

ISO/IEC 11889-1:2015-12 (E)

Information technology - Trusted Platform Module Library - Part 1: Architecture

Contents	Page
Foreword	xiv
Introduction	xv
1 Scope	1
2 Normative references	2
3 Terms and definitions	3
4 Symbols and Abbreviated Terms	12
4.1 Symbols	12
4.2 Abbreviations	13
5 Conventions	15
5.1 Bit and Octet Numbering and Order	15
5.2 Sized Buffer References	15
5.3 Numbers	16
5.4 KDF Label Parameters	16
6 ISO/IEC 11889 Organization	17
7 Compliance	19
8 Changes from Previous Versions	20
9 Trusted Platforms	21
9.1 Trust	21
9.2 Trust Concepts	21
9.2.1 Trusted Building Block	21
9.2.2 Trusted Computing Base	21
9.2.3 Trust Boundaries	21
9.2.4 Transitive Trust	22
9.2.5 Trust Authority	22
9.3 Trusted Platform Module	23
9.4 Roots of Trust	23
9.4.1 Introduction	23
9.4.2 Root of Trust for Measurement (RTM)	24
9.4.3 Root of Trust for Storage (RTS)	24
9.4.4 Root of Trust for Reporting (RTR)	24
9.5 Basic Trusted Platform Features	25
9.5.1 Introduction	25
9.5.2 Certification	26
9.5.3 Attestation and Authentication	26
9.5.4 Protected Location	29
9.5.5 Integrity Measurement and Reporting	30
10 TPM Protections	31
10.1 Introduction	31
10.2 Protection of Protected Capabilities	31
10.3 Protection of Shielded Locations	31
10.4 Exceptions and Clarifications	31
11 TPM Architecture	33
11.1 Introduction	33
11.2 TPM Command Processing Overview	33

11.3 I/O Buffer	37
11.4 Cryptography Subsystem	37
11.4.1 Introduction	37
11.4.2 Hash Functions	37
11.4.3 HMAC Algorithm	38
11.4.4 Asymmetric Operations	38
11.4.5 Signature Operations	39
11.4.6 Symmetric Encryption	41
11.4.7 Extend	43
11.4.8 Key Generation	43
11.4.9 Key Derivation Function	43
11.4.10 Random Number Generator (RNG) Module	47
11.4.11 Algorithms	49
11.5 Authorization Subsystem	50
11.6 Random Access Memory	51
11.6.1 Introduction	51
11.6.2 Platform Configuration Registers (PCR)	51
11.6.3 Object Store	52
11.6.4 Session Store	52
11.6.5 Size Requirements	52
11.7 Non-Volatile (NV) Memory	53
11.8 Power Detection Module	53
12 TPM Operational States	54
12.1 Introduction	54
12.2 Basic TPM Operational States	54
12.2.1 Power-off State	54
12.2.2 Initialization State	54
12.2.3 Startup State	55
12.2.4 Shutdown State	58
12.2.5 Startup Alternatives	58
12.3 Self-Test Modes	59
12.4 Failure Mode	60
12.5 Field Upgrade	61
12.5.1 Introduction	61
12.5.2 Field Upgrade Mode	61
12.5.3 Preserved TPM State	64
12.5.4 Field Upgrade Implementation Options	65
13 TPM Control Domains	66
13.1 Introduction	66
13.2 Controls	66
13.3 Platform Controls	67
13.4 Owner Controls	68
13.5 Privacy Administrator Controls	68
13.6 Primary Seed Authorizations	69
13.7 Lockout Control	69
13.8 TPM Ownership	70
13.8.1 Taking Ownership	70
13.8.2 Releasing Ownership	70
14 Primary Seeds	72

14.1 Introduction.....	72
14.2 Rationale	72
14.3 Primary Seed Properties	73
14.3.1 Introduction	73
14.3.2 Endorsement Primary Seed (EPS).....	73
14.3.3 Platform Primary Seed (PPS).....	74
14.3.4 Storage Primary Seed (SPS).....	74
14.3.5 The Null Seed	74
14.4 Hierarchy Proofs.....	74
15 TPM Handles.....	76
15.1 Introduction.....	76
15.2 PCR Handles (MSO=00 ₁₆)	76
15.3 NV Index Handles (MSO=01 ₁₆).....	76
15.4 Session Handles (MSO=02 ₁₆ and 03 ₁₆).....	76
15.5 Permanent Resource Handles (MSO=40 ₁₆).....	77
15.6 Transient Object Handles (MSO=80 ₁₆)	77
15.7 Persistent Object Handles (MSO=81 ₁₆)	77
16 Names	78
17 PCR Operations	80
17.1 Initializing PCR.....	80
17.2 Extend of a PCR.....	80
17.3 Using Extend with PCR Banks.....	80
17.4 Recording Events	81
17.5 Selecting Multiple PCR.....	81
17.6 Reporting on PCR	82
17.6.1 Reading PCR.....	82
17.6.2 Attesting to PCR	82
17.7 PCR Authorizations	83
17.7.1 Introduction	83
17.7.2 PCR Not in a Set	83
17.7.3 Authorization Set	83
17.7.4 Policy Set.....	84
17.7.5 Order of Checking.....	84
17.8 PCR Allocation	84
17.9 PCR Change Tracking	84
17.10 Other Uses for PCR	85
18 TPM Command/Response Structure	86
18.1 Introduction.....	86
18.2 Command/Response Header Fields	88
18.2.1 Introduction	88
18.2.2 <i>tag</i>	88
18.2.3 <i>commandSize/responseSize</i>	88
18.2.4 <i>commandCode</i>	88
18.2.5 <i>responseCode</i>	88
18.3 Handles	89
18.4 Parameters.....	89
18.5 <i>authorizationSize/parameterSize</i>	90

18.6 Authorization Area	90
18.6.1 Introduction	90
18.6.2 Authorization Structure	92
18.6.3 Session Handles	93
18.6.4 Session Attributes (<i>sessionAttributes</i>)	93
18.7 Command Parameter Hash (<i>cpHash</i>)	95
18.8 Response Parameter Hash (<i>rpHash</i>)	95
18.9 Command Example	96
18.10 Response Example	97
19 Authorizations and Acknowledgments	99
19.1 Introduction	99
19.2 Authorization Roles	99
19.3 Physical Presence Authorization	100
19.4 Password Authorizations	101
19.5 Sessions	102
19.6 Session-Based Authorizations	102
19.6.1 Introduction	102
19.6.2 Authorization Session Formats	103
19.6.3 Session Nonces	103
19.6.4 Authorization Values	105
19.6.5 HMAC Computation	106
19.6.6 Note on Use of Nonces in HMAC Computations	107
19.6.7 Starting an Authorization Session	107
19.6.8 <i>sessionKey</i> Creation	108
19.6.9 Unbound and Unsalted Session Key Generation	109
19.6.10 Bound Session Key Generation	110
19.6.11 Salted Session Key Generation	112
19.6.12 Salted and Bound Session Key Generation	113
19.6.13 Encryption of <i>salt</i>	114
19.6.14 Caution on use of Unsalted Authorization Sessions	115
19.6.15 No HMAC Authorization	115
19.6.16 Authorization Selection Logic for Objects	116
19.6.17 Authorization Session Termination	116
19.7 Enhanced Authorization	117
19.7.1 Introduction	117
19.7.2 Policy Assertion	118
19.7.3 Policy AND	118
19.7.4 Policy OR	120
19.7.5 Order of Evaluation	122
19.7.6 Policy Assertions (Policy Commands)	122
19.7.7 Policy Session Context Values	125
19.7.8 Policy Example	126
19.7.9 Trial Policy	127
19.7.10 Modification of Policies	127
19.7.11 <i>TPM2_PolicySigned()</i> , <i>TPM2_PolicySecret()</i> , and <i>TPM2_PolicyTicket()</i>	128
19.8 Policy Session Creation	130
19.9 Use of TPM for <i>authPolicy</i> Computation	131

19.10 Trial Policy Session	131
19.11 Dictionary Attack Protection.....	132
19.11.1 Introduction.....	132
19.11.2 Lockout Mode Configuration Parameters.....	132
19.11.3 Lockout Mode.....	133
19.11.4 Recovering from Lockout Mode	133
19.11.5 Authorization Failures Involving lockoutAuth	134
19.11.6 Non-orderly Shutdown.....	134
19.11.7 Justification for Lockout Due to Session Binding	134
19.11.8 Sample Configurations for Lockout Parameters	135
20 Audit Session	136
20.1 Introduction.....	136
20.2 Exclusive Audit Sessions	137
20.3 Command Gating Based on Exclusivity	137
20.4 Audit Session Reporting.....	137
20.5 Audit Establishment Failures.....	138
21 Session-based encryption	139
21.1 Introduction.....	139
21.2 XOR Parameter Obfuscation	140
21.3 CFB Mode Parameter Encryption	140
22 Protected Storage	142
22.1 Introduction.....	142
22.2 Object Protections	142
22.3 Protection Values	142
22.4 Symmetric Encryption	143
22.5 Integrity.....	144
23 Protected Storage Hierarchy.....	146
23.1 Introduction.....	146
23.2 Hierarchical Relationship between Objects.....	146
23.3 Duplication.....	147
23.3.1 Definition	147
23.3.2 Protections	148
23.4 Duplication Group.....	153
23.5 Protection Group	155
23.6 Summary of Hierarchy Attributes	156
23.7 Primary Seed Hierarchies	156
23.8 Hierarchy Attributes Settings Matrix.....	156
24 Credential Protection.....	158
24.1 Introduction.....	158
24.2 Protocol	158
24.3 Protection of Credential.....	159
24.4 Symmetric Encrypt	159
24.5 HMAC.....	159
24.6 Summary of Protection Process.....	161
25 Object Attributes.....	162
25.1 Base Attributes	162
25.1.1 Introduction	162
25.1.2 <i>Restricted</i> Attribute	162
25.1.3 <i>Sign</i> Attribute	162

25.1.4 <i>Decrypt</i> Attribute	163
25.1.5 Uses	163
25.2 Other Attributes	165
25.2.1 <i>fixedTPM</i> and <i>fixedParent</i>	165
25.2.2 <i>stClear</i>	165
25.2.3 <i>sensitiveDataOrigin</i>	165
25.2.4 <i>userWithAuth</i>	165
25.2.5 <i>adminWithPolicy</i>	165
25.2.6 <i>noDA</i>	166
25.2.7 <i>encryptedDuplication</i>	166
26 Object Structure Elements	167
26.1 Introduction	167
26.2 Public Area	167
26.3 Sensitive Area	168
26.4 Private Area	168
26.5 Qualified Name	169
26.6 Sensitive Area Encryption	169
26.7 Sensitive Area Integrity	170
27 Object Creation	171
27.1 Introduction	171
27.2 Public Area Template	171
27.2.1 Introduction	171
27.2.2 <i>type</i>	171
27.2.3 <i>nameAlg</i>	172
27.2.4 <i>objectAttributes</i>	172
27.2.5 <i>authPolicy</i>	172
27.2.6 <i>parameters</i>	172
27.2.7 <i>unique</i>	172
27.3 Sensitive Values	172
27.3.1 Overview	172
27.3.2 <i>userAuth</i>	173
27.3.3 <i>data</i>	173
27.4 Creation PCR	173
27.5 Public Area Creation	173
27.5.1 Introduction	173
27.5.2 <i>type</i> , <i>nameAlg</i> , <i>objectAttributes</i> , <i>authPolicy</i> , and <i>parameters</i>	173
27.5.3 <i>unique</i>	174
27.6 Sensitive Area Creation	175
27.6.1 Introduction	175
27.6.2 <i>type</i>	175
27.6.3 <i>authValue</i>	175
27.6.4 <i>seedValue</i>	175
27.6.5 <i>sensitive</i>	176
27.7 Creation Data and Ticket	177
27.8 Creation Resources	178
28 Object Loading	179

28.1 Introduction.....	179
28.2 Load of an Ordinary Object	179
28.3 Public-only Load.....	179
28.4 External Object Load.....	180
29 Object Creation in Reference Implementation	181
30 Context Management.....	182
30.1 Introduction.....	182
30.2 Context Data	183
30.2.1 Introduction	183
30.2.2 Sequence Number.....	183
30.2.3 Handle.....	184
30.2.4 Hierarchy.....	185
30.3 Context Protections	185
30.3.1 Context Confidentiality Protection	185
30.3.2 Context Integrity Protection	186
30.4 Object Context Management	187
30.5 Session Context Management	187
30.6 Eviction.....	188
30.7 Incidental Use of Object Slots	189
31 Attestation	190
31.1 Introduction.....	190
31.2 Standard Attestation Structure	190
31.3 Privacy.....	191
31.4 Qualifying Data	191
31.5 Anonymous Signing	191
32 Cryptographic Support Functions.....	192
32.1 Introduction.....	192
32.2 Hash	192
32.3 HMAC.....	192
32.4 Hash, HMAC, and Event Sequences	193
32.4.1 Introduction	193
32.4.2 Hash Sequence	193
32.4.3 Event Sequence	193
32.4.4 HMAC Sequence	194
32.4.5 Sequence Contexts	194
32.5 Symmetric Encryption	194
32.6 Asymmetric Encryption and Signature Operations	194
33 Locality	195
34 Hardware Core Root of Trust Measurement (H-CRTM) Event Sequence.....	196
34.1 Introduction.....	196
34.2 Dynamic Root of Trust Measurement	196
34.3 H-CRTM before TPM2_Startup()	197
35 Command Audit.....	198
36 Timing Components	200
36.1 Introduction.....	200
36.2 Clock.....	201
36.2.1 Introduction	201
36.2.2 <i>Clock</i> Implementation	201

36.2.3 Orderly Shutdown of <i>Clock</i>	202
36.2.4 <i>Clock</i> Initialization at TPM2_Startup()	202
36.2.5 Setting <i>Clock</i>	203
36.2.6 <i>Clock</i> Periodicity	203
36.3 Time.....	204
36.4 resetCount.....	204
36.5 restartCount.....	204
36.6 Note on the Accuracy and Reliability of <i>Clock</i>	205
36.7 Privacy Aspects of <i>Clock</i>	206
37 NV Memory	207
37.1 Introduction.....	207
37.2 NV Indices	207
37.2.1 Definition	207
37.2.2 NV Index Allocation	208
37.2.3 NV Index Deletion	209
37.2.4 High-Endurance (Hybrid) Indices.....	209
37.2.5 Reading an NV Index.....	210
37.2.6 Updating an Index.....	211
37.2.7 NV Index in a Policy.....	214
37.3 Owner and Platform Evict Objects	214
37.4 State Saved by TPM2_Shutdown().....	215
37.4.1 Background.....	215
37.4.2 NV Orderly Data	215
37.4.3 NV Clear Data.....	216
37.4.4 NV Reset Data.....	217
37.5 Persistent NV Data	218
37.6 NV Rate Limiting	220
37.7 NV Other Considerations	220
37.7.1 Power Interruption	220
37.7.2 External NV.....	220
37.7.3 PCR in NV.....	221
38 Multi-Tasking	222
39 Errors and Response Codes.....	223
39.1 Error Reporting.....	223
39.2 TPM State After an Error.....	223
39.3 Resource Exhaustion Warnings.....	223
39.3.1 Introduction	223
39.3.2 Transient Resources.....	223
39.3.3 Temporary Resources	224
39.4 Response Code Details.....	224
40 General Purpose I/O	226
41 Minimums	227
41.1 Introduction.....	227
41.2 Authorization Sessions.....	227
41.3 Transient Objects	227
41.4 NV Counters and Bit Fields.....	227
Annex A (normative) RSA.....	228

A.1	Introduction.....	228
A.2	RSAEP	229
A.3	RSADP	229
A.4	RSAES_OAEP	229
A.5	RSAES_PKCSV1_5.....	229
A.6	RSASSA_PKCS1v1_5	229
A.7	RSASSA_PSS.....	230
A.8	RSA Cryptographic Primitives.....	231
A.8.1	Introduction	231
A.8.2	TPM2_RSA_Encrypt()	231
A.8.3	TPM2_RSA_Decrypt().....	231
A.9	Secret Sharing.....	231
A.9.1	Overview	231
A.9.2	RSA Encryption of Salt	231
A.9.3	RSA Secret Sharing for Duplication	232
A.9.4	RSA Secret Sharing for Credentials	232
Annex B (normative)	ECC.....	233
B.1	Introduction.....	233
B.2	Split Operations.....	233
B.2.1	Introduction	233
B.2.2	Commit Random Value.....	233
B.2.3	TPM2_Commit().....	234
B.2.4	TPM2_EC_Ephemeral()	235
B.2.5	Recovering the Private Ephemeral Key.....	236
B.3	ECC-Based Secret Sharing	236
B.4	EC Signing	236
B.4.1	ECDSA.....	236
B.4.2	ECDAA.....	236
B.4.3	EC Schnorr	239
B.5	Secret Sharing.....	240
B.5.1	ECDH.....	240
B.5.2	ECDH Encryption of Salt	241
B.5.3	ECC Secret Sharing for Duplication	241
B.5.4	ECC Secret Sharing for Credentials.....	241
B.6	ECC Primitive Operations	241
B.6.1	Introduction	241
B.6.2	TPM2_ECDH_KeyGen().....	241
B.6.3	TPM2_ECDH_ZGen().....	241
B.6.4	Two-phase Key Exchange.....	242
Annex C (normative)	Support for SMx Family of Algorithms	244
C.1	Introduction.....	244
C.1	SM2	244
C.1.1	Introduction	244
C.1.2	SM2 Digital Signature Algorithm.....	245
C.1.3	SM2 Key Exchange	247

C.2 SM3	248
C.3 SM4	248
Annex D (informative) Key Generation	249
D.1 Introduction.....	249
D.2 RSA Key Generation	249
D.2.1 Background.....	249
D.2.2 Prime Generation.....	249
D.2.3 Key Generation Algorithm.....	250
D.3 ECC Ordinary Keys	251
D.4 ECC Primary key	251
Annex E (informative) Policy Examples	252
E.1 Introduction.....	252
E.2 ISO/IEC 11889 (first edition) Compatible Authorization.....	252
Annex F (informative) Acknowledgements and contributors	254
F.1 Acknowledgements	254
F.2 Contributors.....	254
Bibliography	256

Tables

Table 1 — KDF Label Parameters.....	16
Table 2 — Block Cipher Parameters	41
Table 3 — Hierarchy Control Setting Combinations	67
Table 4 — Equations for Computing Entity Names	78
Table 5 — Separators	87
Table 6 — <i>Tag</i> Values	88
Table 7 — Use of Authorization/Session Blocks	91
Table 8 — Description of <i>sessionAttributes</i>	93
Table 9 — Command Layout for Example Command	96
Table 10 — Example Command Showing <i>authorizationSize</i>	97
Table 11 — Response Layout for Example Command	97
Table 12 — Example Response Showing <i>parameterSize</i>	98
Table 13 — Password Authorization of Command.....	101
Table 14 — Password Acknowledgment in Response	101
Table 15 — Session-Based Authorization of Command	103
Table 16 — Session-Based Acknowledgment in Response.....	103
Table 17 — Schematic of TPM2_StartAuthSession Command	107
Table 18 — Handle Parameters for TPM2_StartAuthSession.....	108
Table 19 — Format to Start Unbounded, Unsalted Session.....	109
Table 20 — Format to Start Bound Session	111

Table 21 — Format to Start Salted Session	112
Table 22 — Format to Start Salted and Bound Session.....	113
Table 23 — Mapping of Hierarchy Attributes.....	156
Table 24 — Allowed Hierarchy Settings	156
Table 25 — Mapping of Functional Attributes.....	163
Table 26 — ISO/IEC 11889 (first edition) Correspondence.....	164
Table 27 — Public Area Parameters	167
Table 28 — Sensitive Area Parameters.....	168
Table 29 — Standard Attestation Structure	190
Table 30 — Contents of the ORDERLY_DATA Structure	216
Table 31 — Contents of the STATE_CLEAR_DATA Structure	216
Table 32 — Contents of the STATE_RESET_DATA Structure	217
Table 33 — Contents of the PERSISTENT_DATA Structure.....	218

Figures

Figure 1 — Attestation Hierarchy	30
Figure 2 — Architectural Overview	36
Figure 3 — Command Execution Flow	40
Figure 4 — Random Number Generation	51
Figure 5 — TPM Startup Sequences	60
Figure 6 — On-Demand Self-Test	62
Figure 7 — Failure Mode Behavior	64
Figure 8 — Resuming FUM after <code>_TPM_Init</code>	66
Figure 9 — Field Upgrade Mode.....	67
Figure 10 — Command Structure	90
Figure 11 — Response Structure	90
Figure 12 — Command/Response Header Structure.....	91
Figure 13 — Authorization Layout for Command	95
Figure 14 — Authorization Layout for Response	95
Figure 15 — A Policy Evaluation	121
Figure 16 — Two Different Policy Expressions.....	122
Figure 17 — A Four-Term Policy	122
Figure 18 — Policy with an OR.....	123
Figure 19 — Policy where only one OR Branch is Evaluated.....	124
Figure 20 — A 12-input OR Policy.....	124
Figure 21 — Use of <code>TPM2_PolicyAuthorize()</code> to Avoid PCR Brittleness	131
Figure 22 — Creating a Private Structure.....	148
Figure 23 — Symmetric Protection of Hierarchy.....	150
Figure 24 — Duplication Process with Inner and Outer Wrapper.....	154
Figure 25 — Duplication Process with Outer Wrapper and No Inner Wrapper	155
Figure 26 — Duplication Process with Inner Wrapper and <code>TPM_RH_NULL</code> as NP.....	156
Figure 27 — Duplication Process with no Inner Wrapper and <code>TPM_RH_NULL</code> as NP.....	156
Figure 28 — Duplication Groups.....	158
Figure 29 — Protection Groups	158
Figure 30 — Creating a Identity Structure	164
Figure 31 — Response Code Evaluation.....	228