3LL5PVxUj9RvQWILN81i4ScwUCqH68iQjoshRzg4z/UiXWk1Z+1xf5BjJ0Q
gZGrbnQbd7/gLL1pjueVxGbWFWGeZEE4LG6sAYN06atzzqgLviNceNqRvXm2+C+J
l4XWhwDTk+Z1wiJNa3oa0hMgSVZ5ra7XAWe1CGZx01MQnbe299gTBOzf2Dsxxm7y
SDBrRa0p593Mhj2sVgSLXWnqF1AR92FMAKhqhjeGHKokyh4uax+GsW9pJl7cgZP
DNdfTIF0A03hGsuQE89+qSa05+qs4HDHuiGI760uQx4SI9Rd0FxnHAPC5FzuZBPs
vnUn6HPkVcTmEKYY0arMC9VtJIPnjymLZqR46y9VjLr8qGv0R7rrAsWyFsJNiP6k
3ySbCeZwogcDq6wksKkavEpWRmAUQroQvs/TCZOIAFHQf1agWpN556jmvv7j8i+q
EGOY93BgBuQum+HvidJcJy8RqVCVxYfXE3MihN6dvTxyF7BonihY6w/2lmg=
-----END PRIVATE KEY-----

```

The following is the third example:

```

-----BEGIN PRIVATE KEY-----
MIIKGAIBADALBgIghkgBZQMEAxEEggoEBIIKANeytHJUquDbReeTDUqY0s19jx0X
0Xidr6FwJLMW6b7J0c4Pf3f421ZE3No2a/5HNL2V9DX/mmE6pUqkHCxpTAQymgex
+rtI9SownxGhiY+EjiMi/+Yj7IENs77jNoWFSogmnaMg1RIL/P6JoY4w9xFNg6pA
SmRrbJlziYYNElIu4ABuI4SBkYZhmyYNEYZk1KYoiHhEgkAomBRhSKZhTEJIozII
wjgpUSRICKElwggxCMRxIBQJFINSgKeAhBBuycBwIrVvKCLBhDacEmBJEUYhpWQBG
IpMgQQYUqRZMARZJfChMQahRgEYKURZRWgggAiJE3JhJ0TJR4TbL08CFkqhREqFk
ADkiCUZiHMcM2Qht0AYmUkCFgEQwkQYsUmGJMMWEGpZtSpqsmQZtpEQyIKdkWjJu
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-----END PRIVATE KEY-----

```


Appendix D. Pre-Hashing (External μ -ML-DSA)

Some applications require pre-hashing that ease operational requirements around large or inconsistently-sized payloads. When signing with pre-hashing, the signature-generation process can be separated into a pre-hash step requiring only the message and other public information, and a core signature step that uses the public key.

In the context of ML-DSA, pre-hashing can be performed with the HashML-DSA algorithm defined in Section 5.4 of [FIPS204]. ML-DSA itself supports an External μ pre-hashing mode, which externalizes the message pre-hashing originally performed inside the signing operation. This mode is also laid out in [FIPS204-ExternalMuFAQ]. This document specifies only the use of ML-DSA's External μ mode, and not HashML-DSA, in PKIX for reasons laid out in Section 8.3.

Implementations of ML-DSA using the External μ pre-hashing mode requires the following algorithms, which are modified versions of the algorithms presented in [FIPS204]. The nomenclature used here has been modified from the NIST FAQ [FIPS204-ExternalMuFAQ] for clarity.

Pre-hash operation:

```
Compute $\mu$ (pk, M, ctx):  
  
# Referred to as 'ExternalMu-ML-DSA.Prehash(pk, M, ctx)'  
# in the FIPS 204 FAQ.  
# M is the message, a bit-string  
#  $\mu$  and ctx are byte-strings.  
# ctx is the context string, which defaults to the empty string.  
  
 $\mu$  = H(BytesToBits(H(pk, 64) || IntegerToBytes(0, 1) ||  
                IntegerToBytes(|ctx|, 1) || ctx) || M, 64)  
# The functions `BytesToBits` and `IntegerToBytes` are defined  
# in FIPS 204.  
return  $\mu$ 
```

Figure 1: Compute μ Pre-Hash Operation

Sign operations:

```

Sign $\mu$ (sk,  $\mu$ ):
    # Referred to as 'External $\mu$ -ML-DSA.Sign(sk, mu)'
    # in the FIPS 204 FAQ.

    if | $\mu$ | != 64 then
        return error # return an error indication if the input  $\mu$  is not
                    # 64 bytes.
    end if

    rnd = rand(32) # for the optional deterministic variant,
                  # set rnd to all zeroes
    if rnd = NULL then
        return error # return an error indication if random bit
                    # generation failed
    end if

    sigma = Sign $\mu$ _internal(sk,  $\mu$ , rnd, isExternal $\mu$ =true)
    return sigma

ML-DSA.Sign $\mu$ _internal(sk, M', rnd, isExternal $\mu$ =false):
    #  $\mu$  is passed to the function via the argument M'.
    # Defaulting External $\mu$  to false means that
    # this modified version of Sign_internal can be used
    # in place of the original without interfering with
    # functioning of pure ML-DSA mode.

    # ... identical to FIPS 204 Algorithm 7, but with Line 6
    # replaced with
    6: if (isExternal $\mu$ ):
         $\mu$  = M'
    else:
         $\mu$  = H(BytesToBits(tr) || M', 64)

```

Figure 2: The Operations for Signing μ

There is no need to specify an External μ Verify() routine because this is identical to the original ML-DSA.Verify(). This makes External μ mode simply an internal optimization of the signer, and allows an ML-DSA key to sometimes be used with the "one-shot" Sign() API and to sometimes be used with the External μ API without any interoperability concerns.

The External μ mode requires the Compute μ routine to have access to the hash of the signer's public key, which may not be available in some architectures, or require fetching it. That may allow for mismatches between tr and sk. At worst, this will produce a signature that will fail to verify under the intended public key since a compliant Verify() routine will independently compute tr from the public key. This is not believed to be a security concern since μ is never used as-is within ML-DSA.Sign_internal() (Algorithm 7 in [FIPS204]). Rather, it is hashed with values unknown to an attacker on lines 7 and 15. Thus, a signing oracle exposing Sign μ () does not leak any bits of the secret key. The External μ mode also requires SHAKE256 to be available to the Compute μ routine.

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