

Trusted Platform Module Library

Part 3: Commands

Family “2.0”

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CONTENTS

1	Scope	1
2	Terms and Definitions	1
3	Symbols and abbreviated terms.....	1
4	Notation	1
4.1	Introduction	1
4.2	Table Decorations.....	1
4.3	Handle and Parameter Demarcation	3
4.4	AuthorizationSize and ParameterSize	3
5	Normative References.....	4
6	Symbols and Abbreviated Terms	4
7	Command Processing.....	4
7.1	Introduction	4
7.2	Command Header Validation.....	4
7.3	Mode Checks	4
7.4	Handle Area Validation	5
7.5	Session Area Validation.....	6
7.6	Authorization Checks.....	7
7.7	Parameter Decryption.....	8
7.8	Parameter Unmarshaling.....	9
7.9	Command Post Processing	10
8	Response Values	12
8.1	Tag.....	12
8.2	Response Codes	12
9	Implementation Dependent	15
10	Detailed Actions Assumptions.....	16
10.1	Introduction	16
10.2	Pre-processing.....	16
10.3	Post Processing.....	16
11	Start-up.....	17
11.1	Introduction	17
11.2	_TPM_Init.....	17
11.3	TPM2_Startup.....	19
11.4	TPM2_Shutdown	24
12	Testing.....	28
12.1	Introduction	28
12.2	TPM2_SelfTest	29
12.3	TPM2_IncrementalSelfTest	32
12.4	TPM2_GetTestResult	35
13	Session Commands	38
13.1	TPM2_StartAuthSession	38
13.2	TPM2_PolicyRestart	43
14	Object Commands.....	46

14.1	TPM2_Create.....	46
14.2	TPM2_Load	51
14.3	TPM2_LoadExternal	55
14.4	TPM2_ReadPublic.....	60
14.5	TPM2_ActivateCredential	63
14.6	TPM2_MakeCredential	67
14.7	TPM2_Unseal	70
14.8	TPM2_ObjectChangeAuth.....	73
15	Duplication Commands	77
15.1	TPM2_Duplicate	77
15.2	TPM2_Rewrap.....	81
15.3	TPM2_Import	86
16	Asymmetric Primitives	92
16.1	Introduction	92
16.2	TPM2_RSA_Encrypt.....	92
16.3	TPM2_RSA_Decrypt	97
16.4	TPM2_ECDH_KeyGen	101
16.5	TPM2_ECDH_ZGen	104
16.6	TPM2_ECC_Parameters	107
16.7	TPM2_ZGen_2Phase	108
17	Symmetric Primitives.....	113
17.1	Introduction	113
17.2	TPM2_EncryptDecrypt.....	115
17.3	TPM2_Hash	119
17.4	TPM2_HMAC.....	122
18	Random Number Generator.....	126
18.1	TPM2_GetRandom.....	126
18.2	TPM2_StirRandom	129
19	Hash/HMAC/Event Sequences	132
19.1	Introduction	132
19.2	TPM2_HMAC_Start	132
19.3	TPM2_HashSequenceStart	136
19.4	TPM2_SequenceUpdate	139
19.5	TPM2_SequenceComplete.....	143
19.6	TPM2_EventSequenceComplete	147
20	Attestation Commands.....	151
20.1	Introduction	151
20.2	TPM2_Certify.....	153
20.3	TPM2_CertifyCreation	157
20.4	TPM2_Quote.....	161
20.5	TPM2_GetSessionAuditDigest	165
20.6	TPM2_GetCommandAuditDigest	169
20.7	TPM2_GetTime.....	173
21	Ephemeral EC Keys	177

21.1	Introduction	177
21.2	TPM2_Commit	178
21.3	TPM2_EC_Ephemeral	184
22	Signing and Signature Verification	187
22.1	TPM2_VerifySignature	187
22.2	TPM2_Sign	191
23	Command Audit	195
23.1	Introduction	195
23.2	TPM2_SetCommandCodeAuditStatus	196
24	Integrity Collection (PCR)	200
24.1	Introduction	200
24.2	TPM2_PCR_Extend	201
24.3	TPM2_PCR_Event	204
24.4	TPM2_PCR_Read	207
24.5	TPM2_PCR_Allocate	210
24.6	TPM2_PCR_SetAuthPolicy	213
24.7	TPM2_PCR_SetAuthValue	216
24.8	TPM2_PCR_Reset	219
24.9	_TPM_Hash_Start	222
24.10	_TPM_Hash_Data	224
24.11	_TPM_Hash_End	226
25	Enhanced Authorization (EA) Commands	229
25.1	Introduction	229
25.2	Signed Authorization Actions	230
25.3	TPM2_PolicySigned	234
25.4	TPM2_PolicySecret	240
25.5	TPM2_PolicyTicket	244
25.6	TPM2_PolicyOR	248
25.7	TPM2_PolicyPCR	252
25.8	TPM2_PolicyLocality	256
25.9	TPM2_PolicyNV	260
25.10	TPM2_PolicyCounterTimer	265
25.11	TPM2_PolicyCommandCode	270
25.12	TPM2_PolicyPhysicalPresence	273
25.13	TPM2_PolicyCpHash	276
25.14	TPM2_PolicyNameHash	280
25.15	TPM2_PolicyDuplicationSelect	283
25.16	TPM2_PolicyAuthorize	287
25.17	TPM2_PolicyAuthValue	291
25.18	TPM2_PolicyPassword	294
25.19	TPM2_PolicyGetDigest	297
25.20	TPM2_PolicyNvWritten	300
26	Hierarchy Commands	304
26.1	TPM2_CreatePrimary	304
26.2	TPM2_HierarchyControl	308
26.3	TPM2_SetPrimaryPolicy	312

26.4	TPM2_ChangePPS	315
26.5	TPM2_ChangeEPS	318
26.6	TPM2_Clear	321
26.7	TPM2_ClearControl	325
26.8	TPM2_HierarchyChangeAuth	328
27	Dictionary Attack Functions	331
27.1	Introduction	331
27.2	TPM2_DictionaryAttackLockReset	331
27.3	TPM2_DictionaryAttackParameters	334
28	Miscellaneous Management Functions	337
28.1	Introduction	337
28.2	TPM2_PP_Commands	337
28.3	TPM2_SetAlgorithmSet	340
29	Field Upgrade	343
29.1	Introduction	343
29.2	TPM2_FieldUpgradeStart	345
29.3	TPM2_FieldUpgradeData	348
29.4	TPM2_FirmwareRead	351
30	Context Management	354
30.1	Introduction	354
30.2	TPM2_ContextSave	354
30.3	TPM2_ContextLoad	359
30.4	TPM2_FlushContext	364
30.5	TPM2_EvictControl	367
31	Clocks and Timers	372
31.1	TPM2_ReadClock	372
31.2	TPM2_ClockSet	375
31.3	TPM2_ClockRateAdjust	378
32	Capability Commands	381
32.1	Introduction	381
32.2	TPM2_GetCapability	381
32.3	TPM2_TestParms	389
33	Non-volatile Storage	392
33.1	Introduction	392
33.2	NV Counters	393
33.3	TPM2_NV_DefineSpace	394
33.4	TPM2_NV_UndefineSpace	400
33.5	TPM2_NV_UndefineSpaceSpecial	403
33.6	TPM2_NV_ReadPublic	406
33.7	TPM2_NV_Write	409
33.8	TPM2_NV_Increment	413
33.9	TPM2_NV_Extend	417
33.10	TPM2_NV_SetBits	421
33.11	TPM2_NV_WriteLock	425

33.12 TPM2_NV_GlobalWriteLock.....	429
33.13 TPM2_NV_Read.....	432
33.14 TPM2_NV_ReadLock.....	435
33.15 TPM2_NV_ChangeAuth.....	438
33.16 TPM2_NV_Certify.....	441

Tables

Table 1 — Command Modifiers and Decoration	2
Table 2 — Separators	3
Table 3 — Unmarshaling Errors	10
Table 4 — Command-Independent Response Codes	13
Table 5 — TPM2_Startup Command	21
Table 6 — TPM2_Startup Response	21
Table 7 — TPM2_Shutdown Command	25
Table 8 — TPM2_Shutdown Response	25
Table 9 — TPM2_SelfTest Command	30
Table 10 — TPM2_SelfTest Response	30
Table 11 — TPM2_IncrementalSelfTest Command	33
Table 12 — TPM2_IncrementalSelfTest Response	33
Table 13 — TPM2_GetTestResult Command	36
Table 14 — TPM2_GetTestResult Response	36
Table 15 — TPM2_StartAuthSession Command	40
Table 16 — TPM2_StartAuthSession Response	40
Table 17 — TPM2_PolicyRestart Command	44
Table 18 — TPM2_PolicyRestart Response	44
Table 19 — TPM2_Create Command	48
Table 20 — TPM2_Create Response	48
Table 21 — TPM2_Load Command	52
Table 22 — TPM2_Load Response	52
Table 23 — TPM2_LoadExternal Command	57
Table 24 — TPM2_LoadExternal Response	57
Table 25 — TPM2_ReadPublic Command	61
Table 26 — TPM2_ReadPublic Response	61
Table 27 — TPM2_ActivateCredential Command	64
Table 28 — TPM2_ActivateCredential Response	64
Table 29 — TPM2_MakeCredential Command	68
Table 30 — TPM2_MakeCredential Response	68
Table 31 — TPM2_Unseal Command	71
Table 32 — TPM2_Unseal Response	71
Table 33 — TPM2_ObjectChangeAuth Command	74
Table 34 — TPM2_ObjectChangeAuth Response	74
Table 35 — TPM2_Duplicate Command	78
Table 36 — TPM2_Duplicate Response	78
Table 37 — TPM2_Rewrap Command	82
Table 38 — TPM2_Rewrap Response	82

Table 39 — TPM2_Import Command	88
Table 40 — TPM2_Import Response	88
Table 41 — Padding Scheme Selection	92
Table 42 — Message Size Limits Based on Padding	93
Table 43 — TPM2_RSA_Encrypt Command.....	94
Table 44 — TPM2_RSA_Encrypt Response	94
Table 45 — TPM2_RSA_Decrypt Command	98
Table 46 — TPM2_RSA_Decrypt Response.....	98
Table 47 — TPM2_ECDH_KeyGen Command.....	102
Table 48 — TPM2_ECDH_KeyGen Response	102
Table 49 — TPM2_ECDH_ZGen Command.....	105
Table 50 — TPM2_ECDH_ZGen Response	105
Table 51 — TPM2_ECC_Parameters Command.....	107
Table 52 — TPM2_ECC_Parameters Response	107
Table 53 — TPM2_ZGen_2Phase Command.....	110
Table 54 — TPM2_ZGen_2Phase Response	110
Table 55 — Symmetric Chaining Process	114
Table 56 — TPM2_EncryptDecrypt Command.....	116
Table 57 — TPM2_EncryptDecrypt Response.....	116
Table 58 — TPM2_Hash Command.....	120
Table 59 — TPM2_Hash Response	120
Table 60 — TPM2_HMAC Command.....	123
Table 61 — TPM2_HMAC Response	123
Table 62 — TPM2_GetRandom Command.....	127
Table 63 — TPM2_GetRandom Response	127
Table 64 — TPM2_StirRandom Command	130
Table 65 — TPM2_StirRandom Response.....	130
Table 66 — Hash Selection Matrix	132
Table 67 — TPM2_HMAC_Start Command.....	133
Table 68 — TPM2_HMAC_Start Response	133
Table 69 — TPM2_HashSequenceStart Command.....	137
Table 70 — TPM2_HashSequenceStart Response	137
Table 71 — TPM2_SequenceUpdate Command	140
Table 72 — TPM2_SequenceUpdate Response.....	140
Table 73 — TPM2_SequenceComplete Command	144
Table 74 — TPM2_SequenceComplete Response.....	144
Table 75 — TPM2_EventSequenceComplete Command	148
Table 76 — TPM2_EventSequenceComplete Response.....	148
Table 77 — TPM2_Certify Command.....	154

Table 78 — TPM2_Certify Response	154
Table 79 — TPM2_CertifyCreation Command	158
Table 80 — TPM2_CertifyCreation Response.....	158
Table 81 — TPM2_Quote Command	162
Table 82 — TPM2_Quote Response.....	162
Table 83 — TPM2_GetSessionAuditDigest Command	166
Table 84 — TPM2_GetSessionAuditDigest Response	166
Table 85 — TPM2_GetCommandAuditDigest Command	170
Table 86 — TPM2_GetCommandAuditDigest Response.....	170
Table 87 — TPM2_GetTime Command	174
Table 88 — TPM2_GetTime Response.....	174
Table 89 — TPM2_Commit Command.....	180
Table 90 — TPM2_Commit Response	180
Table 91 — TPM2_EC_Ephemeral Command.....	185
Table 92 — TPM2_EC_Ephemeral Response	185
Table 93 — TPM2_VerifySignature Command.....	188
Table 94 — TPM2_VerifySignature Response.....	188
Table 95 — TPM2_Sign Command	192
Table 96 — TPM2_Sign Response	192
Table 97 — TPM2_SetCommandCodeAuditStatus Command.....	197
Table 98 — TPM2_SetCommandCodeAuditStatus Response	197
Table 99 — TPM2_PCR_Extend Command	202
Table 100 — TPM2_PCR_Extend Response.....	202
Table 101 — TPM2_PCR_Event Command	205
Table 102 — TPM2_PCR_Event Response.....	205
Table 103 — TPM2_PCR_Read Command.....	208
Table 104 — TPM2_PCR_Read Response	208
Table 105 — TPM2_PCR_Allocate Command.....	211
Table 106 — TPM2_PCR_Allocate Response	211
Table 107 — TPM2_PCR_SetAuthPolicy Command.....	214
Table 108 — TPM2_PCR_SetAuthPolicy Response	214
Table 109 — TPM2_PCR_SetAuthValue Command	217
Table 110 — TPM2_PCR_SetAuthValue Response.....	217
Table 111 — TPM2_PCR_Reset Command	220
Table 112 — TPM2_PCR_Reset Response.....	220
Table 113 — TPM2_PolicySigned Command	236
Table 114 — TPM2_PolicySigned Response.....	236
Table 115 — TPM2_PolicySecret Command	241
Table 116 — TPM2_PolicySecret Response.....	241

Table 117 — TPM2_PolicyTicket Command	245
Table 118 — TPM2_PolicyTicket Response	245
Table 119 — TPM2_PolicyOR Command	249
Table 120 — TPM2_PolicyOR Response.....	249
Table 121 — TPM2_PolicyPCR Command	253
Table 122 — TPM2_PolicyPCR Response	253
Table 123 — TPM2_PolicyLocality Command	257
Table 124 — TPM2_PolicyLocality Response.....	257
Table 125 — TPM2_PolicyNV Command.....	261
Table 126 — TPM2_PolicyNV Response	261
Table 127 — TPM2_PolicyCounterTimer Command	266
Table 128 — TPM2_PolicyCounterTimer Response.....	266
Table 129 — TPM2_PolicyCommandCode Command	271
Table 130 — TPM2_PolicyCommandCode Response.....	271
Table 131 — TPM2_PolicyPhysicalPresence Command.....	274
Table 132 — TPM2_PolicyPhysicalPresence Response	274
Table 133 — TPM2_PolicyCpHash Command.....	277
Table 134 — TPM2_PolicyCpHash Response	277
Table 135 — TPM2_PolicyNameHash Command.....	281
Table 136 — TPM2_PolicyNameHash Response	281
Table 137 — TPM2_PolicyDuplicationSelect Command.....	284
Table 138 — TPM2_PolicyDuplicationSelect Response	284
Table 139 — TPM2_PolicyAuthorize Command	288
Table 140 — TPM2_PolicyAuthorize Response.....	288
Table 141 — TPM2_PolicyAuthValue Command	292
Table 142 — TPM2_PolicyAuthValue Response	292
Table 143 — TPM2_PolicyPassword Command.....	295
Table 144 — TPM2_PolicyPassword Response	295
Table 145 — TPM2_PolicyGetDigest Command.....	298
Table 146 — TPM2_PolicyGetDigest Response	298
Table 133 — TPM2_PolicyNvWritten Command.....	301
Table 134 — TPM2_PolicyNvWritten Response	301
Table 147 — TPM2_CreatePrimary Command	305
Table 148 — TPM2_CreatePrimary Response	305
Table 149 — TPM2_HierarchyControl Command	309
Table 150 — TPM2_HierarchyControl Response	309
Table 151 — TPM2_SetPrimaryPolicy Command.....	313
Table 152 — TPM2_SetPrimaryPolicy Response	313
Table 153 — TPM2_ChangePPS Command	316

Table 154 — TPM2_ChangePPS Response.....	316
Table 155 — TPM2_ChangeEPS Command	319
Table 156 — TPM2_ChangeEPS Response.....	319
Table 157 — TPM2_Clear Command.....	322
Table 158 — TPM2_Clear Response	322
Table 159 — TPM2_ClearControl Command	326
Table 160 — TPM2_ClearControl Response	326
Table 161 — TPM2_HierarchyChangeAuth Command.....	329
Table 162 — TPM2_HierarchyChangeAuth Response	329
Table 163 — TPM2_DictionaryAttackLockReset Command	332
Table 164 — TPM2_DictionaryAttackLockReset Response	332
Table 165 — TPM2_DictionaryAttackParameters Command	335
Table 166 — TPM2_DictionaryAttackParameters Response.....	335
Table 167 — TPM2_PP_Commands Command.....	338
Table 168 — TPM2_PP_Commands Response	338
Table 169 — TPM2_SetAlgorithmSet Command	341
Table 170 — TPM2_SetAlgorithmSet Response.....	341
Table 171 — TPM2_FieldUpgradeStart Command.....	346
Table 172 — TPM2_FieldUpgradeStart Response	346
Table 173 — TPM2_FieldUpgradeData Command.....	349
Table 174 — TPM2_FieldUpgradeData Response	349
Table 175 — TPM2_FirmwareRead Command.....	352
Table 176 — TPM2_FirmwareRead Response	352
Table 177 — TPM2_ContextSave Command.....	355
Table 178 — TPM2_ContextSave Response	355
Table 179 — TPM2_ContextLoad Command.....	360
Table 180 — TPM2_ContextLoad Response	360
Table 181 — TPM2_FlushContext Command.....	365
Table 182 — TPM2_FlushContext Response	365
Table 183 — TPM2_EvictControl Command.....	369
Table 184 — TPM2_EvictControl Response	369
Table 185 — TPM2_ReadClock Command.....	373
Table 186 — TPM2_ReadClock Response	373
Table 187 — TPM2_ClockSet Command.....	376
Table 188 — TPM2_ClockSet Response	376
Table 189 — TPM2_ClockRateAdjust Command.....	379
Table 190 — TPM2_ClockRateAdjust Response	379
Table 191 — TPM2_GetCapability Command.....	385
Table 192 — TPM2_GetCapability Response	385

Table 193 — TPM2_TestParms Command.....	390
Table 194 — TPM2_TestParms Response	390
Table 195 — TPM2_NV_DefineSpace Command	396
Table 196 — TPM2_NV_DefineSpace Response	396
Table 197 — TPM2_NV_UndefineSpace Command	401
Table 198 — TPM2_NV_UndefineSpace Response	401
Table 199 — TPM2_NV_UndefineSpaceSpecial Command.....	404
Table 200 — TPM2_NV_UndefineSpaceSpecial Response	404
Table 201 — TPM2_NV_ReadPublic Command.....	407
Table 202 — TPM2_NV_ReadPublic Response	407
Table 203 — TPM2_NV_Write Command.....	410
Table 204 — TPM2_NV_Write Response	410
Table 205 — TPM2_NV_Increment Command	414
Table 206 — TPM2_NV_Increment Response.....	414
Table 207 — TPM2_NV_Extend Command.....	418
Table 208 — TPM2_NV_Extend Response	418
Table 209 — TPM2_NV_SetBits Command.....	422
Table 210 — TPM2_NV_SetBits Response	422
Table 211 — TPM2_NV_WriteLock Command	426
Table 212 — TPM2_NV_WriteLock Response.....	426
Table 213 — TPM2_NV_GlobalWriteLock Command.....	430
Table 214 — TPM2_NV_GlobalWriteLock Response	430
Table 215 — TPM2_NV_Read Command.....	433
Table 216 — TPM2_NV_Read Response	433
Table 217 — TPM2_NV_ReadLock Command	436
Table 218 — TPM2_NV_ReadLock Response	436
Table 219 — TPM2_NV_ChangeAuth Command	439
Table 220 — TPM2_NV_ChangeAuth Response	439
Table 221 — TPM2_NV_Certify Command.....	442
Table 222 — TPM2_NV_Certify Response	442

Trusted Platform Module Library

Part 3: Commands

1 Scope

This part 3 of the *Trusted Module Library* specification contains the definitions of the TPM commands. These commands make use of the constants, flags, structure, and union definitions defined in part 2: *Structures*.

The detailed description of the operation of the commands is written in the C language with extensive comments. The behavior of the C code in this part 3 is normative but does not fully describe the behavior of a TPM. The combination of this part 3 and part 4: *Supporting Routines* is sufficient to fully describe the required behavior of a TPM.

The code in parts 3 and 4 is written to define the behavior of a compliant TPM. In some cases (e.g., firmware update), it is not possible to provide a compliant implementation. In those cases, any implementation provided by the vendor that meets the general description of the function provided in part 3 would be compliant.

The code in parts 3 and 4 is not written to meet any particular level of conformance nor does this specification require that a TPM meet any particular level of conformance.

2 Terms and Definitions

For the purposes of this document, the terms and definitions given in part 1 of this specification apply.

3 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in part 1 apply.

4 Notation

4.1 Introduction

In addition to the notation in this clause, the “Notations” clause in Part 1 of this specification is applicable to this Part 3.

Command and response tables used various decorations to indicate the fields of the command and the allowed types. These decorations are described in this clause.

4.2 Table Decorations

The symbols and terms in the Notation column of Table 1 are used in the tables for the command schematics. These values indicate various qualifiers for the parameters or descriptions with which they are associated.

Table 1 — Command Modifiers and Decoration

Notation	Meaning
+	A Type decoration – When appended to a value in the Type column of a command, this symbol indicates that the parameter is allowed to use the “null” value of the data type (see “Conditional Types” in Part 2). The null value is usually TPM_RH_NULL for a handle or TPM_ALG_NULL for an algorithm selector.
@	A Name decoration – When this symbol precedes a handle parameter in the “Name” column, it indicates that an authorization session is required for use of the entity associated with the handle. If a handle does not have this symbol, then an authorization session is not allowed.
+PP	A Description modifier – This modifier may follow TPM_RH_PLATFORM in the “Description” column to indicate that Physical Presence is required when <i>platformAuth/platformPolicy</i> is provided.
+{PP}	A Description modifier – This modifier may follow TPM_RH_PLATFORM to indicate that Physical Presence may be required when <i>platformAuth/platformPolicy</i> is provided. The commands with this notation may be in the <i>setList</i> or <i>clearList</i> of TPM2_PP_Commands().
{NV}	A Description modifier – This modifier may follow the <i>commandCode</i> in the “Description” column to indicate that the command may result in an update of NV memory and be subject to rate throttling by the TPM. If the command code does not have this notation, then a write to NV memory does not occur as part of the command actions. NOTE Any command that uses authorization may cause a write to NV if there is an authorization failure. A TPM may use the occasion of command execution to update the NV copy of clock.
{F}	A Description modifier – This modifier indicates that the “flushed” attribute will be SET in the TPMA_CC for the command. The modifier may follow the <i>commandCode</i> in the “Description” column to indicate that any transient handle context used by the command will be flushed from the TPM when the command completes. This may be combined with the {NV} modifier but not with the {E} modifier. EXAMPLE 1 {NV F} EXAMPLE 2 TPM2_SequenceComplete() will flush the context associated with the <i>sequenceHandle</i> .
{E}	A Description modifier – This modifier indicates that the “extensive” attribute will be SET in the TPMA_CC for the command. This modifier may follow the <i>commandCode</i> in the “Description” column to indicate that the command may flush many objects and re-enumeration of the loaded context likely will be required. This may be combined with the {NV} modifier but not with the {F} modifier. EXAMPLE 1 {NV E} EXAMPLE 2 TPM2_Clear() will flush all contexts associated with the Storage hierarchy and the Endorsement hierarchy.
Auth Index:	A Description modifier – When a handle has a “@” decoration, the “Description” column will contain an “Auth Index:” entry for the handle. This entry indicates the number of the authorization session. The authorization sessions associated with handles will occur in the session area in the order of the handles with the “@” modifier. Sessions used only for encryption/decryption or only for audit will follow the handles used for authorization.

Notation	Meaning
Auth Role:	<p>A Description modifier – This will be in the “Description” column of a handle with the “@” decoration. It may have a value of USER, ADMIN or DUP. If the handle has the Auth Role of USER and the handle is an Object, the type of authorization is determined by the setting of <i>userWithAuth</i> in the Object's attributes. If the Auth Role is ADMIN and the handle is an Object, the type of authorization is determined by the setting of <i>adminWithPolicy</i> in the Object's attributes. If the DUP role is selected, authorization may only be with a policy session (DUP role only applies to Objects). When either ADMIN or DUP role is selected, a policy command that selects the command being authorized is required to be part of the policy.</p> <p>EXAMPLE TPM2_Certify requires the ADMIN role for the first handle (<i>objectHandle</i>). The policy authorization for <i>objectHandle</i> is required to contain TPM2_PolicyCommandCode(<i>commandCode</i> == TPM_CC_Certify). This sets the state of the policy so that it can be used for ADMIN role authorization in TPM2_Certify().</p> <p>If the handle references an NV Index, then the allowed authorizations are determined by the settings of the attributes of the NV Index as described in Part 2, "TPMA_NV (NV Index Attributes)."</p>

4.3 Handle and Parameter Demarcation

The demarcations between the header, handle, and parameter parts are indicated by:

Table 2 — Separators

Separator	Meaning
*****	the values immediately following are in the handle area
=====	the values immediately following are in the parameter area

4.4 AuthorizationSize and ParameterSize

Authorization sessions are not shown in the command or response schematics. When the tag of a command or response is TPM_ST_SESSIONS, then a 32-bit value will be present in the command/response buffer to indicate the size of the authorization field or the parameter field. This value shall immediately follow the handle area (which may contain no handles). For a command, this value (*authorizationSize*) indicates the size of the Authorization Area and shall have a value of 9 or more. For a response, this value (*parameterSize*) indicates the size of the parameter area and may have a value of zero.

If the *authorizationSize* field is present in the command, *parameterSize* will be present in the response, but only if the *responseCode* is TPM_RC_SUCCESS.

When the command tag is TPM_ST_NO_SESSIONS, no authorizations are present and no *authorizationSize* field is required and shall not be present.

5 Normative References

The “Normative References” clause in Part 1 of this specification is applicable to this Part 3.

6 Symbols and Abbreviated Terms

The “Symbols and Abbreviated Terms” clause in Part 1 of this specification is applicable to this Part 3.

7 Command Processing

7.1 Introduction

This clause defines the command validations that are required of any implementation and the response code returned if the indicated check fails. Unless stated otherwise, the order of the checks is not normative and different TPM may give different responses when a command has multiple errors.

In the description below, some statements that describe a check may be followed by a response code in parentheses. This is the normative response code should the indicated check fail. A normative response code may also be included in the statement.

7.2 Command Header Validation

Before a TPM may begin the actions associated with a command, a set of command format and consistency checks shall be performed. These checks are listed below and should be performed in the indicated order.

- a) The TPM shall successfully unmarshal a `TPMI_ST_COMMAND_TAG` and verify that it is either `TPM_ST_SESSIONS` or `TPM_ST_NO_SESSIONS` (`TPM_RC_BAD_TAG`).
- b) The TPM shall successfully unmarshal a `UINT32` as the *commandSize*. If the TPM has an interface buffer that is loaded by some hardware process, the number of octets in the input buffer for the command reported by the hardware process shall exactly match the value in *commandSize* (`TPM_RC_COMMAND_SIZE`).

NOTE A TPM may have direct access to system memory and unmarshal directly from that memory.

- c) The TPM shall successfully unmarshal a `TPM_CC` and verify that the command is implemented (`TPM_RC_COMMAND_CODE`).

7.3 Mode Checks

The following mode checks shall be performed in the order listed:

- a) If the TPM is in Failure mode, then the *commandCode* is TPM_CC_GetTestResult or TPM_CC_GetCapability (TPM_RC_FAILURE) and the command *tag* is TPM_ST_NO_SESSIONS (TPM_RC_FAILURE).

NOTE 1 In Failure mode, the TPM has no cryptographic capability and processing of sessions is not supported.

- b) The TPM is in Field Upgrade mode (FUM), the *commandCode* is TPM_CC_FieldUpgradeData (TPM_RC_UPGRADE).
- c) If the TPM has not been initialized (TPM2_Startup()), then the *commandCode* is TPM_CC_Startup (TPM_RC_INITIALIZE).

NOTE 2 The TPM may enter Failure mode during _TPM_Init processing, before TPM2_Startup(). Since the platform firmware cannot know that the TPM is in Failure mode without accessing it, and since the first command is required to be TPM2_Startup(), the expected sequence will be that platform firmware (the CRTM) will issue TPM2_Startup() and receive TPM_RC_FAILURE indicating that the TPM is in Failure mode.

There may be failures where a TPM cannot record that it received TPM2_Startup(). In those cases, a TPM in failure mode may process TPM2_GetTestResult(), TPM2_GetCapability(), or the field upgrade commands. As a side effect, that TPM may process TPM2_GetTestResult(), TPM2_GetCapability() or the field upgrade commands before TPM2_Startup().

This is a corner case exception to the rule that TPM2_Startup() must be the first command.

The mode checks may be performed before or after the command header validation.

7.4 Handle Area Validation

After successfully unmarshaling and validating the command header, the TPM shall perform the following checks on the handles and sessions. These checks may be performed in any order.

- a) The TPM shall successfully unmarshal the number of handles required by the command and validate that the value of the handle is consistent with the command syntax. If not, the TPM shall return TPM_RC_VALUE.

NOTE 1 The TPM may unmarshal a handle and validate that it references an entity on the TPM before unmarshaling a subsequent handle.

NOTE 2 If the submitted command contains fewer handles than required by the syntax of the command, the TPM may continue to read into the next area and attempt to interpret the data as a handle.

- b) For all handles in the handle area of the command, the TPM will validate that the referenced entity is present in the TPM.

- 1) If the handle references a transient object, the handle shall reference a loaded object (TPM_RC_REFERENCE_H0 + N where N is the number of the handle in the command).

NOTE 3 If the hierarchy for a transient object is disabled, then the transient objects will be flushed so this check will fail.

- 2) If the handle references a persistent object, then

- i) the handle shall reference a persistent object that is currently in TPM non-volatile memory (TPM_RC_HANDLE);
- ii) the hierarchy associated with the object is not disabled (TPM_RC_HIERARCHY); and
- iii) if the TPM implementation moves a persistent object to RAM for command processing then sufficient RAM space is available (TPM_RC_OBJECT_MEMORY).

- 3) If the handle references an NV Index, then
 - i) an Index exists that corresponds to the handle (TPM_RC_HANDLE); and
 - ii) the hierarchy associated with the existing NV Index is not disabled (TPM_RC_HANDLE).
 - iii) the hierarchy associated with an NV index being defined is not disabled (TPM_RC_HIERARCHY)
- 4) If the handle references a session, then the session context shall be present in TPM memory (TPM_RC_REFERENCE_S0 + N).
- 5) If the handle references a primary seed for a hierarchy (TPM_RH_ENDORSEMENT, TPM_RH_OWNER, or TPM_RH_PLATFORM) then the enable for the hierarchy is SET (TPM_RC_HIERARCHY).
- 6) If the handle references a PCR, then the value is within the range of PCR supported by the TPM (TPM_RC_VALUE)

NOTE 4 In the reference implementation, this TPM_RC_VALUE is returned by the unmarshaling code for a TPMI_DH_PCR.

7.5 Session Area Validation

- a) If the tag is TPM_ST_SESSIONS and the command is a context management command (TPM2_ContextSave(), TPM2_ContextLoad(), or TPM2_FlushContext()) the TPM will return TPM_RC_AUTH_CONTEXT.
- b) If the tag is TPM_ST_SESSIONS, the TPM will attempt to unmarshal an *authorizationSize* and return TPM_RC_AUTHSIZE if the value is not within an acceptable range.
 - 1) The minimum value is (sizeof(TPM_HANDLE) + sizeof(UINT16) + sizeof(TPMA_SESSION) + sizeof(UINT16)).
 - 2) The maximum value of *authorizationSize* is equal to $\text{commandSize} - (\text{sizeof(TPM_ST)} + \text{sizeof(UINT32)} + \text{sizeof(TPM_CC)} + (N * \text{sizeof(TPM_HANDLE)}) + \text{sizeof(UINT32)})$ where N is the number of handles associated with the *commandCode* and may be zero.

NOTE 1 (sizeof(TPM_ST) + sizeof(UINT32) + sizeof(TPM_CC)) is the size of a command header. The last UINT32 contains the *authorizationSize* octets, which are not counted as being in the authorization session area.

- c) The TPM will unmarshal the authorization sessions and perform the following validations:
 - 1) If the session handle is not a handle for an HMAC session, a handle for a policy session, or, TPM_RS_PW then the TPM shall return TPM_RC_HANDLE.
 - 2) If the session is not loaded, the TPM will return the warning TPM_RC_REFERENCE_S0 + N where N is the number of the session. The first session is session zero, N = 0.

NOTE 2 If the HMAC and policy session contexts use the same memory, the type of the context must match the type of the handle.

- 3) If the maximum allowed number of sessions have been unmarshaled and fewer octets than indicated in *authorizationSize* were unmarshaled (that is, *authorizationSize* is too large), the TPM shall return TPM_RC_AUTHSIZE.

- 4) The consistency of the authorization session attributes is checked.
 - i) An authorization session is present for each of the handles with the “@” decoration (TPM_RC_AUTH_MISSING).
 - ii) Only one session is allowed for:
 - (a) session auditing (TPM_RC_ATTRIBUTES) – this session may be used for encrypt or decrypt but may not be a session that is also used for authorization;
 - (b) decrypting a command parameter (TPM_RC_ATTRIBUTES) – this may be any of the authorization sessions, or the audit session, or a session may be added for the single purpose of decrypting a command parameter, as long as the total number of sessions does not exceed three; and
 - (c) encrypting a response parameter (TPM_RC_ATTRIBUTES) – this may be any of the authorization sessions, or the audit session if present, or a session may be added for the single purpose of encrypting a response parameter, as long as the total number of sessions does not exceed three.

NOTE 3 A session used for decrypting a command parameter may also be used for encrypting a response parameter.

7.6 Authorization Checks

After unmarshaling and validating the handles and the consistency of the authorization sessions, the authorizations shall be checked. Authorization checks only apply to handles if the handle in the command schematic has the “@” decoration.

- a) The public and sensitive portions of the object shall be present on the TPM (TPM_RC_AUTH_UNAVAILABLE).
- b) If the associated handle is TPM_RH_PLATFORM, and the command requires confirmation with physical presence, then physical presence is asserted (TPM_RC_PP).
- c) If the object or NV Index is subject to DA protection, and the authorization is with an HMAC or password, then the TPM is not in lockout (TPM_RC_LOCKOUT).

NOTE 1 An object is subject to DA protection if its *noDA* attribute is CLEAR. An NV Index is subject to DA protection if its TPMA_NV_NO_DA attribute is CLEAR.

NOTE 2 An HMAC or password is required in a policy session when the policy contains TPM2_PolicyAuthValue() or TPM2_PolicyPassword().

- d) If the command requires a handle to have DUP role authorization, then the associated authorization session is a policy session (TPM_RC_POLICY_FAIL).
- e) If the command requires a handle to have ADMIN role authorization:
 - 1) If the entity being authorized is an object and its *adminWithPolicy* attribute is SET, then the authorization session is a policy session (TPM_RC_POLICY_FAIL).

NOTE 3 If *adminWithPolicy* is CLEAR, then any type of authorization session is allowed.

- 2) If the entity being authorized is an NV Index, then the associated authorization session is a policy session.

NOTE 4 The only commands that are currently defined that required use of ADMIN role authorization are commands that operate on objects and NV Indices.

- f) If the command requires a handle to have USER role authorization:
- 1) If the entity being authorized is an object and its *userWithAuth* attribute is CLEAR, then the associated authorization session is a policy session (TPM_RC_POLICY_FAIL).
 - 2) If the entity being authorized is an NV Index;
 - i) if the authorization session is a policy session;
 - (a) the TPMA_NV_POLICYWRITE attribute of the NV Index is SET if the command modifies the NV Index data (TPM_RC_AUTH_UNAVAILABLE);
 - (b) the TPMA_NV_POLICYREAD attribute of the NV Index is SET if the command reads the NV Index data (TPM_RC_AUTH_UNAVAILABLE);
 - ii) if the authorization is an HMAC session or a password;
 - (a) the TPMA_NV_AUTHWRITE attribute of the NV Index is SET if the command modifies the NV Index data (TPM_RC_AUTH_UNAVAILABLE);
 - (b) the TPMA_NV_AUTHREAD attribute of the NV Index is SET if the command reads the NV Index data (TPM_RC_AUTH_UNAVAILABLE).
- g) If the authorization is provided by a policy session, then:
- 1) if *policySession→timeOut* has been set, the session shall not have expired (TPM_RC_EXPIRED);
 - 2) if *policySession→cpHash* has been set, it shall match the *cpHash* of the command (TPM_RC_POLICY_FAIL);
 - 3) if *policySession→commandCode* has been set, then *commandCode* of the command shall match (TPM_RC_POLICY_CC);
 - 4) *policySession→policyDigest* shall match the *authPolicy* associated with the handle (TPM_RC_POLICY_FAIL);
 - 5) if *policySession→pcrUpdateCounter* has been set, then it shall match the value of *pcrUpdateCounter* (TPM_RC_PCR_CHANGED);
 - 6) if *policySession→commandLocality* has been set, it shall match the locality of the command (TPM_RC_LOCALITY), and
 - 7) if the authorization uses an HMAC, then the HMAC is properly constructed using the *authValue* associated with the handle and/or the session secret (TPM_RC_AUTH_FAIL or TPM_RC_BAD_AUTH).

NOTE 5 For a bound session, if the handle references the object used to initiate the session, then the *authValue* will not be required but proof of knowledge of the session secret is necessary.

NOTE 6 A policy session may require proof of knowledge of the *authValue* of the object being authorized.

If the TPM returns an error other than TPM_RC_AUTH_FAIL then the TPM shall not alter any TPM state. If the TPM return TPM_RC_AUTH_FAIL, then the TPM shall not alter any TPM state other than *lockoutCount*.

NOTE 7 The TPM may decrease failedTries regardless of any other processing performed by the TPM. That is, the TPM may exit Lockout mode, regardless of the return code.

7.7 Parameter Decryption

If an authorization session has the TPMA_SESSION.*decrypt* attribute SET, and the command does not allow a command parameter to be encrypted, then the TPM will return TPM_RC_ATTRIBUTES.

Otherwise, the TPM will decrypt the parameter using the values associated with the session before parsing parameters.

7.8 Parameter Unmarshaling

7.8.1 Introduction

The detailed actions for each command assume that the input parameters of the command have been unmarshaled into a command-specific structure with the structure defined by the command schematic. Additionally, a response-specific output structure is assumed which will receive the values produced by the detailed actions.

NOTE An implementation is not required to process parameters in this manner or to separate the parameter parsing from the command actions. This method was chosen for the specification so that the normative behavior described by the detailed actions would be clear and unencumbered.

Unmarshaling is the process of processing the parameters in the input buffer and preparing the parameters for use by the command-specific action code. No data movement need take place but it is required that the TPM validate that the parameters meet the requirements of the expected data type as defined in Part 2 of this specification.

7.8.2 Unmarshaling Errors

When an error is encountered while unmarshaling a command parameter, an error response code is returned and no command processing occurs. A table defining a data type may have response codes embedded in the table to indicate the error returned when the input value does not match the parameters of the table.

NOTE In the reference implementation, a parameter number is added to the response code so that the offending parameter can be isolated. This is optional.

In many cases, the table contains no specific response code value and the return code will be determined as defined in Table 3.

Table 3 — Unmarshaling Errors

Response Code	Meaning
TPM_RC_ASYMMETRIC	a parameter that should be an asymmetric algorithm selection does not have a value that is supported by the TPM
TPM_RC_BAD_TAG	a parameter that should be a command tag selection has a value that is not supported by the TPM
TPM_RC_COMMAND_CODE	a parameter that should be a command code does not have a value that is supported by the TPM
TPM_RC_HASH	a parameter that should be a hash algorithm selection does not have a value that is supported by the TPM
TPM_RC_INSUFFICIENT	the input buffer did not contain enough octets to allow unmarshaling of the expected data type;
TPM_RC_KDF	a parameter that should be a key derivation scheme (KDF) selection does not have a value that is supported by the TPM
TPM_RC_KEY_SIZE	a parameter that is a key size has a value that is not supported by the TPM
TPM_RC_MODE	a parameter that should be a symmetric encryption mode selection does not have a value that is supported by the TPM
TPM_RC_RESERVED	a non-zero value was found in a reserved field of an attribute structure (TPMA_)
TPM_RC_SCHEME	a parameter that should be signing or encryption scheme selection does not have a value that is supported by the TPM
TPM_RC_SIZE	the value of a size parameter is larger or smaller than allowed
TPM_RC_SYMMETRIC	a parameter that should be a symmetric algorithm selection does not have a value that is supported by the TPM
TPM_RC_TAG	a parameter that should be a structure tag has a value that is not supported by the TPM
TPM_RC_TYPE	The type parameter of a TPMT_PUBLIC or TPMT_SENSITIVE has a value that is not supported by the TPM
TPM_RC_VALUE	a parameter does not have one of its allowed values

In some commands, a parameter may not be used because of various options of that command. However, the unmarshaling code is required to validate that all parameters have values that are allowed by the Part 2 definition of the parameter type even if that parameter is not used in the command actions.

7.9 Command Post Processing

When the code that implements the detailed actions of the command completes, it returns a response code. If that code is not TPM_RC_SUCCESS, the post processing code will not update any session or audit data and will return a 10-octet response packet.

If the command completes successfully, the tag of the command determines if any authorization sessions will be in the response. If so, the TPM will encrypt the first parameter of the response if indicated by the authorization attributes. The TPM will then generate a new nonce value for each session and, if appropriate, generate an HMAC.

NOTE 1 The authorization attributes were validated during the session area validation to ensure that only one session was used for parameter encryption of the response and that the command allowed encryption in the response.

NOTE 2 No session nonce value is used for a password authorization but the session data is present.

Additionally, if the command is being audited by Command Audit, the audit digest is updated with the *cpHash* of the command and *rpHash* of the response.

8 Response Values

8.1 Tag

When a command completes successfully, the *tag* parameter in the response shall have the same value as the *tag* parameter in the command (TPM_ST_SESSIONS or TPM_RC_NO_SESSIONS). When a command fails (the *responseCode* is not TPM_RC_SUCCESS), then the *tag* parameter in the response shall be TPM_ST_NO_SESSIONS.

A special case exists when the command *tag* parameter is not an allowed value (TPM_ST_SESSIONS or TPM_ST_NO_SESSIONS). For this case, it is assumed that the system software is attempting to send a command formatted for a TPM 1.2 but the TPM is not capable of executing TPM 1.2 commands. So that the TPM 1.2 compatible software will have a recognizable response, the TPM sets *tag* to TPM_ST_RSP_COMMAND, *responseSize* to 00 00 00 0A₁₆ and *responseCode* to TPM_RC_BAD_TAG. This is the same response as the TPM 1.2 fatal error for TPM_BADTAG.

8.2 Response Codes

The normal response for any command is TPM_RC_SUCCESS. Any other value indicates that the command did not complete and the state of the TPM is unchanged. An exception to this general rule is that the logic associated with dictionary attack protection is allowed to be modified when an authorization failure occurs.

Commands have response codes that are specific to that command, and those response codes are enumerated in the detailed actions of each command. The codes associated with the unmarshaling of parameters are documented Table 3. Another set of response code value are not command specific and indicate a problem that is not specific to the command. That is, if the indicated problem is remedied, the same command could be resubmitted and may complete normally.

The response codes that are not command specific are listed and described in Table 4.

The reference code for the command actions may have code that generates specific response codes associated with a specific check but the listing of responses may not have that response code listed.

Table 4 — Command-Independent Response Codes

Response Code	Meaning
TPM_RC_CANCELLED	This response code may be returned by a TPM that supports command cancel. When the TPM receives an indication that the current command should be cancelled, the TPM may complete the command or return this code. If this code is returned, then the TPM state is not changed and the same command may be retried.
TPM_RC_CONTEXT_GAP	This response code can be returned for commands that manage session contexts. It indicates that the gap between the lowest numbered active session and the highest numbered session is at the limits of the session tracking logic. The remedy is to load the session context with the lowest number so that its tracking number can be updated.
TPM_RC_LOCKOUT	This response indicates that authorizations for objects subject to DA protection are not allowed at this time because the TPM is in DA lockout mode. The remedy is to wait or to execute TPM2_DictionaryAttackLockoutReset().
TPM_RC_MEMORY	A TPM may use a common pool of memory for objects, sessions, and other purposes. When the TPM does not have enough memory available to perform the actions of the command, it may return TPM_RC_MEMORY. This indicates that the TPM resource manager may flush either sessions or objects in order to make memory available for the command execution. A TPM may choose to return TPM_RC_OBJECT_MEMORY or TPM_RC_SESSION_MEMORY if it needs contexts of a particular type to be flushed.
TPM_RC_NV_RATE	This response code indicates that the TPM is rate-limiting writes to the NV memory in order to prevent wearout. This response is possible for any command that explicitly writes to NV or commands that incidentally use NV such as a command that uses authorization session that may need to update the dictionary attack logic.
TPM_RC_NV_UNAVAILABLE	This response code is similar to TPM_RC_NV_RATE but indicates that access to NV memory is currently not available and the command is not allowed to proceed until it is. This would occur in a system where the NV memory used by the TPM is not exclusive to the TPM and is a shared system resource.
TPM_RC_OBJECT_HANDLES	This response code indicates that the TPM has exhausted its handle space and no new objects can be loaded unless the TPM is rebooted. This does not occur in the reference implementation because of the way that object handles are allocated. However, other implementations are allowed to assign each object a unique handle each time the object is loaded. A TPM using this implementation would be able to load 2^{24} objects before the object space is exhausted.
TPM_RC_OBJECT_MEMORY	This response code can be returned by any command that causes the TPM to need an object 'slot'. The most common case where this might be returned is when an object is loaded (TPM2_Load, TPM2_CreatePrimary(), or TPM2_ContextLoad()). However, the TPM implementation is allowed to use object slots for other reasons. In the reference implementation, the TPM copies a referenced persistent object into RAM for the duration of the command. If all the slots are previously occupied, the TPM may return this value. A TPM is allowed to use object slots for other purposes and return this value. The remedy when this response is returned is for the TPM resource manager to flush a transient object.
TPM_RC_REFERENCE_Hx	This response code indicates that a handle in the handle area of the command is not associated with a loaded object. The value of 'x' is in the range 0 to 6 with a value of 0 indicating the 1 st handle and 6 representing the 7 th . The TPM resource manager needs to find the correct object and load it. It may then adjust the handle and retry the command. NOTE Usually, this error indicates that the TPM resource manager has a corrupted database.

Response Code	Meaning
TPM_RC_REFERENCE_Sx	<p>This response code indicates that a handle in the session area of the command is not associated with a loaded session. The value of 'x' is in the range 0 to 6 with a value of 0 indicating the 1st session handle and 6 representing the 7th. The TPM resource manager needs to find the correct session and load it. It may then retry the command.</p> <p>NOTE Usually, this error indicates that the TPM resource manager has a corrupted database.</p>
TPM_RC_RETRY	the TPM was not able to start the command
TPM_RC_SESSION_HANDLES	<p>This response code indicates that the TPM does not have a handle to assign to a new session. This response is only returned by TPM2_StartAuthSession(). It is listed here because the command is not in error and the TPM resource manager can remedy the situation by flushing a session (TPM2_FlushContext()).</p>
TPM_RC_SESSION_MEMORY	<p>This response code can be returned by any command that causes the TPM to need a session 'slot'. The most common case where this might be returned is when a session is loaded (TPM2_StartAuthSession() or TPM2_ContextLoad()). However, the TPM implementation is allowed to use object slots for other purposes. The remedy when this response is returned is for the TPM resource manager to flush a transient object.</p>
TPM_RC_SUCCESS	<p>Normal completion for any command. If the responseCode is TPM_RC_SESSIONS, then the rest of the response has the format indicated in the response schematic. Otherwise, the response is a 10 octet value indicating an error.</p>
TPM_RC_TESTING	This response code indicates that the TPM is performing tests and cannot respond to the request at this time. The command may be retried.
TPM_RC_YIELDED	<p>the TPM has suspended operation on the command; forward progress was made and the command may be retried.</p> <p>See Part 1, "Multi-tasking."</p> <p>NOTE This cannot occur on the reference implementation.</p>

9 Implementation Dependent

The actions code for each command makes assumptions about the behavior of various sub-systems. There are many possible implementations of the subsystems that would achieve equivalent results. The actions code is not written to anticipate all possible implementations of the sub-systems. Therefore, it is the responsibility of the implementer to ensure that the necessary changes are made to the actions code when the sub-system behavior changes.

10 Detailed Actions Assumptions

10.1 Introduction

The C code in the Detailed Actions for each command is written with a set of assumptions about the processing performed before the action code is called and the processing that will be done after the action code completes.

10.2 Pre-processing

Before calling the command actions code, the following actions have occurred.

- Verification that the handles in the handle area reference entities that are resident on the TPM.

NOTE If a handle is in the parameter portion of the command, the associated entity does not have to be loaded, but the handle is required to be the correct type.

- If use of a handle requires authorization, the Password, HMAC, or Policy session associated with the handle has been verified.
- If a command parameter was encrypted using parameter encryption, it was decrypted before being unmarshaled.
- If the command uses handles or parameters, the calling stack contains a pointer to a data structure (**in**) that holds the unmarshaled values for the handles and commands. If the response has handles or parameters, the calling stack contains a pointer to a data structure (**out**) to hold the handles and parameters generated by the command.
- All parameters of the **in** structure have been validated and meet the requirements of the parameter type as defined in Part 2.
- Space set aside for the **out** structure is sufficient to hold the largest **out** structure that could be produced by the command

10.3 Post Processing

When the function implementing the command actions completes,

- response parameters that require parameter encryption will be encrypted after the command actions complete;
- audit and session contexts will be updated if the command response is TPM_RC_SUCCESS; and
- the command header and command response parameters will be marshaled to the response buffer.

11 Start-up

11.1 Introduction

This clause contains the commands used to manage the startup and restart state of a TPM.

11.2 `_TPM_Init`

11.2.1 General Description

`_TPM_Init` initializes a TPM.

Initialization actions include testing code required to execute the next expected command. If the TPM is in FUM, the next expected command is `TPM2_FieldUpgradeData()`; otherwise, the next expected command is `TPM2_Startup()`.

NOTE 1 If the TPM performs self-tests after receiving `_TPM_Init()` and the TPM enters Failure mode before receiving `TPM2_Startup()` or `TPM2_FieldUpgradeData()`, then the TPM may be able to accept `TPM2_GetTestResult()` or `TPM2_GetCapability()`.

The means of signaling `_TPM_Init` shall be defined in the platform-specific specifications that define the physical interface to the TPM. The platform shall send this indication whenever the platform starts its boot process and only when the platform starts its boot process.

There shall be no software method of generating this indication that does not also reset the platform and begin execution of the CRTM.

NOTE 2 In the reference implementation, this signal causes an internal flag (*s_initialized*) to be CLEAR. While this flag is CLEAR, the TPM will only accept the next expected command described above.

11.2.2 Detailed Actions

```
1 #include "InternalRoutines.h"
```

This function is used to process a `_TPM_Init()` indication.

```
2 void _TPM_Init(void)
3 {
4     // Initialize crypto engine
5     CryptInitUnits();
6
7     // Initialize NV environment
8     NvPowerOn();
9
10    // Start clock
11    TimePowerOn();
12
13    // Set initialization state
14    TPMInit();
15
16    // Set g_DRTMHandle as unassigned
17    g_DRTMHandle = TPM_RH_UNASSIGNED;
18
19    // No H-CRTM, yet.
20    g_DrtmPreStartup = FALSE;
21
22
23    return;
24 }
```


11.3 TPM2_Startup

11.3.1 General Description

TPM2_Startup() is always preceded by _TPM_Init, which is the physical indication that TPM initialization is necessary because of a system-wide reset. TPM2_Startup() is only valid after _TPM_Init. Additional TPM2_Startup() commands are not allowed after it has completed successfully. If a TPM requires TPM2_Startup() and another command is received, or if the TPM receives TPM2_Startup() when it is not required, the TPM shall return TPM_RC_INITIALIZE.

NOTE 1 See 11.2.1 for other command options for a TPM supporting field upgrade mode.

NOTE 2 _TPM_Hash_Start, _TPM_Hash_Data, and _TPM_Hash_End are not commands and a platform-specific specification may allow these indications between _TPM_Init and TPM2_Startup().

If in Failure mode the TPM shall accept TPM2_GetTestResult() and TPM2_GetCapability() even if TPM2_Startup() is not completed successfully or processed at all.

A Shutdown/Startup sequence determines the way in which the TPM will operate in response to TPM2_Startup(). The three sequences are:

- 1) TPM Reset – This is a Startup(CLEAR) preceded by either Shutdown(CLEAR) or no TPM2_Shutdown(). On TPM Reset, all variables go back to their default initialization state.

NOTE 3 Only those values that are specified as having a default initialization state are changed by TPM Reset. Persistent values that have no default initialization state are not changed by this command. Values such as seeds have no default initialization state and only change due to specific commands.

- 2) TPM Restart – This is a Startup(CLEAR) preceded by Shutdown(STATE). This preserves much of the previous state of the TPM except that PCR and the controls associated with the Platform hierarchy are all returned to their default initialization state;
- 3) TPM Resume – This is a Startup(STATE) preceded by Shutdown(STATE). This preserves the previous state of the TPM including the static Root of Trust for Measurement (S-RTM) PCR and the platform controls other than the *phEnable* and *phEnableNV*.

If a TPM receives Startup(STATE) and that was not preceded by Shutdown(STATE), the TPM shall return TPM_RC_VALUE.

If, during TPM Restart or TPM Resume, the TPM fails to restore the state saved at the last Shutdown(STATE), the TPM shall enter Failure Mode and return TPM_RC_FAILURE.

On any TPM2_Startup(),

- *phEnable* and *phEnableNV* shall be SET;
- all transient contexts (objects, sessions, and sequences) shall be flushed from TPM memory;
- TPMS_TIME_INFO.*time* shall be reset to zero; and
- use of *lockoutAuth* shall be enabled if *lockoutRecovery* is zero.

Additional actions are performed based on the Shutdown/Startup sequence.

On TPM Reset

- *platformAuth* and *platformPolicy* shall be set to the Empty Buffer,
- tracking data for saved session contexts shall be set to its initial value,
- the object context sequence number is reset to zero,
- a new context encryption key shall be generated,
- TPMS_CLOCK_INFO.*restartCount* shall be reset to zero,
- TPMS_CLOCK_INFO.*resetCount* shall be incremented,
- the PCR Update Counter shall be clear to zero,
- *shEnable* and *ehEnable* shall be SET, and
- PCR in all banks are reset to their default initial conditions as determined by the relevant platform-specific specification.

NOTE 4 PCR may be initialized any time between `_TPM_Init` and the end of `TPM2_Startup()`. PCR that are preserved by TPM Resume will need to be restored during `TPM2_Startup()`.

NOTE 5 See "Initializing PCR" in Part 1 of this specification for a description of the default initial conditions for a PCR.

On TPM Restart

- TPMS_CLOCK_INFO.*restartCount* shall be incremented,
- *shEnable* and *ehEnable* shall be SET,
- *platformAuth* and *platformPolicy* shall be set to the Empty Buffer, and
- PCR in all banks are reset to their default initial conditions.
- If a CRTM Event sequence is active, extend the PCR designated by the platform-specific specification.

On TPM Resume

- the H-CRTM startup method is the same for this `TPM2_Startup()` as for the previous `TPM2_Startup()`; (`TPM_RC_LOCALITY`)
- TPMS_CLOCK_INFO.*restartCount* shall be incremented; and
- PCR that are specified in a platform-specific specification to be preserved on TPM Resume are restored to their saved state and other PCR are set to their initial value as determined by a platform-specific specification.

Other TPM state may change as required to meet the needs of the implementation.

If the *startupType* is `TPM_SU_STATE` and the TPM requires `TPM_SU_CLEAR`, then the TPM shall return `TPM_RC_VALUE`.

NOTE 6 The TPM will require `TPM_SU_CLEAR` when no shutdown was performed or after `Shutdown(CLEAR)`.

NOTE 7 If *startupType* is neither `TPM_SU_STATE` nor `TPM_SU_CLEAR`, then the unmarshaling code returns `TPM_RC_VALUE`.

11.3.2 Command and Response

Table 5 — TPM2_Startup Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	TPM_ST_NO_SESSIONS
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Startup {NV}
TPM_SU	startupType	TPM_SU_CLEAR or TPM_SU_STATE

Table 6 — TPM2_Startup Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

11.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Startup_fp.h"

```

Error Returns	Meaning
TPM_RC_VALUE	start up type is not compatible with previous shutdown sequence

```

3  TPM_RC
4  TPM2_Startup(
5      Startup_In      *in          // IN: input parameter list
6  )
7  {
8      STARTUP_TYPE      startup;
9      TPM_RC            result;
10     BOOL              prevDrtmPreStartup;
11
12     // The command needs NV update. Check if NV is available.
13     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
14     // this point
15     result = NvIsAvailable();
16     if(result != TPM_RC_SUCCESS)
17         return result;
18
19     // Input Validation
20
21     // Read orderly shutdown states from previous power cycle
22     NvReadReserved(NV_ORDERLY, &g_prevOrderlyState);
23
24     // HACK to extract the DRTM startup type associated with the previous shutdown
25     prevDrtmPreStartup = (g_prevOrderlyState == (TPM_SU_STATE + 0x8000));
26     if(prevDrtmPreStartup)
27         g_prevOrderlyState = TPM_SU_STATE;
28
29
30     // if the previous power cycle was shut down with no StateSave command, or
31     // with StateSave command for CLEAR, this cycle can not startup up with
32     // STATE
33     if( ( g_prevOrderlyState == SHUTDOWN_NONE
34         || g_prevOrderlyState == TPM_SU_CLEAR
35         )
36         && in->startupType == TPM_SU_STATE
37     )
38         return TPM_RC_VALUE + RC_Startup_startupType;
39
40     // Internal Date Update
41
42     // Translate the TPM2_ShutDown and TPM2_Startup sequence into the startup
43     // types.
44     if(in->startupType == TPM_SU_CLEAR && g_prevOrderlyState == TPM_SU_STATE)
45     {
46         startup = SU_RESTART;
47         // Read state reset data
48         NvReadReserved(NV_STATE_RESET, &gr);
49     }
50     else if(in->startupType == TPM_SU_STATE && g_prevOrderlyState == TPM_SU_STATE)
51     {
52         // For a resume, the H-CRITM startup method must be the same
53         if(g_DrtmPreStartup != prevDrtmPreStartup)
54             return TPM_RC_LOCALITY;

```

```
55
56     // Read state clear and state reset data
57     NvReadReserved(NV_STATE_CLEAR, &gc);
58     NvReadReserved(NV_STATE_RESET, &gr);
59     startup = SU_RESUME;
60 }
61 else
62 {
63     startup = SU_RESET;
64 }
65 // Read persistent data from NV
66 NvReadPersistent();
67
68 // Crypto Startup
69 CryptUtilStartup(startup);
70
71 // Start up subsystems
72 // Start counters and timers
73 TimeStartup(startup);
74
75 // Start dictionary attack subsystem
76 DASTartup(startup);
77
78 // Enable hierarchies
79 HierarchyStartup(startup);
80
81 // Restore/Initialize PCR
82 PCRStartup(startup);
83
84 // Restore/Initialize command audit information
85 CommandAuditStartup(startup);
86
87 // Object context variables
88 if(startup == SU_RESET)
89 {
90     // Reset object context ID to 0
91     gr.objectContextID = 0;
92     // Reset clearCount to 0
93     gr.clearCount= 0;
94 }
95
96 // Initialize object table
97 ObjectStartup();
98
99 // Initialize session table
100 SessionStartup(startup);
101
102 // Initialize index/evict data. This function clear read/write locks
103 // in NV index
104 NvEntityStartup(startup);
105
106 // Initialize the orderly shut down flag for this cycle to SHUTDOWN_NONE.
107 gp.orderlyState = SHUTDOWN_NONE;
108 NvWriteReserved(NV_ORDERLY, &gp.orderlyState);
109
110 // Update TPM internal states if command succeeded.
111 // Record a TPM2_Startup command has been received.
112 TPMRegisterStartup();
113
114 return TPM_RC_SUCCESS;
115
116 }
```

11.4 TPM2_Shutdown

11.4.1 General Description

This command is used to prepare the TPM for a power cycle. The *shutdownType* parameter indicates how the subsequent TPM2_Startup() will be processed.

For a *shutdownType* of any type, the volatile portion of Clock is saved to NV memory and the orderly shutdown indication is SET. NV with the TPMA_NV_ORDERLY attribute will be updated.

For a *shutdownType* of TPM_SU_STATE, the following additional items are saved:

- tracking information for saved session contexts;
- the session context counter;
- PCR that are designated as being preserved by TPM2_Shutdown(TPM_SU_STATE);
- the PCR Update Counter;
- flags associated with supporting the TPMA_NV_WRITESTCLEAR and TPMA_NV_READSTCLEAR attributes; and
- the command audit digest and count.

The following items shall not be saved and will not be in TPM memory after the next TPM2_Startup:

- TPM-memory-resident session contexts;
- TPM-memory-resident transient objects; or
- TPM-memory-resident hash contexts created by TPM2_HashSequenceStart().

Some values may be either derived from other values or saved to NV memory.

This command saves TPM state but does not change the state other than the internal indication that the context has been saved. The TPM shall continue to accept commands. If a subsequent command changes TPM state saved by this command, then the effect of this command is nullified. The TPM MAY nullify this command for any subsequent command rather than check whether the command changed state saved by this command. If this command is nullified, and if no TPM2_Shutdown() occurs before the next TPM2_Startup(), then the next TPM2_Startup() shall be TPM2_Startup(CLEAR).

11.4.2 Command and Response

Table 7 — TPM2_Shutdown Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Shutdown {NV}
TPM_SU	shutdownType	TPM_SU_CLEAR or TPM_SU_STATE

Table 8 — TPM2_Shutdown Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

11.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Shutdown_fp.h"

```

Error Returns	Meaning
TPM_RC_TYPE	if PCR bank has been re-configured, a CLEAR StateSave() is required

```

3  TPM_RC
4  TPM2_Shutdown(
5      Shutdown_In      *in           // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9
10     // The command needs NV update. Check if NV is available.
11     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
12     // this point
13     result = NvIsAvailable();
14     if(result != TPM_RC_SUCCESS) return result;
15
16     // Input Validation
17
18     // If PCR bank has been reconfigured, a CLEAR state save is required
19     if(g_pcrReConfig && in->shutdownType == TPM_SU_STATE)
20         return TPM_RC_TYPE + RC_Shutdown_shutdownType;
21
22     // Internal Data Update
23
24     // PCR private data state save
25     PCRStateSave(in->shutdownType);
26
27     // Get DRBG state
28     CryptDrbgGetPutState(GET_STATE);
29
30     // Save all orderly data
31     NvWriteReserved(NV_ORDERLY_DATA, &go);
32
33     // Save RAM backed NV index data
34     NvStateSave();
35
36     if(in->shutdownType == TPM_SU_STATE)
37     {
38         // Save STATE_RESET and STATE_CLEAR data
39         NvWriteReserved(NV_STATE_CLEAR, &gc);
40         NvWriteReserved(NV_STATE_RESET, &gr);
41     }
42     else if(in->shutdownType == TPM_SU_CLEAR)
43     {
44         // Save STATE_RESET data
45         NvWriteReserved(NV_STATE_RESET, &gr);
46     }
47
48     // Write orderly shut down state
49     if(in->shutdownType == TPM_SU_CLEAR)
50         gp.orderlyState = TPM_SU_CLEAR;
51     else if(in->shutdownType == TPM_SU_STATE)
52         gp.orderlyState = TPM_SU_STATE;
53     else

```



```
54         pAssert(FALSE);
55
56     NvWriteReserved(NV_ORDERLY, &gp.orderlyState);
57
58     return TPM_RC_SUCCESS;
59 }
```

12 Testing

12.1 Introduction

Compliance to standards for hardware security modules may require that the TPM test its functions before the results that depend on those functions may be returned. The TPM may perform operations using testable functions before those functions have been tested as long as the TPM returns no value that depends on the correctness of the testable function.

EXAMPLE TPM2_PCR_Event() may be executed before the hash algorithms have been tested. However, until the hash algorithms have been tested, the contents of a PCR may not be used in any command if that command may result in a value being returned to the TPM user. This means that TPM2_PCR_Read() or TPM2_PolicyPCR() could not complete until the hashes have been checked but other TPM2_PCR_Event() commands may be executed even though the operation uses previous PCR values.

If a command is received that requires return of a value that depends on untested functions, the TPM shall test the required functions before completing the command.

Once the TPM has received TPM2_SelfTest() and before completion of all tests, the TPM is required to return TPM_RC_TESTING for any command that uses a function that requires a test.

If a self-test fails at any time, the TPM will enter Failure mode. While in Failure mode, the TPM will return TPM_RC_FAILURE for any command other than TPM2_GetTestResult() and TPM2_GetCapability(). The TPM will remain in Failure mode until the next _TPM_Init.

12.2 TPM2_SelfTest

12.2.1 General Description

This command causes the TPM to perform a test of its capabilities. If the *fullTest* is YES, the TPM will test all functions. If *fullTest* = NO, the TPM will only test those functions that have not previously been tested.

If any tests are required, the TPM shall either

- a) return TPM_RC_TESTING and begin self-test of the required functions, or

NOTE 1 If *fullTest* is NO, and all functions have been tested, the TPM shall return TPM_RC_SUCCESS.

- b) perform the tests and return the test result when complete.

If the TPM uses option a), the TPM shall return TPM_RC_TESTING for any command that requires use of a testable function, even if the functions required for completion of the command have already been tested.

NOTE 2 This command may cause the TPM to continue processing after it has returned the response. So that software can be notified of the completion of the testing, the interface may include controls that would allow the TPM to generate an interrupt when the “background” processing is complete. This would be in addition to the interrupt may be available for signaling normal command completion. It is not necessary that there be two interrupts, but the interface should provide a way to indicate the nature of the interrupt (normal command or deferred command).

12.2.2 Command and Response

Table 9 — TPM2_SelfTest Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_SelfTest {NV}
TPMI_YES_NO	fullTest	YES if full test to be performed NO if only test of untested functions required

Table 10 — TPM2_SelfTest Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

12.2.3 Detailed Actions

```
1 #include "InternalRoutines.h"
2 #include "SelfTest_fp.h"
```

Error Returns	Meaning
TPM_RC_TESTING	self test in process

```
3 TPM_RC
4 TPM2_SelfTest(
5     SelfTest_In *in // IN: input parameter list
6 )
7 {
8     // Command Output
9
10    // Call self test function in crypt module
11    return CryptSelfTest(in->fullTest);
12 }
```

12.3 TPM2_IncrementalSelfTest

12.3.1 General Description

This command causes the TPM to perform a test of the selected algorithms.

NOTE 1 The *toTest* list indicates the algorithms that software would like the TPM to test in anticipation of future use. This allows tests to be done so that a future commands will not be delayed due to testing.

If *toTest* contains an algorithm that has already been tested, it will not be tested again.

NOTE 2 The only way to force retesting of an algorithm is with `TPM2_SelfTest(fullTest = YES)`.

The TPM will return in *toDoList* a list of algorithms that are yet to be tested. This list is not the list of algorithms that are scheduled to be tested but the algorithms/functions that have not been tested. Only the algorithms on the *toTest* list are scheduled to be tested by this command.

Making *toTest* an empty list allows the determination of the algorithms that remain untested without triggering any testing.

If *toTest* is not an empty list, the TPM shall return `TPM_RC_SUCCESS` for this command and then return `TPM_RC_TESTING` for any subsequent command (including `TPM2_IncrementalSelfTest()`) until the requested testing is complete.

NOTE 3 If *toDoList* is empty, then no additional tests are required and `TPM_RC_TESTING` will not be returned in subsequent commands and no additional delay will occur in a command due to testing.

NOTE 4 If none of the algorithms listed in *toTest* is in the *toDoList*, then no tests will be performed.

If all the parameters in this command are valid, the TPM returns `TPM_RC_SUCCESS` and the *toDoList* (which may be empty).

NOTE 5 An implementation may perform all requested tests before returning `TPM_RC_SUCCESS`, or it may return `TPM_RC_SUCCESS` for this command and then return `TPM_RC_TESTING` for all subsequent commands (including `TPM2_IncrementatSelfTest()`) until the requested tests are complete.

12.3.2 Command and Response

Table 11 — TPM2_IncrementalSelfTest Command

Type	Name	Description
TPML_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_IncrementalSelfTest {NV}
TPML_ALG	toTest	list of algorithms that should be tested

Table 12 — TPM2_IncrementalSelfTest Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPML_ALG	toDoList	list of algorithms that need testing

12.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "IncrementalSelfTest_fp.h"
3  TPM_RC
4  TPM2_IncrementalSelfTest(
5      IncrementalSelfTest_In    *in,           // IN: input parameter list
6      IncrementalSelfTest_Out    *out          // OUT: output parameter list
7  )
8  {
9  // Command Output
10
11     // Call incremental self test function in crypt module
12     return CryptIncrementalSelfTest(&in->toTest, &out->toDoList);
13 }
```


12.4 TPM2_GetTestResult

12.4.1 General Description

This command returns manufacturer-specific information regarding the results of a self-test and an indication of the test status.

If TPM2_SelfTest() has not been executed and a testable function has not been tested, *testResult* will be TPM_RC_NEEDS_TEST. If TPM2_SelfTest() has been received and the tests are not complete, *testResult* will be TPM_RC_TESTING. If testing of all functions is complete without functional failures, *testResult* will be TPM_RC_SUCCESS. If any test failed, *testResult* will be TPM_RC_FAILURE. If the TPM is in Failure mode because of an invalid *startupType* in TPM2_Startup(), *testResult* will be TPM_RC_INITIALIZE.

This command will operate when the TPM is in Failure mode so that software can determine the test status of the TPM and so that diagnostic information can be obtained for use in failure analysis. If the TPM is in Failure mode, then *tag* is required to be TPM_ST_NO_SESSIONS or the TPM shall return TPM_RC_FAILURE.

12.4.2 Command and Response

Table 13 — TPM2_GetTestResult Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_GetTestResult

Table 14 — TPM2_GetTestResult Response

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_MAX_BUFFER	outData	test result data contains manufacturer-specific information
TPM_RC	testResult	

12.4.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "GetTestResult_fp.h"
3  TPM_RC
4  TPM2_GetTestResult(
5      GetTestResult_Out    *out          // OUT: output parameter list
6  )
7  {
8  // Command Output
9
10     // Call incremental self test function in crypt module
11     out->testResult = CryptGetTestResult(&out->outData);
12
13     return TPM_RC_SUCCESS;
14 }
```

13 Session Commands

13.1 TPM2_StartAuthSession

13.1.1 General Description

This command is used to start an authorization session using alternative methods of establishing the session key (*sessionKey*). The session key is then used to derive values used for authorization and for encrypting parameters.

This command allows injection of a secret into the TPM using either asymmetric or symmetric encryption. The type of *tpmKey* determines how the value in *encryptedSalt* is encrypted. The decrypted secret value is used to compute the *sessionKey*.

NOTE 1 If *tpmKey* is TPM_RH_NULL, then *encryptedSalt* is required to be an Empty Buffer.

The label value of “SECRET” (see “Terms and Definitions” in Part 1 of this specification) is used in the recovery of the secret value.

The TPM generates the *sessionKey* from the recovered secret value.

No authorization is required for *tpmKey* or *bind*.

NOTE 2 The justification for using *tpmKey* without providing authorization is that the result of using the key is not available to the caller, except indirectly through the *sessionKey*. This does not represent a point of attack on the value of the key. If the caller attempts to use the session without knowing the *sessionKey* value, it is an authorization failure that will trigger the dictionary attack logic.

The entity referenced with the *bind* parameter contributes an authorization value to the *sessionKey* generation process.

If both *tpmKey* and *bind* are TPM_ALG_NULL, then *sessionKey* is set to the Empty Buffer. If *tpmKey* is not TPM_ALG_NULL, then *encryptedSalt* is used in the computation of *sessionKey*. If *bind* is not TPM_ALG_NULL, the *authValue* of *bind* is used in the *sessionKey* computation.

If *symmetric* specifies a block cipher, then TPM_ALG_CFB is the only allowed value for the *mode* field in the *symmetric* parameter (TPM_RC_MODE).

This command starts an authorization session and returns the session handle along with an initial *nonceTPM* in the response.

If the TPM does not have a free slot for an authorization session, it shall return TPM_RC_SESSION_HANDLES.

If the TPM implements a “gap” scheme for assigning *contextID* values, then the TPM shall return TPM_RC_CONTEXT_GAP if creating the session would prevent recycling of old saved contexts (See “Context Management” in Part 1).

If *tpmKey* is not TPM_ALG_NULL then *encryptedSalt* shall be a TPM2B_ENCRYPTED_SECRET of the proper type for *tpmKey*. The TPM shall return TPM_RC_VALUE if:

- a) *tpmKey* references an RSA key and
 - 1) *encryptedSalt* does not contain a value that is the size of the public modulus of *tpmKey*,
 - 2) *encryptedSalt* has a value that is greater than the public modulus of *tpmKey*,
 - 3) *encryptedSalt* is not a properly encode OAEP value, or
 - 4) the decrypted *salt* value is larger than the size of the digest produced by the *nameAlg* of *tpmKey*;
or

b) *tpmKey* references an ECC key and *encryptedSalt*

- 1) does not contain a TPMS_ECC_POINT or
- 2) is not a point on the curve of *tpmKey*;

NOTE 3 When ECC is used, the point multiply process produces a value (Z) that is used in a KDF to produce the final secret value. The size of the secret value is an input parameter to the KDF and the result will be set to be the size of the digest produced by the *nameAlg* of *tpmKey*.

c) *tpmKey* references a symmetric block cipher or a *keyedHash* object and *encryptedSalt* contains a value that is larger than the size of the digest produced by the *nameAlg* of *tpmKey*.

For all session types, this command will cause initialization of the *sessionKey* and may establish binding between the session and an object (the *bind* object). If *sessionType* is TPM_SE_POLICY or TPM_SE_TRIAL, the additional session initialization is:

- set *policySession*→*policyDigest* to a Zero Digest (the digest size for *policySession*→*policyDigest* is the size of the digest produced by *authHash*);
- authorization may be given at any locality;
- authorization may apply to any command code;
- authorization may apply to any command parameters or handles;
- the authorization has no time limit;
- an *authValue* is not needed when the authorization is used;
- the session is not bound;
- the session is not an audit session; and
- the time at which the policy session was created is recorded.

Additionally, if *sessionType* is TPM_SE_TRIAL, the session will not be usable for authorization but can be used to compute the *authPolicy* for an object.

NOTE 4 Although this command changes the session allocation information in the TPM, it does not invalidate a saved context. That is, TPM2_Shutdown() is not required after this command in order to re-establish the orderly state of the TPM. This is because the created context will occupy an available slot in the TPM and sessions in the TPM do not survive any TPM2_Startup(). However, if a created session is context saved, the orderly state does change.

The TPM shall return TPM_RC_SIZE if *nonceCaller* is less than 16 octets or is greater than the size of the digest produced by *authHash*.

13.1.2 Command and Response

Table 15 — TPM2_StartAuthSession Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_StartAuthSession
TPMI_DH_OBJECT+	tpmKey	handle of a loaded decrypt key used to encrypt <i>salt</i> may be TPM_RH_NULL Auth Index: None
TPMI_DH_ENTITY+	bind	entity providing the <i>authValue</i> may be TPM_RH_NULL Auth Index: None
TPM2B_NONCE	nonceCaller	initial <i>nonceCaller</i> , sets nonce size for the session shall be at least 16 octets
TPM2B_ENCRYPTED_SECRET	encryptedSalt	value encrypted according to the type of <i>tpmKey</i> If <i>tpmKey</i> is TPM_RH_NULL, this shall be the Empty Buffer.
TPM_SE	sessionType	indicates the type of the session; simple HMAC or policy (including a trial policy)
TPMT_SYM_DEF+	symmetric	the algorithm and key size for parameter encryption may select TPM_ALG_NULL
TPMI_ALG_HASH	authHash	hash algorithm to use for the session Shall be a hash algorithm supported by the TPM and not TPM_ALG_NULL

Table 16 — TPM2_StartAuthSession Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMI_SH_AUTH_SESSION	sessionHandle	handle for the newly created session
TPM2B_NONCE	nonceTPM	the initial nonce from the TPM, used in the computation of the <i>sessionKey</i>

13.1.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "StartAuthSession_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>tpmKey</i> does not reference a decrypt key
TPM_RC_CONTEXT_GAP	the difference between the most recently created active context and the oldest active context is at the limits of the TPM
TPM_RC_HANDLE	input decrypt key handle only has public portion loaded
TPM_RC_MODE	<i>symmetric</i> specifies a block cipher but the mode is not TPM_ALG_CFB.
TPM_RC_SESSION_HANDLES	no session handle is available
TPM_RC_SESSION_MEMORY	no more slots for loading a session
TPM_RC_SIZE	nonce less than 16 octets or greater than the size of the digest produced by <i>authHash</i>
TPM_RC_VALUE	secret size does not match decrypt key type; or the recovered secret is larger than the digest size of the <i>nameAlg</i> of <i>tpmKey</i> ; or, for an RSA decrypt key, if <i>encryptedSecret</i> is greater than the public exponent of <i>tpmKey</i> .

```

3  TPM_RC
4  TPM2_StartAuthSession(
5      StartAuthSession_In    *in,        // IN: input parameter buffer
6      StartAuthSession_Out  *out        // OUT: output parameter buffer
7  )
8  {
9      TPM_RC                    result = TPM_RC_SUCCESS;
10     OBJECT                    *tpmKey; // TPM key for decrypt salt
11     SESSION                    *session; // session internal data
12     TPM2B_DATA                 salt;
13
14     // Input Validation
15
16     // Check input nonce size. IT should be at least 16 bytes but not larger
17     // than the digest size of session hash.
18     if( in->nonceCaller.t.size < 16
19         || in->nonceCaller.t.size > CryptGetHashDigestSize(in->authHash))
20         return TPM_RC_SIZE + RC_StartAuthSession_nonceCaller;
21
22     // If an decrypt key is passed in, check its validation
23     if(in->tpmKey != TPM_RH_NULL)
24     {
25         // secret size cannot be 0
26         if(in->encryptedSalt.t.size == 0)
27             return TPM_RC_VALUE + RC_StartAuthSession_encryptedSalt;
28
29         // Get pointer to loaded decrypt key
30         tpmKey = ObjectGet(in->tpmKey);
31
32         // Decrypting salt requires accessing the private portion of a key.
33         // Therefore, tpmKey can not be a key with only public portion loaded
34         if(tpmKey->attributes.publicOnly)
35             return TPM_RC_HANDLE + RC_StartAuthSession_tpmKey;
36

```

```

37     // HMAC session input handle check.
38     // tpmKey should be a decryption key
39     if(tpmKey->publicArea.objectAttributes.decrypt != SET)
40         return TPM_RC_ATTRIBUTES + RC_StartAuthSession_tpmKey;
41
42
43     // Secret Decryption. A TPM_RC_VALUE, TPM_RC_KEY or Unmarshal errors
44     // may be returned at this point
45     result = CryptSecretDecrypt(in->tpmKey, &in->nonceCaller, "SECRET",
46                               &in->encryptedSalt, &salt);
47     if(result != TPM_RC_SUCCESS)
48         return TPM_RC_VALUE + RC_StartAuthSession_encryptedSalt;
49
50
51 }
52 else
53 {
54     // secret size must be 0
55     if(in->encryptedSalt.t.size != 0)
56         return TPM_RC_VALUE + RC_StartAuthSession_encryptedSalt;
57     salt.t.size = 0;
58 }
59 // If 'symmetric' is a symmetric block cipher (not TPM_ALG_NULL or TPM_ALG_XOR)
60 // then the mode must be CFB.
61 if(    in->symmetric.algorithm != TPM_ALG_NULL
62     && in->symmetric.algorithm != TPM_ALG_XOR
63     && in->symmetric.mode.sym != TPM_ALG_CFB)
64     return TPM_RC_MODE + RC_StartAuthSession_symmetric;
65
66 // Internal Data Update
67
68 // Create internal session structure. TPM_RC_CONTEXT_GAP, TPM_RC_NO_HANDLES
69 // or TPM_RC_SESSION_MEMORY errors may be returned returned at this point.
70 //
71 // The detailed actions for creating the session context are not shown here
72 // as the details are implementation dependent
73 // SessionCreate sets the output handle
74 result = SessionCreate(in->sessionType, in->authHash,
75                       &in->nonceCaller, &in->symmetric,
76                       in->bind, &salt, &out->sessionHandle);
77
78 if(result != TPM_RC_SUCCESS)
79     return result;
80
81 // Command Output
82
83 // Get session pointer
84 session = SessionGet(out->sessionHandle);
85
86 // Copy nonceTPM
87 out->nonceTPM = session->nonceTPM;
88
89 return TPM_RC_SUCCESS;
90 }

```


13.2 TPM2_PolicyRestart

13.2.1 General Description

This command allows a policy authorization session to be returned to its initial state. This command is used after the TPM returns TPM_RC_PCR_CHANGED. That response code indicates that a policy will fail because the PCR have changed after TPM2_PolicyPCR() was executed. Restarting the session allows the authorizations to be replayed because the session restarts with the same *nonceTPM*. If the PCR are valid for the policy, the policy may then succeed.

This command does not reset the policy ID or the policy start time.

13.2.2 Command and Response

Table 17 — TPM2_PolicyRestart Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyRestart
TPMI_SH_POLICY	sessionHandle	the handle for the policy session

Table 18 — TPM2_PolicyRestart Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

13.2.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PolicyRestart_fp.h"
3  TPM_RC
4  TPM2_PolicyRestart(
5      PolicyRestart_In      *in          // IN: input parameter list
6  )
7  {
8      SESSION                *session;
9      BOOL                   wasTrialSession;
10
11     // Internal Data Update
12
13     session = SessionGet(in->sessionHandle);
14     wasTrialSession = session->attributes.isTrialPolicy == SET;
15
16     // Initialize policy session
17     SessionResetPolicyData(session);
18
19     session->attributes.isTrialPolicy = wasTrialSession;
20
21     return TPM_RC_SUCCESS;
22 }
```

14 Object Commands

14.1 TPM2_Create

14.1.1 General Description

This command is used to create an object that can be loaded into a TPM using TPM2_Load(). If the command completes successfully, the TPM will create the new object and return the object's creation data (*creationData*), its public area (*outPublic*), and its encrypted sensitive area (*outPrivate*). Preservation of the returned data is the responsibility of the caller. The object will need to be loaded (TPM2_Load()) before it may be used.

TPM2B_PUBLIC template (*inPublic*) contains all of the fields necessary to define the properties of the new object. The setting for these fields is defined in "Public Area Template" in Part 1 and "TPMA_OBJECT" in Part 2.

The *parentHandle* parameter shall reference a loaded decryption key that has both the public and sensitive area loaded.

When defining the object, the caller provides a template structure for the object in a TPM2B_PUBLIC structure (*inPublic*), an initial value for the object's *authValue* (*inSensitive.authValue*), and, if the object is a symmetric object, an optional initial data value (*inSensitive.data*). The TPM shall validate the consistency of *inPublic.attributes* according to the Creation rules in "TPMA_OBJECT" in Part 2.

The *sensitive* parameter may be encrypted using parameter encryption.

The methods in this clause are used by both TPM2_Create() and TPM2_CreatePrimary(). When a value is indicated as being TPM-generated, the value is filled in by bits from the RNG if the command is TPM2_Create() and with values from KDFa() if the command is TPM2_CreatePrimary(). The parameters of each creation value are specified in Part 1.

The *sensitiveDataOrigin* attribute of *inPublic* shall be SET if *inSensitive.data* is an Empty Buffer and CLEAR if *inSensitive.data* is not an Empty Buffer or the TPM shall return TPM_RC_ATTRIBUTES.

The TPM will create new data for the sensitive area and compute a TPMT_PUBLIC.*unique* from the sensitive area based on the object type:

- a) For a symmetric key:
 - 1) If *inSensitive.data* is the Empty Buffer, a TPM-generated key value is placed in the new object's TPMT_SENSITIVE.*sensitive.sym*. The size of the key will be determined by *inPublic.publicArea.parameters*.
 - 2) If *inSensitive.data* is not the Empty Buffer, the TPM will validate that the size of *inSensitive.data* is no larger than the key size indicated in the *inPublic template* (TPM_RC_SIZE) and copy the *inSensitive.data* to TPMT_SENSITIVE.*sensitive.sym* of the new object.
 - 3) A TPM-generated obfuscation value is placed in TPMT_SENSITIVE.*sensitive.seedValue*. The size of the obfuscation value is the size of the digest produced by the *nameAlg* in *inPublic*. This value prevents the public *unique* value from leaking information about the *sensitive* area.
 - 4) The TPMT_PUBLIC.*unique.sym.buffer* value for the new object is then generated, as shown in equation (1) below, by hashing the key and obfuscation values in the TPMT_SENSITIVE with the *nameAlg* of the object.

$$unique := H_{nameAlg}(sensitive.seedValue.buffer || sensitive.any.buffer) \quad (1)$$

- b) If the Object is an asymmetric key:
 - 1) If *sensitive.data* is not the Empty Buffer, then the TPM shall return TPM_RC_VALUE.

- 2) A TPM-generated private key value is created with the size determined by the parameters of `inPublic.publicArea.parameters`.
- 3) If the key is a Storage Key, a TPM-generated `TPMT_SENSITIVE.symKey` value is created; otherwise, `TPMT_SENSITIVE.symKey.size` is set to zero.
- 4) The public *unique* value is computed from the private key according to the methods of the key type.
- 5) If the key is an ECC key and the scheme required by the `curveID` is not the same as *scheme* in the public area of the template, then the TPM shall return `TPM_RC_SCHEME`.
- 6) If the key is an ECC key and the KDF required by the `curveID` is not the same as *kdf* in the public area of the template, then the TPM shall return `TPM_RC_KDF`.

NOTE 1 There is currently no command in which the caller may specify the KDF to be used with an ECC decryption key. Since there is no use for this capability, the reference implementation requires that the *kdf* in the template be set to `TPM_ALG_NULL` or `TPM_RC_KDF` is returned.

c) If the Object is a keyedHash object:

- 1) If `inSensitive.data` is an Empty Buffer, and neither *sign* nor *decrypt* is SET in `inPublic.attributes`, the TPM shall return `TPM_RC_ATTRIBUTES`. This would be a data object with no data.
- 2) If `inSensitive.data` is not an Empty Buffer, the TPM will copy the `inSensitive.data` to `TPMT_SENSITIVE.sensitive` of the new object.

NOTE 2 The size of `inSensitive.data` is limited to be no larger than the largest value of `TPMT_SENSITIVE.sensitive.bits.data` by `MAX_SYM_DATA`.

- 3) If `inSensitive.data` is an Empty Buffer, a TPM-generated key value that is the size of the digest produced by the *nameAlg* in `inPublic` is placed in `TPMT_SENSITIVE.sensitive.any.buffer`.
- 4) A TPM-generated obfuscation value that is the size of the digest produced by the *nameAlg* of `inPublic` is placed in `TPMT_SENSITIVE.symKey.buffer`.
- 5) The `TPMT_PUBLIC.unique.sym.buffer` value for the new object is then generated, as shown in equation (1) above, by hashing the key and obfuscation values in the `TPMT_SENSITIVE` with the *nameAlg* of the object.

For `TPM2_Load()`, the TPM will apply normal symmetric protections to the created `TPMT_SENSITIVE` to create `outPublic`.

NOTE 3 The encryption key is derived from the symmetric seed in the sensitive area of the parent.

In addition to `outPublic` and `outPrivate`, the TPM will build a `TPMS_CREATION_DATA` structure for the object. `TPMS_CREATION_DATA.outsideInfo` is set to `outsideInfo`. This structure is returned in `creationData`. Additionally, the digest of this structure is returned in `creationHash`, and, finally, a `TPMT_TK_CREATION` is created so that the association between the creation data and the object may be validated by `TPM2_CertifyCreation()`.

If the object being created is a Storage Key and `inPublic.objectAttributes.fixedParent` is SET, then the algorithms of `inPublic` are required to match those of the parent. The algorithms that must match are `inPublic.type`, `inPublic.nameAlg`, and `inPublic.parameters`. If `inPublic.type` does not match, the TPM shall return `TPM_RC_TYPE`. If `inPublic.nameAlg` does not match, the TPM shall return `TPM_RC_HASH`. If `inPublic.parameters` does not match, the TPM shall return `TPM_RC_ASSYMETRIC`. The TPM shall not differentiate between mismatches of the components of `inPublic.parameters`.

EXAMPLE If the `inPublic.parameters.ecc.symmetric.algorithm` does not match the parent, the TPM shall return `TPM_RC_ASSYMETRIC` rather than `TPM_RC_SYMMETRIC`.

14.1.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Object_spt_fp.h"
3  #include "Create_fp.h"

```

Error Returns	Meaning
TPM_RC_ASYMMETRIC	non-duplicable storage key and its parent have different public params
TPM_RC_ATTRIBUTES	<i>sensitiveDataOrigin</i> is CLEAR when 'sensitive. data' is an Empty Buffer, or is SET when 'sensitive. data' is not empty; <i>fixedTPM</i> , <i>fixedParent</i> , or <i>encryptedDuplication</i> attributes are inconsistent between themselves or with those of the parent object; inconsistent <i>restricted</i> , <i>decrypt</i> and <i>sign</i> attributes; attempt to inject sensitive data for an asymmetric key; attempt to create a symmetric cipher key that is not a decryption key
TPM_RC_HASH	non-duplicable storage key and its parent have different name algorithm
TPM_RC_KDF	incorrect KDF specified for decrypting keyed hash object
TPM_RC_KEY	invalid key size values in an asymmetric key public area
TPM_RC_KEY_SIZE	key size in public area for symmetric key differs from the size in the sensitive creation area; may also be returned if the TPM does not allow the key size to be used for a Storage Key
TPM_RC_RANGE	FOR() an RSA key, the exponent value is not supported.
TPM_RC_SCHEME	inconsistent attributes <i>decrypt</i> , <i>sign</i> , <i>restricted</i> and key's scheme ID; or hash algorithm is inconsistent with the scheme ID for keyed hash object
TPM_RC_SIZE	size of public auth policy or sensitive auth value does not match digest size of the name algorithm sensitive data size for the keyed hash object is larger than is allowed for the scheme
TPM_RC_SYMMETRIC	a storage key with no symmetric algorithm specified; or non-storage key with symmetric algorithm different from TPM_ALG_NULL
TPM_RC_TYPE	unknown object type; non-duplicable storage key and its parent have different types; <i>parentHandle</i> does not reference a restricted decryption key in the storage hierarchy with both public and sensitive portion loaded
TPM_RC_VALUE	exponent is not prime or could not find a prime using the provided parameters for an RSA key; unsupported name algorithm for an ECC key
TPM_RC_OBJECT_MEMORY	there is no free slot for the object. This implementation does not return this error.

```

4  TPM_RC
5  TPM2_Create(
6      Create_In      *in,           // IN: input parameter list
7      Create_Out     *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result = TPM_RC_SUCCESS;
11     TPMT_SENSITIVE sensitive;
12     TPM2B_NAME      name;
13

```

```

14 // Input Validation
15
16     OBJECT      *parentObject;
17
18     parentObject = ObjectGet(in->parentHandle);
19
20     // Does parent have the proper attributes?
21     if(!AreAttributesForParent(parentObject))
22         return TPM_RC_TYPE + RC_Create_parentHandle;
23
24     // The sensitiveDataOrigin attribute must be consistent with the setting of
25     // the size of the data object in inSensitive.
26     if( (in->inPublic.t.publicArea.objectAttributes.sensitiveDataOrigin == SET)
27         != (in->inSensitive.t.sensitive.data.t.size == 0))
28         // Mismatch between the object attributes and the parameter.
29         return TPM_RC_ATTRIBUTES + RC_Create_inSensitive;
30
31     // Check attributes in input public area. TPM_RC_ASYMMETRIC, TPM_RC_ATTRIBUTES,
32     // TPM_RC_HASH, TPM_RC_KDF, TPM_RC_SCHEME, TPM_RC_SIZE, TPM_RC_SYMMETRIC,
33     // or TPM_RC_TYPE error may be returned at this point.
34     result = PublicAttributesValidation(FALSE, in->parentHandle,
35                                       &in->inPublic.t.publicArea);
36     if(result != TPM_RC_SUCCESS)
37         return RcSafeAddToResult(result, RC_Create_inPublic);
38
39     // Validate the sensitive area values
40     if( MemoryRemoveTrailingZeros(&in->inSensitive.t.sensitive.userAuth)
41         > CryptGetHashDigestSize(in->inPublic.t.publicArea.nameAlg))
42         return TPM_RC_SIZE + RC_Create_inSensitive;
43
44 // Command Output
45
46     // Create object crypto data
47     result = CryptCreateObject(in->parentHandle, &in->inPublic.t.publicArea,
48                               &in->inSensitive.t.sensitive, &sensitive);
49     if(result != TPM_RC_SUCCESS)
50         return result;
51
52     // Fill in creation data
53     FillInCreationData(in->parentHandle, in->inPublic.t.publicArea.nameAlg,
54                       &in->creationPCR, &in->outsideInfo,
55                       &out->creationData, &out->creationHash);
56
57     // Copy public area from input to output
58     out->outPublic.t.publicArea = in->inPublic.t.publicArea;
59
60     // Compute name from public area
61     ObjectComputeName(&(out->outPublic.t.publicArea), &name);
62
63     // Compute creation ticket
64     TicketComputeCreation(EntityGetHierarchy(in->parentHandle), &name,
65                            &out->creationHash, &out->creationTicket);
66
67     // Prepare output private data from sensitive
68     SensitiveToPrivate(&sensitive, &name, in->parentHandle,
69                       out->outPublic.t.publicArea.nameAlg,
70                       &out->outPrivate);
71
72     return TPM_RC_SUCCESS;
73 }

```


14.2 TPM2_Load

14.2.1 General Description

This command is used to load objects into the TPM. This command is used when both a TPM2B_PUBLIC and TPM2B_PRIVATE are to be loaded. If only a TPM2B_PUBLIC is to be loaded, the TPM2_LoadExternal command is used.

NOTE 1 Loading an object is not the same as restoring a saved object context.

The object's TPMA_OBJECT attributes will be checked according to the rules defined in "TPMA_OBJECT" in Part 2 of this specification.

Objects loaded using this command will have a Name. The Name is the concatenation of *nameAlg* and the digest of the public area using the *nameAlg*.

NOTE 2 *nameAlg* is a parameter in the public area of the inPublic structure.

If *inPrivate.size* is zero, the load will fail.

After *inPrivate.buffer* is decrypted using the symmetric key of the parent, the integrity value shall be checked before the sensitive area is used, or unmarshaled.

NOTE 3 Checking the integrity before the data is used prevents attacks on the sensitive area by fuzzing the data and looking at the differences in the response codes.

The command returns a handle for the loaded object and the Name that the TPM computed for *inPublic.public* (that is, the digest of the TPMT_PUBLIC structure in *inPublic*).

NOTE 4 The TPM-computed Name is provided as a convenience to the caller for those cases where the caller does not implement the hash algorithms specified in the *nameAlg* of the object.

NOTE 5 The returned handle is associated with the object until the object is flushed (TPM2_FlushContext) or until the next TPM2_Startup.

For all objects, the size of the key in the sensitive area shall be consistent with the key size indicated in the public area or the TPM shall return TPM_RC_KEY_SIZE.

Before use, a loaded object shall be checked to validate that the public and sensitive portions are properly linked, cryptographically. Use of an object includes use in any policy command. If the parts of the object are not properly linked, the TPM shall return TPM_RC_BINDING.

EXAMPLE 1 For a symmetric object, the unique value in the public area shall be the digest of the sensitive key and the obfuscation value.

EXAMPLE 2 For a two-prime RSA key, the remainder when dividing the public modulus by the private key shall be zero and it shall be possible to form a private exponent from the two prime factors of the public modulus.

EXAMPLE 3 For an ECC key, the public point shall be $f(x)$ where x is the private key.

14.2.2 Command and Response

Table 21 — TPM2_Load Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Load
TPMI_DH_OBJECT	@parentHandle	TPM handle of parent key; shall not be a reserved handle Auth Index: 1 Auth Role: USER
TPM2B_PRIVATE	inPrivate	the private portion of the object
TPM2B_PUBLIC	inPublic	the public portion of the object

Table 22 — TPM2_Load Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM_HANDLE	objectHandle	handle for the loaded object
TPM2B_NAME	name	Name of the loaded object

14.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Load_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ASYMMETRIC	storage key with different asymmetric type than parent
TPM_RC_ATTRIBUTES	<i>inPublic</i> attributes are not allowed with selected parent
TPM_RC_BINDING	<i>inPrivate</i> and <i>inPublic</i> are not cryptographically bound
TPM_RC_HASH	incorrect hash selection for signing key
TPM_RC_INTEGRITY	HMAC on <i>inPrivate</i> was not valid
TPM_RC_KDF	KDF selection not allowed
TPM_RC_KEY	the size of the object's <i>unique</i> field is not consistent with the indicated size in the object's parameters
TPM_RC_OBJECT_MEMORY	no available object slot
TPM_RC_SCHEME	the signing scheme is not valid for the key
TPM_RC_SENSITIVE	the <i>inPrivate</i> did not unmarshal correctly
TPM_RC_SIZE	<i>inPrivate</i> missing, or <i>authPolicy</i> size for <i>inPublic</i> or is not valid
TPM_RC_SYMMETRIC	symmetric algorithm not provided when required
TPM_RC_TYPE	<i>parentHandle</i> is not a storage key, or the object to load is a storage key but its parameters do not match the parameters of the parent.
TPM_RC_VALUE	decryption failure

```

4  TPM_RC
5  TPM2_Load(
6      Load_In *in,           // IN: input parameter list
7      Load_Out *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC          result = TPM_RC_SUCCESS;
11     TPMT_SENSITIVE sensitive;
12     TPMT_HIERARCHY hierarchy;
13     OBJECT          *parentObject = NULL;
14     BOOL            skipChecks = FALSE;
15
16     // Input Validation
17     if(in->inPrivate.t.size == 0)
18         return TPM_RC_SIZE + RC_Load_inPrivate;
19
20     parentObject = ObjectGet(in->parentHandle);
21     // Is the object that is being used as the parent actually a parent.
22     if(!AreAttributesForParent(parentObject))
23         return TPM_RC_TYPE + RC_Load_parentHandle;
24
25     // If the parent is fixedTPM, then the attributes of the object
26     // are either "correct by construction" or were validated
27     // when the object was imported. If they pass the integrity
28     // check, then the values are valid
29     if(parentObject->publicArea.objectAttributes.fixedTPM)
30         skipChecks = TRUE;

```

```
31     else
32     {
33         // If parent doesn't have fixedTPM SET, then this can't have
34         // fixedTPM SET.
35         if(in->inPublic.t.publicArea.objectAttributes.fixedTPM == SET)
36             return TPM_RC_ATTRIBUTES + RC_Load_inPublic;
37
38         // Perform self check on input public area. A TPM_RC_SIZE, TPM_RC_SCHEME,
39         // TPM_RC_VALUE, TPM_RC_SYMMETRIC, TPM_RC_TYPE, TPM_RC_HASH,
40         // TPM_RC_ASYMMETRIC, TPM_RC_ATTRIBUTES or TPM_RC_KDF error may be returned
41         // at this point
42         result = PublicAttributesValidation(TRUE, in->parentHandle,
43                                             &in->inPublic.t.publicArea);
44         if(result != TPM_RC_SUCCESS)
45             return RcSafeAddToResult(result, RC_Load_inPublic);
46     }
47
48     // Compute the name of object
49     ObjectComputeName(&in->inPublic.t.publicArea, &out->name);
50
51     // Retrieve sensitive data. PrivateToSensitive() may return TPM_RC_INTEGRITY or
52     // TPM_RC_SENSITIVE
53     // errors may be returned at this point
54     result = PrivateToSensitive(&in->inPrivate, &out->name, in->parentHandle,
55                                 in->inPublic.t.publicArea.nameAlg,
56                                 &sensitive);
57     if(result != TPM_RC_SUCCESS)
58         return RcSafeAddToResult(result, RC_Load_inPrivate);
59
60     // Internal Data Update
61
62     // Get hierarchy of parent
63     hierarchy = ObjectGetHierarchy(in->parentHandle);
64
65     // Create internal object. A lot of different errors may be returned by this
66     // loading operation as it will do several validations, including the public
67     // binding check
68     result = ObjectLoad(hierarchy, &in->inPublic.t.publicArea, &sensitive,
69                         &out->name, in->parentHandle, skipChecks,
70                         &out->objectHandle);
71
72     if(result != TPM_RC_SUCCESS)
73         return result;
74
75     return TPM_RC_SUCCESS;
76 }
```

14.3 TPM2_LoadExternal

14.3.1 General Description

This command is used to load an object that is not a Protected Object into the TPM. The command allows loading of a public area or both a public and sensitive area.

NOTE 1 Typical use for loading a public area is to allow the TPM to validate an asymmetric signature. Typical use for loading both a public and sensitive area is to allow the TPM to be used as a crypto accelerator.

Load of a public external object area allows the object be associated with a hierarchy so that the correct algorithms may be used when creating tickets. The *hierarchy* parameter provides this association. If the public and sensitive portions of the object are loaded, *hierarchy* is required to be TPM_RH_NULL.

NOTE 2 If both the public and private portions of an object are loaded, the object is not allowed to appear to be part of a hierarchy.

The object's TPMA_OBJECT attributes will be checked according to the rules defined in "TPMA_OBJECT" in Part 2. In particular, *fixedTPM*, *fixedParent*, and *restricted* shall be CLEAR if *inPrivate* is not the Empty Buffer.

NOTE 3 The duplication status of a public key needs to be able to be the same as the full key which may be resident on a different TPM. If both the public and private parts of the key are loaded, then it is not possible for the key to be either *fixedTPM* or *fixedParent*, since, its private area would not be available in the clear to load.

Objects loaded using this command will have a Name. The Name is the *nameAlg* of the object concatenated with the digest of the public area using the *nameAlg*. The Qualified Name for the object will be the same as its Name. The TPM will validate that the *authPolicy* is either the size of the digest produced by *nameAlg* or the Empty Buffer.

NOTE 4 If *nameAlg* is TPM_ALG_NULL, then the Name is the Empty Buffer. When the authorization value for an object with no Name is computed, no Name value is included in the HMAC. To ensure that these unnamed entities are not substituted, they should have an *authValue* that is statistically unique.

NOTE 5 The digest size for TPM_ALG_NULL is zero.

If the *nameAlg* is TPM_ALG_NULL, the TPM shall not verify the cryptographic binding between the public and sensitive areas, but the TPM will validate that the size of the key in the sensitive area is consistent with the size indicated in the public area. If it is not, the TPM shall return TPM_RC_KEY_SIZE.

NOTE 6 For an ECC object, the TPM will verify that the public key is on the curve of the key before the public area is used.

If *nameAlg* is not TPM_ALG_NULL, then the same consistency checks between *inPublic* and *inPrivate* are made as for TPM2_Load().

NOTE 7 Consistency checks are necessary because an object with a Name needs to have the public and sensitive portions cryptographically bound so that an attacker cannot mix public and sensitive areas.

The command returns a handle for the loaded object and the Name that the TPM computed for *inPublic.public* (that is, the TPMT_PUBLIC structure in *inPublic*).

NOTE 8 The TPM-computed Name is provided as a convenience to the caller for those cases where the caller does not implement the hash algorithm specified in the *nameAlg* of the object.

The *hierarchy* parameter associates the external object with a hierarchy. External objects are flushed when their associated hierarchy is disabled. If *hierarchy* is TPM_RH_NULL, the object is part of no hierarchy, and there is no implicit flush.

If *hierarchy* is TPM_RH_NULL or *nameAlg* is TPM_ALG_NULL, a ticket produced using the object shall be a NULL Ticket.

EXAMPLE If a key is loaded with hierarchy set to TPM_RH_NULL, then TPM2_VerifySignature() will produce a NULL Ticket of the required type.

External objects are Temporary Objects. The saved external object contexts shall be invalidated at the next TPM Reset.

14.3.2 Command and Response

Table 23 — TPM2_LoadExternal Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_LoadExternal
TPM2B_SENSITIVE	inPrivate	the sensitive portion of the object (optional)
TPM2B_PUBLIC+	inPublic	the public portion of the object
TPMI_RH_HIERARCHY+	hierarchy	hierarchy with which the object area is associated

Table 24 — TPM2_LoadExternal Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM_HANDLE	objectHandle	handle for the loaded object
TPM2B_NAME	name	name of the loaded object

14.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "LoadExternal_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	'fixedParent' and fixedTPM must be CLEAR on an external key if both public and sensitive portions are loaded
TPM_RC_BINDING	the inPublic and inPrivate structures are not cryptographically bound.
TPM_RC_HASH	incorrect hash selection for signing key
TPM_RC_HIERARCHY	hierarchy is turned off, or only NULL hierarchy is allowed when loading public and private parts of an object
TPM_RC_KDF	incorrect KDF selection for decrypting keyedHash object
TPM_RC_KEY	the size of the object's unique field is not consistent with the indicated size in the object's parameters
TPM_RC_OBJECT_MEMORY	if there is no free slot for an object
TPM_RC_SCHEME	the signing scheme is not valid for the key
TPM_RC_SIZE	authPolicy is not zero and is not the size of a digest produced by the object's nameAlg TPM_RH_NULL hierarchy
TPM_RC_SYMMETRIC	symmetric algorithm not provided when required
TPM_RC_TYPE	inPublic and inPrivate are not the same type

```

4  TPM_RC
5  TPM2_LoadExternal(
6      LoadExternal_In  *in,          // IN: input parameter list
7      LoadExternal_Out *out,        // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     TPMT_SENSITIVE *sensitive;
12     BOOL            skipChecks;
13
14     // Input Validation
15
16     // If the target hierarchy is turned off, the object can not be loaded.
17     if(!HierarchyIsEnabled(in->hierarchy))
18         return TPM_RC_HIERARCHY + RC_LoadExternal_hierarchy;
19
20     // the size of authPolicy is either 0 or the digest size of nameAlg
21     if(in->inPublic.t.publicArea.authPolicy.t.size != 0
22         && in->inPublic.t.publicArea.authPolicy.t.size !=
23         CryptGetHashDigestSize(in->inPublic.t.publicArea.nameAlg))
24         return TPM_RC_SIZE + RC_LoadExternal_inPublic;
25
26     // For loading an object with both public and sensitive
27     if(in->inPrivate.t.size != 0)
28     {
29         // An external object can only be loaded at TPM_RH_NULL hierarchy
30         if(in->hierarchy != TPM_RH_NULL)
31             return TPM_RC_HIERARCHY + RC_LoadExternal_hierarchy;
32         // An external object with a sensitive area must have fixedTPM == CLEAR
33         // fixedParent == CLEAR, and must have restrict CLEAR so that it does not

```



```
34     // appear to be a key that was created by this TPM.
35     if( in->inPublic.t.publicArea.objectAttributes.fixedTPM != CLEAR
36         || in->inPublic.t.publicArea.objectAttributes.fixedParent != CLEAR
37         || in->inPublic.t.publicArea.objectAttributes.restricted != CLEAR
38     )
39         return TPM_RC_ATTRIBUTES + RC_LoadExternal_inPublic;
40 }
41
42 // Validate the scheme parameters
43 result = SchemeChecks(TRUE, TPM_RH_NULL, &in->inPublic.t.publicArea);
44 if(result != TPM_RC_SUCCESS)
45     return RcSafeAddToResult(result, RC_LoadExternal_inPublic);
46
47
48 // Internal Data Update
49 // Need the name to compute the qualified name
50 ObjectComputeName(&in->inPublic.t.publicArea, &out->name);
51 skipChecks = (in->inPublic.t.publicArea.nameAlg == TPM_ALG_NULL);
52
53 // If a sensitive area was provided, load it
54 if(in->inPrivate.t.size != 0)
55     sensitive = &in->inPrivate.t.sensitiveArea;
56 else
57     sensitive = NULL;
58
59 // Create external object. A TPM_RC_BINDING, TPM_RC_KEY, TPM_RC_OBJECT_MEMORY
60 // or TPM_RC_TYPE error may be returned by ObjectLoad()
61 result = ObjectLoad(in->hierarchy, &in->inPublic.t.publicArea,
62                    sensitive, &out->name, TPM_RH_NULL, skipChecks,
63                    &out->objectHandle);
64 return result;
65 }
```

14.4 TPM2_ReadPublic

14.4.1 General Description

This command allows access to the public area of a loaded object.

Use of the *objectHandle* does not require authorization.

NOTE Since the caller is not likely to know the public area of the object associated with *objectHandle*, it would not be possible to include the Name associated with *objectHandle* in the *cpHash* computation.

If *objectHandle* references a sequence object, the TPM shall return TPM_RC_SEQUENCE.

14.4.2 Command and Response

Table 25 — TPM2_ReadPublic Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ReadPublic
TPMI_DH_OBJECT	objectHandle	TPM handle of an object Auth Index: None

Table 26 — TPM2_ReadPublic Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_PUBLIC	outPublic	structure containing the public area of an object
TPM2B_NAME	name	name of the object
TPM2B_NAME	qualifiedName	the Qualified Name of the object

14.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ReadPublic_fp.h"

```

Error Returns	Meaning
TPM_RC_SEQUENCE	can not read the public area of a sequence object

```

3  TPM_RC
4  TPM2_ReadPublic(
5      ReadPublic_In          *in,          // IN: input parameter list
6      ReadPublic_Out        *out          // OUT: output parameter list
7  )
8  {
9      OBJECT                  *object;
10
11     // Input Validation
12
13     // Get loaded object pointer
14     object = ObjectGet(in->objectHandle);
15
16     // Can not read public area of a sequence object
17     if(ObjectIsSequence(object))
18         return TPM_RC_SEQUENCE;
19
20
21     // Command Output
22
23     // Compute size of public area in canonical form
24     out->outPublic.t.size = TPMT_PUBLIC_Marshal(&object->publicArea, NULL, NULL);
25
26     // Copy public area to output
27     out->outPublic.t.publicArea = object->publicArea;
28
29     // Copy name to output
30     out->name.t.size = ObjectGetName(in->objectHandle, &out->name.t.name);
31
32     // Copy qualified name to output
33     ObjectGetQualifiedname(in->objectHandle, &out->qualifiedName);
34
35     return TPM_RC_SUCCESS;
36 }

```

14.5 TPM2_ActivateCredential

14.5.1 General Description

This command enables the association of a credential with an object in a way that ensures that the TPM has validated the parameters of the credentialed object.

If both the public and private portions of *activateHandle* and *keyHandle* are not loaded, then the TPM shall return TPM_RC_AUTH_UNAVAILABLE.

If *keyHandle* is not a Storage Key, then the TPM shall return TPM_RC_TYPE.

Authorization for *activateHandle* requires the ADMIN role.

The key associated with *keyHandle* is used to recover a seed from secret, which is the encrypted seed. The Name of the object associated with *activateHandle* and the recovered seed are used in a KDF to recover the symmetric key. The recovered seed (but not the Name) is used in a KDF to recover the HMAC key.

The HMAC is used to validate that the *credentialBlob* is associated with *activateHandle* and that the data in *credentialBlob* has not been modified. The linkage to the object associated with *activateHandle* is achieved by including the Name in the HMAC calculation.

If the integrity checks succeed, *credentialBlob* is decrypted and returned as *certInfo*.

14.5.2 Command and Response

Table 27 — TPM2_ActivateCredential Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ActivateCredential
TPMI_DH_OBJECT	@activateHandle	handle of the object associated with certificate in <i>credentialBlob</i> Auth Index: 1 Auth Role: ADMIN
TPMI_DH_OBJECT	@keyHandle	loaded key used to decrypt the TPMS_SENSITIVE in <i>credentialBlob</i> Auth Index: 2 Auth Role: USER
TPM2B_ID_OBJECT	credentialBlob	the credential
TPM2B_ENCRYPTED_SECRET	secret	<i>keyHandle</i> algorithm-dependent encrypted seed that protects <i>credentialBlob</i>

Table 28 — TPM2_ActivateCredential Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DIGEST	certInfo	the decrypted certificate information the data should be no larger than the size of the digest of the <i>nameAlg</i> associated with <i>keyHandle</i>

14.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ActivateCredential_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>keyHandle</i> does not reference a decryption key
TPM_RC_ECC_POINT	<i>secret</i> is invalid (when <i>keyHandle</i> is an ECC key)
TPM_RC_INSUFFICIENT	<i>secret</i> is invalid (when <i>keyHandle</i> is an ECC key)
TPM_RC_INTEGRITY	<i>credentialBlob</i> fails integrity test
TPM_RC_NO_RESULT	<i>secret</i> is invalid (when <i>keyHandle</i> is an ECC key)
TPM_RC_SIZE	<i>secret</i> size is invalid or the <i>credentialBlob</i> does not unmarshal correctly
TPM_RC_TYPE	<i>keyHandle</i> does not reference an asymmetric key.
TPM_RC_VALUE	<i>secret</i> is invalid (when <i>keyHandle</i> is an RSA key)

```

4  TPM_RC
5  TPM2_ActivateCredential(
6      ActivateCredential_In      *in,           // IN: input parameter list
7      ActivateCredential_Out     *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result = TPM_RC_SUCCESS;
11     OBJECT          *object;           // decrypt key
12     OBJECT          *activateObject; // key associated with
13     // credential
14     TPM2B_DATA      data;             // credential data
15
16     // Input Validation
17
18     // Get decrypt key pointer
19     object = ObjectGet(in->keyHandle);
20
21     // Get certificated object pointer
22     activateObject = ObjectGet(in->activateHandle);
23
24
25     // input decrypt key must be an asymmetric, restricted decryption key
26     if( !CryptIsAsymAlgorithm(object->publicArea.type)
27         || object->publicArea.objectAttributes.decrypt == CLEAR
28         || object->publicArea.objectAttributes.restricted == CLEAR)
29         return TPM_RC_TYPE + RC_ActivateCredential_keyHandle;
30
31     // Command output
32
33     // Decrypt input credential data via asymmetric decryption. A
34     // TPM_RC_VALUE, TPM_RC_KEY or unmarshal errors may be returned at this
35     // point
36     result = CryptSecretDecrypt(in->keyHandle, NULL,
37                                "IDENTITY", &in->secret, &data);
38     if(result != TPM_RC_SUCCESS)
39     {
40         if(result == TPM_RC_KEY)
41             return TPM_RC_FAILURE;

```

```
42     return RcSafeAddToResult(result, RC_ActivateCredential_secret);
43 }
44
45 // Retrieve secret data. A TPM_RC_INTEGRITY error or unmarshal
46 // errors may be returned at this point
47 result = CredentialToSecret(&in->credentialBlob,
48                             &activateObject->name,
49                             (TPM2B_SEED *) &data,
50                             in->keyHandle,
51                             &out->certInfo);
52 if(result != TPM_RC_SUCCESS)
53     return RcSafeAddToResult(result,RC_ActivateCredential_credentialBlob);
54
55 return TPM_RC_SUCCESS;
56 }
```


14.6 TPM2_MakeCredential

14.6.1 General Description

This command allows the TPM to perform the actions required of a Certificate Authority (CA) in creating a TPM2B_ID_OBJECT containing an activation credential.

The TPM will produce a TPM_ID_OBJECT according to the methods in “Credential Protection” in Part 1.

The loaded public area referenced by *handle* is required to be the public area of a Storage key, otherwise, the credential cannot be properly sealed.

This command does not use any TPM secrets nor does it require authorization. It is a convenience function, using the TPM to perform cryptographic calculations that could be done externally.

14.6.2 Command and Response

Table 29 — TPM2_MakeCredential Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_MakeCredential
TPMI_DH_OBJECT	handle	loaded public area, used to encrypt the sensitive area containing the credential key Auth Index: None
TPM2B_DIGEST	credential	the credential information
TPM2B_NAME	objectName	Name of the object to which the credential applies

Table 30 — TPM2_MakeCredential Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ID_OBJECT	credentialBlob	the credential
TPM2B_ENCRYPTED_SECRET	secret	<i>handle</i> algorithm-dependent data that wraps the key that encrypts <i>credentialBlob</i>

14.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "MakeCredential_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	<i>handle</i> referenced an ECC key that has a unique field that is not a point on the curve of the key
TPM_RC_SIZE	<i>credential</i> is larger than the digest size of Name algorithm of <i>handle</i>
TPM_RC_TYPE	<i>handle</i> does not reference an asymmetric decryption key

```

4  TPM_RC
5  TPM2_MakeCredential(
6      MakeCredential_In      *in,          // IN: input parameter list
7      MakeCredential_Out     *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC                  result = TPM_RC_SUCCESS;
11
12     OBJECT                  *object;
13     TPM2B_DATA              data;
14
15     // Input Validation
16
17     // Get object pointer
18     object = ObjectGet(in->handle);
19
20     // input key must be an asymmetric, restricted decryption key
21     // NOTE: Needs to be restricted to have a symmetric value.
22     if( !CryptIsAsymAlgorithm(object->publicArea.type)
23         || object->publicArea.objectAttributes.decrypt == CLEAR
24         || object->publicArea.objectAttributes.restricted == CLEAR
25     )
26         return TPM_RC_TYPE + RC_MakeCredential_handle;
27
28     // The credential information may not be larger than the digest size used for
29     // the Name of the key associated with handle.
30     if(in->credential.t.size > CryptGetHashDigestSize(object->publicArea.nameAlg))
31         return TPM_RC_SIZE + RC_MakeCredential_credential;
32
33     // Command Output
34
35     // Make encrypt key and its associated secret structure.
36     // Even though CrypeSecretEncrypt() may return
37     out->secret.t.size = sizeof(out->secret.t.secret);
38     result = CryptSecretEncrypt(in->handle, "IDENTITY", &data, &out->secret);
39     if(result != TPM_RC_SUCCESS)
40         return result;
41
42     // Prepare output credential data from secret
43     SecretToCredential(&in->credential, &in->objectName, (TPM2B_SEED *) &data,
44                      in->handle, &out->credentialBlob);
45
46     return TPM_RC_SUCCESS;
47 }

```

14.7 TPM2_Unseal

14.7.1 General Description

This command returns the data in a loaded Sealed Data Object.

NOTE A random, TPM-generated, Sealed Data Object may be created by the TPM with TPM2_Create() or TPM2_CreatePrimary() using the template for a Sealed Data Object. A Sealed Data Object is more likely to be created externally and imported (TPM2_Import()) so that the data is not created by the TPM.

The returned value may be encrypted using authorization session encryption.

If either *restricted*, *decrypt*, or *sign* is SET in the attributes of *itemHandle*, then the TPM shall return TPM_RC_ATTRIBUTES. If the *type* of *itemHandle* is not TPM_ALG_KEYEDHASH, then the TPM shall return TPM_RC_TYPE.

14.7.2 Command and Response

Table 31 — TPM2_Unseal Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	Tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Unseal
TPMI_DH_OBJECT	@itemHandle	handle of a loaded data object Auth Index: 1 Auth Role: USER

Table 32 — TPM2_Unseal Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_SENSITIVE_DATA	outData	unsealed data Size of <i>outData</i> is limited to be no more than 128 octets.

14.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Unseal_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>itemHandle</i> has wrong attributes
TPM_RC_TYPE	<i>itemHandle</i> is not a KEYEDHASH data object

```

3  TPM_RC
4  TPM2_Unseal(Unseal_In *in, Unseal_Out *out)
5  {
6      OBJECT                *object;
7
8      // Input Validation
9
10     // Get pointer to loaded object
11     object = ObjectGet(in->itemHandle);
12
13     // Input handle must be a data object
14     if(object->publicArea.type != TPM_ALG_KEYEDHASH)
15         return TPM_RC_TYPE + RC_Unseal_itemHandle;
16     if( object->publicArea.objectAttributes.decrypt == SET
17         || object->publicArea.objectAttributes.sign == SET
18         || object->publicArea.objectAttributes.restricted == SET)
19         return TPM_RC_ATTRIBUTES + RC_Unseal_itemHandle;
20
21     // Command Output
22
23     // Copy data
24     MemoryCopy2B(&out->outData.b, &object->sensitive.sensitive.bits.b,
25                 sizeof(out->outData.t.buffer));
26
27     return TPM_RC_SUCCESS;
28 }

```

14.8 TPM2_ObjectChangeAuth

14.8.1 General Description

This command is used to change the authorization secret for a TPM-resident object.

If successful, a new private area for the TPM-resident object associated with *objectHandle* is returned, which includes the new authorization value.

This command does not change the authorization of the TPM-resident object on which it operates. Therefore, the old authValue (of the TPM-resident object) is used when generating the response HMAC key if required..

NOTE 1 The returned *outPrivate* will need to be loaded before the new authorization will apply.

NOTE 2 The TPM-resident object may be persistent and changing the authorization value of the persistent object could prevent other users from accessing the object. This is why this command does not change the TPM-resident object.

EXAMPLE If a persistent key is being used as a Storage Root Key and the authorization of the key is a well-known value so that the key can be used generally, then changing the authorization value in the persistent key would deny access to other users.

This command may not be used to change the authorization value for an NV Index or a Primary Object.

NOTE 3 If an NV Index is to have a new authorization, it is done with TPM2_NV_ChangeAuth().

NOTE 4 If a Primary Object is to have a new authorization, it needs to be recreated (TPM2_CreatePrimary()).

14.8.2 Command and Response

Table 33 — TPM2_ObjectChangeAuth Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ObjectChangeAuth
TPMI_DH_OBJECT	@objectHandle	handle of the object Auth Index: 1 Auth Role: ADMIN
TPMI_DH_OBJECT	parentHandle	handle of the parent Auth Index: None
TPM2B_AUTH	newAuth	new authorization value

Table 34 — TPM2_ObjectChangeAuth Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_PRIVATE	outPrivate	private area containing the new authorization value

14.8.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ObjectChangeAuth_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_SIZE	<i>newAuth</i> is larger than the size of the digest of the Name algorithm of <i>objectHandle</i>
TPM_RC_TYPE	the key referenced by <i>parentHandle</i> is not the parent of the object referenced by <i>objectHandle</i> ; or <i>objectHandle</i> is a sequence object.

```

4  TPM_RC
5  TPM2_ObjectChangeAuth(
6      ObjectChangeAuth_In      *in,           // IN: input parameter list
7      ObjectChangeAuth_Out     *out          // OUT: output parameter list
8  )
9  {
10     TPMT_SENSITIVE            sensitive;
11
12     OBJECT                    *object;
13     TPM2B_NAME                objectQN, QNCompare;
14     TPM2B_NAME                parentQN;
15
16     // Input Validation
17
18     // Get object pointer
19     object = ObjectGet(in->objectHandle);
20
21     // Can not change auth on sequence object
22     if(ObjectIsSequence(object))
23         return TPM_RC_TYPE + RC_ObjectChangeAuth_objectHandle;
24
25     // Make sure that the auth value is consistent with the nameAlg
26     if( MemoryRemoveTrailingZeros(&in->newAuth)
27         > CryptGetHashDigestSize(object->publicArea.nameAlg))
28         return TPM_RC_SIZE + RC_ObjectChangeAuth_newAuth;
29
30
31     // Check parent for object
32     // parent handle must be the parent of object handle. In this
33     // implementation we verify this by checking the QN of object. Other
34     // implementation may choose different method to verify this attribute.
35     ObjectGetQualifiedName(in->parentHandle, &parentQN);
36     ObjectComputeQualifiedName(&parentQN, object->publicArea.nameAlg,
37                               &object->name, &QNCompare);
38
39     ObjectGetQualifiedName(in->objectHandle, &objectQN);
40     if(!Memory2BEqual(&objectQN.b, &QNCompare.b))
41         return TPM_RC_TYPE + RC_ObjectChangeAuth_parentHandle;
42
43     // Command Output
44
45     // Copy internal sensitive area
46     sensitive = object->sensitive;
47     // Copy authValue
48     sensitive.authValue = in->newAuth;
49
50     // Prepare output private data from sensitive
51     SensitiveToPrivate(&sensitive, &object->name, in->parentHandle,

```

```
52         object->publicArea.nameAlg,  
53         &out->outPrivate);  
54  
55     return TPM_RC_SUCCESS;  
56 }
```

15 Duplication Commands

15.1 TPM2_Duplicate

15.1.1 General Description

This command duplicates a loaded object so that it may be used in a different hierarchy. The new parent key for the duplicate may be on the same or different TPM or TPM_RH_NULL. Only the public area of *newParentHandle* is required to be loaded.

NOTE 1 Since the new parent may only be extant on a different TPM, it is likely that the new parent's sensitive area could not be loaded in the TPM from which *objectHandle* is being duplicated.

If *encryptedDuplication* is SET in the object being duplicated, then the TPM shall return TPM_RC_SYMMETRIC if *symmetricAlg* is TPM_RH_NULL or TPM_RC_HIERARCHY if *newParentHandle* is TPM_RH_NULL.

The authorization for this command shall be with a policy session.

If *fixedParent* of *objectHandle*→*attributes* is SET, the TPM shall return TPM_RC_ATTRIBUTES. If *objectHandle*→*nameAlg* is TPM_ALG_NULL, the TPM shall return TPM_RC_TYPE.

The *policySession*→*commandCode* parameter in the policy session is required to be TPM_CC_Duplicate to indicate that authorization for duplication has been provided. This indicates that the policy that is being used is a policy that is for duplication, and not a policy that would approve another use. That is, authority to use an object does not grant authority to duplicate the object.

The policy is likely to include cpHash in order to restrict where duplication can occur. If TPM2_PolicyCpHash() has been executed as part of the policy, the *policySession*→*cpHash* is compared to the cpHash of the command.

If TPM2_PolicyDuplicationSelect() has been executed as part of the policy, the *policySession*→*nameHash* is compared to

$$H_{policyAlg}(objectHandle \rightarrow Name || newParentHandle \rightarrow Name) \quad (2)$$

If the compared hashes are not the same, then the TPM shall return TPM_RC_POLICY_FAIL.

NOTE 2 It is allowed that *policySession*→*nameHash* and *policySession*→*cpHash* share the same memory space.

NOTE 3 A duplication policy is not required to have either TPM2_PolicyDuplicationSelect() or TPM2_PolicyCpHash() as part of the policy. If neither is present, then the duplication policy may be satisfied with a policy that only contains TPM2_PolicyCommandCode(*code* = TPM_CC_Duplicate).

The TPM shall follow the process of encryption defined in the “Duplication” subclause of “Protected Storage Hierarchy” in Part 1 of this specification.

15.1.2 Command and Response

Table 35 — TPM2_Duplicate Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Duplicate loaded object to duplicate
TPMI_DH_OBJECT	@objectHandle	Auth Index: 1 Auth Role: DUP
TPMI_DH_OBJECT+	newParentHandle	shall reference the public area of an asymmetric key Auth Index: None
TPM2B_DATA	encryptionKeyIn	optional symmetric encryption key The size for this key is set to zero when the TPM is to generate the key. This parameter may be encrypted.
TPMT_SYM_DEF_OBJECT+	symmetricAlg	definition for the symmetric algorithm to be used for the inner wrapper may be TPM_ALG_NULL if no inner wrapper is applied

Table 36 — TPM2_Duplicate Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DATA	encryptionKeyOut	If the caller provided an encryption key or if <i>symmetricAlg</i> was TPM_ALG_NULL, then this will be the Empty Buffer; otherwise, it shall contain the TPM-generated, symmetric encryption key for the inner wrapper.
TPM2B_PRIVATE	duplicate	private area that may be encrypted by <i>encryptionKeyIn</i> ; and may be doubly encrypted
TPM2B_ENCRYPTED_SECRET	outSymSeed	seed protected by the asymmetric algorithms of new parent (NP)

15.1.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Duplicate_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	key to duplicate has <i>fixedParent</i> SET
TPM_RC_HIERARCHY	<i>encryptedDuplication</i> is SET and <i>newParentHandle</i> specifies Null Hierarchy
TPM_RC_KEY	<i>newParentHandle</i> references invalid ECC key (public point not on the curve)
TPM_RC_SIZE	input encryption key size does not match the size specified in symmetric algorithm
TPM_RC_SYMMETRIC	<i>encryptedDuplication</i> is SET but no symmetric algorithm is provided
TPM_RC_TYPE	<i>newParentHandle</i> is neither a storage key nor TPM_RH_NULL; or the object has a NULL <i>nameAlg</i>

```

4  TPM_RC
5  TPM2_Duplicate(
6      Duplicate_In      *in,          // IN: input parameter list
7      Duplicate_Out     *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC              result = TPM_RC_SUCCESS;
11     TPMT_SENSITIVE     sensitive;
12
13     UINT16              innerKeySize = 0; // encrypt key size for inner wrap
14
15     OBJECT              *object;
16     TPM2B_DATA          data;
17
18     // Input Validation
19
20     // Get duplicate object pointer
21     object = ObjectGet(in->objectHandle);
22
23     // duplicate key must have fixParent bit CLEAR.
24     if(object->publicArea.objectAttributes.fixedParent == SET)
25         return TPM_RC_ATTRIBUTES + RC_Duplicate_objectHandle;
26
27     // Do not duplicate object with NULL nameAlg
28     if(object->publicArea.nameAlg == TPM_ALG_NULL)
29         return TPM_RC_TYPE + RC_Duplicate_objectHandle;
30
31     // new parent key must be a storage object or TPM_RH_NULL
32     if(in->newParentHandle != TPM_RH_NULL
33         && !ObjectIsStorage(in->newParentHandle))
34         return TPM_RC_TYPE + RC_Duplicate_newParentHandle;
35
36     // If the duplicates object has encryptedDuplication SET, then there must be
37     // an inner wrapper and the new parent may not be TPM_RH_NULL
38     if(object->publicArea.objectAttributes.encryptedDuplication == SET)
39     {
40         if(in->symmetricAlg.algorithm == TPM_ALG_NULL)
41             return TPM_RC_SYMMETRIC + RC_Duplicate_symmetricAlg;
42         if(in->newParentHandle == TPM_RH_NULL)

```

```

43         return TPM_RC_HIERARCHY + RC_Duplicate_newParentHandle;
44     }
45
46     if(in->symmetricAlg.algorithm == TPM_ALG_NULL)
47     {
48         // if algorithm is TPM_ALG_NULL, input key size must be 0
49         if(in->encryptionKeyIn.t.size != 0)
50             return TPM_RC_SIZE + RC_Duplicate_encryptionKeyIn;
51     }
52     else
53     {
54         // Get inner wrap key size
55         innerKeySize = in->symmetricAlg.keyBits.sym;
56
57         // If provided the input symmetric key must match the size of the algorithm
58         if(in->encryptionKeyIn.t.size != 0
59            && in->encryptionKeyIn.t.size != (innerKeySize + 7) / 8)
60             return TPM_RC_SIZE + RC_Duplicate_encryptionKeyIn;
61     }
62
63     // Command Output
64
65     if(in->newParentHandle != TPM_RH_NULL)
66     {
67
68         // Make encrypt key and its associated secret structure. A TPM_RC_KEY
69         // error may be returned at this point
70         out->outSymSeed.t.size = sizeof(out->outSymSeed.t.secret);
71         result = CryptSecretEncrypt(in->newParentHandle,
72                                   "DUPLICATE", &data, &out->outSymSeed);
73         pAssert(result != TPM_RC_VALUE);
74         if(result != TPM_RC_SUCCESS)
75             return result;
76     }
77     else
78     {
79         // Do not apply outer wrapper
80         data.t.size = 0;
81         out->outSymSeed.t.size = 0;
82     }
83
84     // Copy sensitive area
85     sensitive = object->sensitive;
86
87     // Prepare output private data from sensitive
88     SensitiveToDuplicate(&sensitive, &object->name, in->newParentHandle,
89                        object->publicArea.nameAlg, (TPM2B_SEED *) &data,
90                        &in->symmetricAlg, &in->encryptionKeyIn,
91                        &out->duplicate);
92
93     out->encryptionKeyOut = in->encryptionKeyIn;
94
95     return TPM_RC_SUCCESS;
96 }

```

15.2 TPM2_Rewrap

15.2.1 General Description

This command allows the TPM to serve in the role as a Duplication Authority. If proper authorization for use of the *oldParent* is provided, then an HMAC key and a symmetric key are recovered from *inSymSeed* and used to integrity check and decrypt *inDuplicate*. A new protection seed value is generated according to the methods appropriate for *newParent* and the blob is re-encrypted and a new integrity value is computed. The re-encrypted blob is returned in *outDuplicate* and the symmetric key returned in *outSymKey*.

In the rewrap process, L is “DUPLICATE” (see “Terms and Definitions” in Part 1).

If *inSymSeed* has a zero length, then *oldParent* is required to be TPM_RH_NULL and no decryption of *inDuplicate* takes place.

If *newParent* is TPM_RH_NULL, then no encryption is performed on *outDuplicate*. *outSymSeed* will have a zero length. See Part 2 *encryptedDuplication*.

15.2.2 Command and Response

Table 37 — TPM2_Rewrap Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Rewrap
TPMI_DH_OBJECT+	@oldParent	parent of object Auth Index: 1 Auth Role: User
TPMI_DH_OBJECT+	newParent	new parent of the object Auth Index: None
TPM2B_PRIVATE	inDuplicate	an object encrypted using symmetric key derived from <i>inSymSeed</i>
TPM2B_NAME	name	the Name of the object being rewrapped
TPM2B_ENCRYPTED_SECRET	inSymSeed	seed for symmetric key needs <i>oldParent</i> private key to recover the seed and generate the symmetric key

Table 38 — TPM2_Rewrap Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_PRIVATE	outDuplicate	an object encrypted using symmetric key derived from <i>outSymSeed</i>
TPM2B_ENCRYPTED_SECRET	outSymSeed	seed for a symmetric key protected by <i>newParent</i> asymmetric key

15.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Rewrap_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>newParent</i> is not a decryption key
TPM_RC_HANDLE	<i>oldParent</i> does not consistent with <i>inSymSeed</i>
TPM_RC_INTEGRITY	the integrity check of <i>inDuplicate</i> failed
TPM_RC_KEY	for an ECC key, the public key is not on the curve of the curve ID
TPM_RC_KEY_SIZE	the decrypted input symmetric key size does not matches the symmetric algorithm key size of <i>oldParent</i>
TPM_RC_TYPE	<i>oldParent</i> is not a storage key, or ' <i>newParent</i> ' is not a storage key
TPM_RC_VALUE	for an ' <i>oldParent</i> ', RSA key, the data to be decrypted is greater than the public exponent
Unmarshal errors	errors during unmarshaling the input encrypted buffer to a ECC public key, or unmarshal the private buffer to sensitive

```

4  TPM_RC
5  TPM2_Rewrap(
6      Rewrap_In          *in,          // IN: input parameter list
7      Rewrap_Out        *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC              result = TPM_RC_SUCCESS;
11     OBJECT              *oldParent;
12     TPM2B_DATA          data;        // symmetric key
13     UINT16              hashCode = 0;
14     TPM2B_PRIVATE       privateBlob; // A temporary private blob
15                             // to transit between old
16                             // and new wrappers
17
18     // Input Validation
19
20     if((in->inSymSeed.t.size == 0 && in->oldParent != TPM_RH_NULL)
21        || (in->inSymSeed.t.size != 0 && in->oldParent == TPM_RH_NULL))
22         return TPM_RC_HANDLE + RC_Rewrap_oldParent;
23
24     if(in->oldParent != TPM_RH_NULL)
25     {
26         // Get old parent pointer
27         oldParent = ObjectGet(in->oldParent);
28
29         // old parent key must be a storage object
30         if(!ObjectIsStorage(in->oldParent))
31             return TPM_RC_TYPE + RC_Rewrap_oldParent;
32
33         // Decrypt input secret data via asymmetric decryption. A
34         // TPM_RC_VALUE, TPM_RC_KEY or unmarshal errors may be returned at this
35         // point
36         result = CryptSecretDecrypt(in->oldParent, NULL,
37                                    "DUPLICATE", &in->inSymSeed, &data);
38         if(result != TPM_RC_SUCCESS)
39             return TPM_RC_VALUE + RC_Rewrap_inSymSeed;

```

```

40
41 // Unwrap Outer
42 result = UnwrapOuter(in->oldParent, &in->name,
43                     oldParent->publicArea.nameAlg, (TPM2B_SEED *) &data,
44                     FALSE,
45                     in->inDuplicate.t.size, in->inDuplicate.t.buffer);
46 if(result != TPM_RC_SUCCESS)
47     return RcSafeAddToResult(result, RC_Rewrap_inDuplicate);
48
49 // Copy unwrapped data to temporary variable, remove the integrity field
50 hashSize = sizeof(UINT16) +
51           CryptGetHashDigestSize(oldParent->publicArea.nameAlg);
52 privateBlob.t.size = in->inDuplicate.t.size - hashSize;
53 MemoryCopy(privateBlob.t.buffer, in->inDuplicate.t.buffer + hashSize,
54            privateBlob.t.size, sizeof(privateBlob.t.buffer));
55 }
56 else
57 {
58     // No outer wrap from input blob. Direct copy.
59     privateBlob = in->inDuplicate;
60 }
61
62 if(in->newParent != TPM_RH_NULL)
63 {
64     OBJECT *newParent;
65     newParent = ObjectGet(in->newParent);
66
67     // New parent must be a storage object
68     if(!ObjectIsStorage(in->newParent))
69         return TPM_RC_TYPE + RC_Rewrap_newParent;
70
71     // Make new encrypt key and its associated secret structure. A
72     // TPM_RC_VALUE error may be returned at this point if RSA algorithm is
73     // enabled in TPM
74     out->outSymSeed.t.size = sizeof(out->outSymSeed.t.secret);
75     result = CryptSecretEncrypt(in->newParent,
76                                "DUPLICATE", &data, &out->outSymSeed);
77     if(result != TPM_RC_SUCCESS) return result;
78
79 // Command output
80 // Copy temporary variable to output, reserve the space for integrity
81 hashSize = sizeof(UINT16) +
82           CryptGetHashDigestSize(newParent->publicArea.nameAlg);
83 out->outDuplicate.t.size = privateBlob.t.size;
84 MemoryCopy(out->outDuplicate.t.buffer + hashSize, privateBlob.t.buffer,
85            privateBlob.t.size, sizeof(out->outDuplicate.t.buffer));
86
87 // Produce outer wrapper for output
88 out->outDuplicate.t.size = ProduceOuterWrap(in->newParent, &in->name,
89                                           newParent->publicArea.nameAlg,
90                                           (TPM2B_SEED *) &data,
91                                           FALSE,
92                                           out->outDuplicate.t.size,
93                                           out->outDuplicate.t.buffer);
94 }
95
96 else // New parent is a null key so there is no seed
97 {
98     out->outSymSeed.t.size = 0;
99
100 // Copy privateBlob directly
101 out->outDuplicate = privateBlob;
102 }
103

```

```
104     return TPM_RC_SUCCESS;  
105 }
```

15.3 TPM2_Import

15.3.1 General Description

This command allows an object to be encrypted using the symmetric encryption values of a Storage Key. After encryption, the object may be loaded and used in the new hierarchy. The imported object (*duplicate*) may be singly encrypted, multiply encrypted, or unencrypted.

If *fixedTPM* or *fixedParent* is SET in *objectPublic*, the TPM shall return TPM_RC_ATTRIBUTES.

If *encryptedDuplication* is SET in the object referenced by *parentHandle*, then *encryptedDuplication* shall be set in *objectPublic* (TPM_RC_ATTRIBUTES). However, see Note 2.

Recovery of the sensitive data of the object occurs in the TPM in a three-step process in the following order:

- If present, the outer layer of symmetric encryption is removed. If *inSymSeed* has a non-zero size, the asymmetric parameters and private key of *parentHandle* are used to recover the seed used in the creation of the HMAC key and encryption keys used to protect the duplication blob. When recovering the seed, *L* is “DUPLICATE”.

NOTE 1 If the *encryptedDuplication* attribute of the object is SET, the TPM shall return TPM_RC_ATTRIBUTES if *inSymSeed* is an empty buffer.

- If present, the inner layer of symmetric encryption is removed. If *encryptionKey* and *symmetricAlg* are provided, they are used to decrypt duplication.
- If present, the integrity value of the blob is checked. The presence of the integrity value is indicated by a non-zero value for *duplicate.data.integrity.size*. The integrity of the private area is validated using the Name of *objectPublic* in the integrity HMAC computation. If either the outer layer or inner layer of encryption is performed, then the integrity value shall be present.

If the inner or outer wrapper is present, then a valid integrity value shall be present or the TPM shall return TPM_RC_INTEGRITY.

NOTE 2 It is not necessary to validate that the sensitive area data is cryptographically bound to the public area other than that the Name of the public area is included in the HMAC. However, if the binding is not validated by this command, the binding must be checked each time the object is loaded. For an object that is imported under a parent with *fixedTPM* SET, binding need only be checked at import. If the parent has *fixedTPM* CLEAR, then the binding needs to be checked each time the object is loaded, or before the TPM performs an operation for which the binding affects the outcome of the operation (for example, TPM2_PolicySigned() or TPM2_Certify()).

Similarly, if the new parent's *fixedTPM* is set, the *encryptedDuplication* state need only be checked at import.

If the new parent is not *fixedTPM*, then that object will be loadable on any TPM (including SW versions) on which the new parent exists. This means that, each time an object is loaded under a parent that is not *fixedTPM*, it is necessary to validate all of the properties of that object. If the parent is *fixedTPM*, then the new private blob is integrity protected by the TPM that “owns” the parent. So, it is sufficient to validate the object's properties (attribute and public-private binding) on import and not again.

Before *duplicate.buffer* is decrypted using the symmetric key of the parent, the integrity value shall be checked before the sensitive area is used, or unmarshaled.

After integrity checks and decryption, the TPM will create a new symmetrically encrypted private area using the encryption key of the parent.

NOTE 3 Checking the integrity before the data is used prevents attacks on the sensitive area by fuzzing the data and looking at the differences in the response codes.

NOTE 4 The symmetric re-encryption is the normal integrity generation and symmetric encryption applied to a child object.

15.3.2 Command and Response

Table 39 — TPM2_Import Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Import
TPMI_DH_OBJECT	@parentHandle	the handle of the new parent for the object Auth Index: 1 Auth Role: USER
TPM2B_DATA	encryptionKey	the optional symmetric encryption key used as the inner wrapper for <i>duplicate</i> If <i>symmetricAlg</i> is TPM_ALG_NULL, then this parameter shall be the Empty Buffer.
TPM2B_PUBLIC	objectPublic	the public area of the object to be imported This is provided so that the integrity value for <i>duplicate</i> and the object attributes can be checked. NOTE Even if the integrity value of the object is not checked on input, the object Name is required to create the integrity value for the imported object.
TPM2B_PRIVATE	duplicate	the symmetrically encrypted duplicate object that may contain an inner symmetric wrapper
TPM2B_ENCRYPTED_SECRET	inSymSeed	symmetric key used to encrypt <i>duplicate</i> <i>inSymSeed</i> is encrypted/encoded using the algorithms of <i>newParent</i> .
TPMT_SYM_DEF_OBJECT+	symmetricAlg	definition for the symmetric algorithm to use for the inner wrapper If this algorithm is TPM_ALG_NULL, no inner wrapper is present and <i>encryptionKey</i> shall be the Empty Buffer.

Table 40 — TPM2_Import Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_PRIVATE	outPrivate	the sensitive area encrypted with the symmetric key of <i>parentHandle</i>

15.3.3 Detailed Actions

```

1 #include "InternalRoutines.h"
2 #include "Import_fp.h"
3 #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ASYMMETRIC	non-duplicable storage key represented by <i>objectPublic</i> and its parent referenced by <i>parentHandle</i> have different public params
TPM_RC_ATTRIBUTES	attributes <i>FixedTPM</i> and <i>fixedParent</i> of <i>objectPublic</i> are not both CLEAR; or <i>inSymSeed</i> is nonempty and <i>parentHandle</i> does not reference a decryption key; or <i>objectPublic</i> and <i>parentHandle</i> have incompatible or inconsistent attributes
TPM_RC_BINDING	<i>duplicate</i> and <i>objectPublic</i> are not cryptographically bound
TPM_RC_ECC_POINT	<i>inSymSeed</i> is nonempty and ECC point in <i>inSymSeed</i> is not on the curve
TPM_RC_HASH	non-duplicable storage key represented by <i>objectPublic</i> and its parent referenced by <i>parentHandle</i> have different name algorithm
TPM_RC_INSUFFICIENT	<i>inSymSeed</i> is nonempty and failed to retrieve ECC point from the secret; or unmarshaling sensitive value from <i>duplicate</i> failed the result of <i>inSymSeed</i> decryption
TPM_RC_INTEGRITY	<i>duplicate</i> integrity is broken
TPM_RC_KDF	<i>objectPublic</i> representing decrypting keyed hash object specifies invalid KDF
TPM_RC_KEY	inconsistent parameters of <i>objectPublic</i> ; or <i>inSymSeed</i> is nonempty and <i>parentHandle</i> does not reference a key of supported type; or invalid key size in <i>objectPublic</i> representing an asymmetric key
TPM_RC_NO_RESULT	<i>inSymSeed</i> is nonempty and multiplication resulted in ECC point at infinity
TPM_RC_OBJECT_MEMORY	no available object slot
TPM_RC_SCHEME	inconsistent attributes <i>decrypt</i> , <i>sign</i> , <i>restricted</i> and key's scheme ID in <i>objectPublic</i> ; or hash algorithm is inconsistent with the scheme ID for keyed hash object
TPM_RC_SIZE	<i>authPolicy</i> size does not match digest size of the name algorithm in <i>objectPublic</i> ; or <i>symmetricAlg</i> and <i>encryptionKey</i> have different sizes; or <i>inSymSeed</i> is nonempty and it is not of the same size as RSA key referenced by <i>parentHandle</i> ; or unmarshaling sensitive value from <i>duplicate</i> failed
TPM_RC_SYMMETRIC	<i>objectPublic</i> is either a storage key with no symmetric algorithm or a non-storage key with symmetric algorithm different from TPM_ALG_NULL
TPM_RC_TYPE	unsupported type of <i>objectPublic</i> ; or non-duplicable storage key represented by <i>objectPublic</i> and its parent referenced by <i>parentHandle</i> are of different types; or <i>parentHandle</i> is not a storage key; or only the public portion of <i>parentHandle</i> is loaded; or <i>objectPublic</i> and <i>duplicate</i> are of different types
TPM_RC_VALUE	nonempty <i>inSymSeed</i> and its numeric value is greater than the modulus of the key referenced by <i>parentHandle</i> or <i>inSymSeed</i> is larger than the size of the digest produced by the name algorithm of the symmetric key referenced by <i>parentHandle</i>

```

4  TPM_RC
5  TPM2_Import(
6      Import_In      *in,          // IN: input parameter list
7      Import_Out     *out          // OUT: output parameter list
8  )
9  {
10
11      TPM_RC          result = TPM_RC_SUCCESS;
12      OBJECT          *parentObject;
13      TPM2B_DATA      data;        // symmetric key
14      TPMT_SENSITIVE  sensitive;
15      TPM2B_NAME      name;
16
17      UINT16          innerKeySize = 0;    // encrypt key size for inner
18                                          // wrapper
19
20  // Input Validation
21
22  // FixedTPM and fixedParent must be CLEAR
23  if( in->objectPublic.t.publicArea.objectAttributes.fixedTPM == SET
24      || in->objectPublic.t.publicArea.objectAttributes.fixedParent == SET)
25      return TPM_RC_ATTRIBUTES + RC_Import_objectPublic;
26
27  // Get parent pointer
28  parentObject = ObjectGet(in->parentHandle);
29
30  if(!AreAttributesForParent(parentObject))
31      return TPM_RC_TYPE + RC_Import_parentHandle;
32
33  if(in->symmetricAlg.algorithm != TPM_ALG_NULL)
34  {
35      // Get inner wrap key size
36      innerKeySize = in->symmetricAlg.keyBits.sym;
37      // Input symmetric key must match the size of algorithm.
38      if(in->encryptionKey.t.size != (innerKeySize + 7) / 8)
39          return TPM_RC_SIZE + RC_Import_encryptionKey;
40  }
41  else
42  {
43      // If input symmetric algorithm is NULL, input symmetric key size must
44      // be 0 as well
45      if(in->encryptionKey.t.size != 0)
46          return TPM_RC_SIZE + RC_Import_encryptionKey;
47  }
48
49  // See if there is an outer wrapper
50  if(in->inSymSeed.t.size != 0)
51  {
52      // Decrypt input secret data via asymmetric decryption. TPM_RC_ATTRIBUTES,
53      // TPM_RC_ECC_POINT, TPM_RC_INSUFFICIENT, TPM_RC_KEY, TPM_RC_NO_RESULT,
54      // TPM_RC_SIZE, TPM_RC_VALUE may be returned at this point
55      result = CryptSecretDecrypt(in->parentHandle, NULL, "DUPLICATE",
56                                 &in->inSymSeed, &data);
57      pAssert(result != TPM_RC_BINDING);
58      if(result != TPM_RC_SUCCESS)
59          return TPM_RC_VALUE + RC_Import_inSymSeed;
60  }
61  else
62  {
63      data.t.size = 0;
64  }
65
66  // Compute name of object
67  ObjectComputeName(&(in->objectPublic.t.publicArea), &name);

```



```
68
69 // Retrieve sensitive from private.
70 // TPM_RC_INSUFFICIENT, TPM_RC_INTEGRITY, TPM_RC_SIZE may be returned here.
71 result = DuplicateToSensitive(&in->duplicate, &name, in->parentHandle,
72                             in->objectPublic.t.publicArea.nameAlg,
73                             (TPM2B_SEED *) &data, &in->symmetricAlg,
74                             &in->encryptionKey, &sensitive);
75
76 if(result != TPM_RC_SUCCESS)
77     return RcSafeAddToResult(result, RC_Import_duplicate);
78
79 // If the parent of this object has fixedTPM SET, then fully validate this
80 // object so that validation can be skipped when it is loaded
81 if(parentObject->publicArea.objectAttributes.fixedTPM == SET)
82 {
83     TPM_HANDLE      objectHandle;
84
85     // Perform self check on input public area. A TPM_RC_SIZE, TPM_RC_SCHEME,
86     // TPM_RC_VALUE, TPM_RC_SYMMETRIC, TPM_RC_TYPE, TPM_RC_HASH,
87     // TPM_RC_ASYMMETRIC, TPM_RC_ATTRIBUTES or TPM_RC_KDF error may be returned
88     // at this point
89     result = PublicAttributesValidation(TRUE, in->parentHandle,
90                                       &in->objectPublic.t.publicArea);
91     if(result != TPM_RC_SUCCESS)
92         return RcSafeAddToResult(result, RC_Import_objectPublic);
93
94     // Create internal object. A TPM_RC_KEY_SIZE, TPM_RC_KEY or
95     // TPM_RC_OBJECT_MEMORY error may be returned at this point
96     result = ObjectLoad(TPM_RH_NULL, &in->objectPublic.t.publicArea,
97                       &sensitive, NULL, in->parentHandle, FALSE,
98                       &objectHandle);
99     if(result != TPM_RC_SUCCESS)
100         return result;
101
102     // Don't need the object, just needed the checks to be performed so
103     // flush the object
104     ObjectFlush(objectHandle);
105 }
106 // Command output
107
108 // Prepare output private data from sensitive
109 SensitiveToPrivate(&sensitive, &name, in->parentHandle,
110                 in->objectPublic.t.publicArea.nameAlg,
111                 &out->outPrivate);
112
113 return TPM_RC_SUCCESS;
114 }
```

16 Asymmetric Primitives

16.1 Introduction

The commands in this clause provide low-level primitives for access to the asymmetric algorithms implemented in the TPM. Many of these commands are only allowed if the asymmetric key is an unrestricted key.

16.2 TPM2_RSA_Encrypt

16.2.1 General Description

This command performs RSA encryption using the indicated padding scheme according to PKCS#1v2.1 (PKCS#1). If the *scheme* of *keyHandle* is TPM_ALG_NULL, then the caller may use *inScheme* to specify the padding scheme. If *scheme* of *keyHandle* is not TPM_ALG_NULL, then *inScheme* shall either be TPM_ALG_NULL or be the same as *scheme* (TPM_RC_SCHEME).

The key referenced by *keyHandle* is required to be an RSA key (TPM_RC_KEY) with the *decrypt* attribute SET (TPM_RC_ATTRIBUTES).

NOTE Requiring that the *decrypt* attribute be set allows the TPM to ensure that the scheme selection is done with the presumption that the scheme of the key is a decryption scheme selection. It is understood that this command will operate on a key with only the public part loaded so the caller may modify any key in any desired way. So, this constraint only serves to simplify the TPM logic.

The three types of allowed padding are:

- 1) TPM_ALG_OAEP – Data is OAEP padded as described in 7.1 of PKCS#1v2.1. The only supported mask generation is MGF1.
- 2) TPM_ALG_RSAES – Data is padded as described in 7.2 of PKCS#1v2.1.
- 3) TPM_ALG_NULL – Data is not padded by the TPM and the TPM will treat *message* as an unsigned integer and perform a modular exponentiation of *message* using the public exponent of the key referenced by *keyHandle*. This scheme is only used if both the *scheme* in the key referenced by *keyHandle* is TPM_ALG_NULL, and the *inScheme* parameter of the command is TPM_ALG_NULL. The input value cannot be larger than the public modulus of the key referenced by *keyHandle*.

Table 41 — Padding Scheme Selection

<i>keyHandle</i> → <i>scheme</i>	<i>inScheme</i>	padding scheme used
TPM_ALG_NULL	TPM_ALG_NULL	none
	TPM_ALG_RSAES	RSAES
	TPM_ALG_OAEP	OAEP
TPM_ALG_RSAES	TPM_ALG_NULL	RSAES
	TPM_ALG_RSAES	RSAES
	TPM_ALG_OAEP	error (TPM_RC_SCHEME)
TPM_ALG_OAEP	TPM_ALG_NULL	OAEP
	TPM_ALG_RSAES	error (TPM_RC_SCHEME)
	TPM_AGL_OAEP	OAEP

After padding, the data is RSAEP encrypted according to 5.1.1 of PKCS#1v2.1.

NOTE 1 It is required that *decrypt* be SET so that the commands that load a key can validate that the scheme is consistent rather than have that deferred until the key is used.

NOTE 2 If it is desired to use a key that had restricted SET, the caller may CLEAR restricted and load the public part of the key and use that unrestricted version of the key for encryption.

If *inScheme* is used, and the scheme requires a hash algorithm it may not be TPM_ALG_NULL.

NOTE 3 Because only the public portion of the key needs to be loaded for this command, the caller can manipulate the attributes of the key in any way desired. As a result, the TPM shall not check the consistency of the attributes. The only property checking is that the key is an RSA key and that the padding scheme is supported.

The *message* parameter is limited in size by the padding scheme according to the following table:

Table 42 — Message Size Limits Based on Padding

Scheme	Maximum Message Length (<i>mLen</i>) in Octets	Comments
TPM_ALG_OAEP	$mLen \leq k - 2hLen - 2$	
TPM_ALG_RSAES	$mLen \leq k - 11$	
TPM_ALG_NULL	$mLen \leq k$	The numeric value of the message must be less than the numeric value of the public modulus (<i>n</i>).
NOTES		
1) <i>k</i> := the number of bytes in the public modulus		
2) <i>hLen</i> := the number of octets in the digest produced by the hash algorithm used in the process		

The *label* parameter is optional. If provided (*label.size* != 0) then the TPM shall return TPM_RC_VALUE if the last octet in *label* is not zero. If a zero octet occurs before *label.buffer[label.size-1]*, the TPM shall truncate the label at that point. The terminating octet of zero is included in the *label* used in the padding scheme.

NOTE 4 If the scheme does not use a label, the TPM will still verify that label is properly formatted if label is present.

The function returns padded and encrypted value *outData*.

The *message* parameter in the command may be encrypted using parameter encryption.

NOTE 5 Only the public area of *keyHandle* is required to be loaded. A public key may be loaded with any desired scheme. If the scheme is to be changed, a different public area must be loaded.

16.2.2 Command and Response

Table 43 — TPM2_RSA_Encrypt Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_RSA_Encrypt
TPMI_DH_OBJECT	keyHandle	reference to public portion of RSA key to use for encryption Auth Index: None
TPM2B_PUBLIC_KEY_RSA	message	message to be encrypted NOTE 1 The data type was chosen because it limits the overall size of the input to no greater than the size of the largest RSA public key. This may be larger than allowed for <i>keyHandle</i> .
TPMT_RSA_DECRYPT+	inScheme	the padding scheme to use if <i>scheme</i> associated with <i>keyHandle</i> is TPM_ALG_NULL
TPM2B_DATA	label	optional label <i>L</i> to be associated with the message Size of the buffer is zero if no label is present NOTE 2 See description of label above.

Table 44 — TPM2_RSA_Encrypt Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_PUBLIC_KEY_RSA	outData	encrypted output

16.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "RSA_Encrypt_fp.h"
3  #ifdef TPM_ALG_RSA

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>decrypt</i> attribute is not SET in key referenced by <i>keyHandle</i>
TPM_RC_KEY	<i>keyHandle</i> does not reference an RSA key
TPM_RC_SCHEME	incorrect input scheme, or the chosen scheme is not a valid RSA decrypt scheme
TPM_RC_VALUE	the numeric value of <i>message</i> is greater than the public modulus of the key referenced by <i>keyHandle</i> , or <i>label</i> is not a null-terminated string

```

4  TPM_RC
5  TPM2_RSA_Encrypt(
6      RSA_Encrypt_In      *in,          // IN: input parameter list
7      RSA_Encrypt_Out     *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC      result;
11     OBJECT     *rsaKey;
12     TPMT_RSA_DECRYPT *scheme;
13     char        *label = NULL;
14
15     // Input Validation
16
17     rsaKey = ObjectGet(in->keyHandle);
18
19     // selected key must be an RSA key
20     if(rsaKey->publicArea.type != TPM_ALG_RSA)
21         return TPM_RC_KEY + RC_RSA_Encrypt_keyHandle;
22
23     // selected key must have the decryption attribute
24     if(rsaKey->publicArea.objectAttributes.decrypt != SET)
25         return TPM_RC_ATTRIBUTES + RC_RSA_Encrypt_keyHandle;
26
27     // Is there a label?
28     if(in->label.t.size > 0)
29     {
30         // label is present, so make sure that is it NULL-terminated
31         if(in->label.t.buffer[in->label.t.size - 1] != 0)
32             return TPM_RC_VALUE + RC_RSA_Encrypt_label;
33         label = (char *)in->label.t.buffer;
34     }
35
36     // Command Output
37
38     // Select a scheme for encryption
39     scheme = CryptSelectRSAScheme(in->keyHandle, &in->inScheme);
40     if(scheme == NULL)
41         return TPM_RC_SCHEME + RC_RSA_Encrypt_inScheme;
42
43     // Encryption. TPM_RC_VALUE, or TPM_RC_SCHEME errors my be returned buy
44     // CryptEncryptRSA. Note: It can also return TPM_RC_ATTRIBUTES if the key does
45     // not have the decrypt attribute but that was checked above.
46     out->outData.t.size = sizeof(out->outData.t.buffer);

```

```
47     result = CryptEncryptRSA(&out->outData.t.size, out->outData.t.buffer, rsaKey,
48                             scheme, in->message.t.size, in->message.t.buffer,
49                             label);
50     return result;
51 }
52 #endif
```

16.3 TPM2_RSA_Decrypt

16.3.1 General Description

This command performs RSA decryption using the indicated padding scheme according to PKCS#1v2.1 (PKCS#1).

The scheme selection for this command is the same as for TPM2_RSA_Encrypt() and is shown in Table 41.

The key referenced by *keyHandle* shall be an RSA key (TPM_RC_KEY) with *restricted* CLEAR and *decrypt* SET (TPM_RC_ATTRIBUTES).

This command uses the private key of *keyHandle* for this operation and authorization is required.

The TPM will perform a modular exponentiation of ciphertext using the private exponent associated with *keyHandle* (this is described in PKCS#1v2.1, clause 5.1.2). It will then validate the padding according to the selected scheme. If the padding checks fail, TPM_RC_VALUE is returned. Otherwise, the data is returned with the padding removed. If no padding is used, the returned value is an unsigned integer value that is the result of the modular exponentiation of *cipherText* using the private exponent of *keyHandle*. The returned value may include leading octets zeros so that it is the same size as the public modulus. For the other padding schemes, the returned value will be smaller than the public modulus but will contain all the data remaining after padding is removed and this may include leading zeros if the original encrypted value contained leading zeros..

If a label is used in the padding process of the scheme, the *label* parameter is required to be present in the decryption process and *label* is required to be the same in both cases. The TPM shall verify that the label is consistent and if not it shall return TPM_RC_VALUE. If *label* is present (*label.size* != 0), it shall be a NULL-terminated string or the TPM will return TPM_RC_VALUE.

NOTE 1 The size of *label* includes the terminating null.

The *message* parameter in the response may be encrypted using parameter encryption.

If the decryption scheme does not require a hash function, the *hash* parameter of *inScheme* may be set to any valid hash function or TPM_ALG_NULL.

If the description scheme does not require a label, the value in *label* is not used but the size of the label field is checked for consistency with the indicated data type (TPM2B_DATA). That is, the field may not be larger than allowed for a TPM2B_DATA.

16.3.2 Command and Response

Table 45 — TPM2_RSA_Decrypt Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_RSA_Decrypt
TPMI_DH_OBJECT	@keyHandle	RSA key to use for decryption Auth Index: 1 Auth Role: USER
TPM2B_PUBLIC_KEY_RSA	cipherText	cipher text to be decrypted NOTE An encrypted RSA data block is the size of the public modulus.
TPMT_RSA_DECRYPT+	inScheme	the padding scheme to use if <i>scheme</i> associated with <i>keyHandle</i> is TPM_ALG_NULL
TPM2B_DATA	label	label whose association with the message is to be verified

Table 46 — TPM2_RSA_Decrypt Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_PUBLIC_KEY_RSA	message	decrypted output

16.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "RSA_Decrypt_fp.h"
3  #ifdef TPM_ALG_RSA

```

Error Returns	Meaning
TPM_RC_KEY	<i>keyHandle</i> does not reference an unrestricted decrypt key
TPM_RC_SCHEME	incorrect input scheme, or the chosen <i>scheme</i> is not a valid RSA decrypt scheme
TPM_RC_SIZE	<i>cipherText</i> is not the size of the modulus of key referenced by <i>keyHandle</i>
TPM_RC_VALUE	<i>label</i> is not a null terminated string or the value of <i>cipherText</i> is greater than the modulus of <i>keyHandle</i>

```

4  TPM_RC
5  TPM2_RSA_Decrypt(
6      RSA_Decrypt_In      *in,          // IN: input parameter list
7      RSA_Decrypt_Out     *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC                result;
11     OBJECT                *rsaKey;
12     TPMT_RSA_DECRYPT       *scheme;
13     char                  *label = NULL;
14
15     // Input Validation
16
17     rsaKey = ObjectGet(in->keyHandle);
18
19     // The selected key must be an RSA key
20     if(rsaKey->publicArea.type != TPM_ALG_RSA)
21         return TPM_RC_KEY + RC_RSA_Decrypt_keyHandle;
22
23     // The selected key must be an unrestricted decryption key
24     if( (rsaKey->publicArea.objectAttributes.restricted == SET
25         || rsaKey->publicArea.objectAttributes.decrypt == CLEAR)
26         return TPM_RC_ATTRIBUTES + RC_RSA_Decrypt_keyHandle;
27
28     // NOTE: Proper operation of this command requires that the sensitive area
29     // of the key is loaded. This is assured because authorization is required
30     // to use the sensitive area of the key. In order to check the authorization,
31     // the sensitive area has to be loaded, even if authorization is with policy.
32
33     // If label is present, make sure that it is a NULL-terminated string
34     if(in->label.t.size > 0)
35     {
36         // Present, so make sure that it is NULL-terminated
37         if(in->label.t.buffer[in->label.t.size - 1] != 0)
38             return TPM_RC_VALUE + RC_RSA_Decrypt_label;
39         label = (char *)in->label.t.buffer;
40     }
41
42     // Command Output
43
44     // Select a scheme for decrypt.
45     scheme = CryptSelectRSAScheme(in->keyHandle, &in->inScheme);
46     if(scheme == NULL)

```

```
47     return TPM_RC_SCHEME + RC_RSA_Decrypt_inScheme;
48
49     // Decryption.  TPM_RC_VALUE, TPM_RC_SIZE, and TPM_RC_KEY error may be
50     // returned by CryptDecryptRSA.
51     // NOTE: CryptDecryptRSA can also return TPM_RC_ATTRIBUTES or TPM_RC_BINDING
52     // when the key is not a decryption key but that was checked above.
53     out->message.t.size = sizeof(out->message.t.buffer);
54     result = CryptDecryptRSA(&out->message.t.size, out->message.t.buffer, rsaKey,
55                             scheme, in->cipherText.t.size,
56                             in->cipherText.t.buffer,
57                             label);
58
59     return result;
60 }
61 #endif
```

16.4 TPM2_ECDH_KeyGen

16.4.1 General Description

This command uses the TPM to generate an ephemeral key pair $(d_e, Q_e$ where $Q_e := [d_e]G$). It uses the private ephemeral key and a loaded public key (Q_s) to compute the shared secret value $(P := [hd_e]Q_s)$.

keyHandle shall refer to a loaded ECC key. The sensitive portion of this key need not be loaded.

The curve parameters of the loaded ECC key are used to generate the ephemeral key.

NOTE 1 This function is the equivalent of encrypting data to another object's public key. The *seed* value is used in a KDF to generate a symmetric key and that key is used to encrypt the data. Once the data is encrypted and the symmetric key discarded, only the object with the private portion of the *keyHandle* will be able to decrypt it.

The *zPoint* in the response may be encrypted using parameter encryption.

16.4.2 Command and Response

Table 47 — TPM2_ECDH_KeyGen Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ECDH_KeyGen
TPMI_DH_OBJECT	keyHandle	Handle of a loaded ECC key public area. Auth Index: None

Table 48 — TPM2_ECDH_KeyGen Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ECC_POINT	zPoint	results of $P := h[d_e]Q_s$
TPM2B_ECC_POINT	pubPoint	generated ephemeral public point (Q_e)

16.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ECDH_KeyGen_fp.h"
3  #ifdef TPM_ALG_ECC

```

Error Returns	Meaning
TPM_RC_KEY	<i>keyHandle</i> does not reference a non-restricted decryption ECC key

```

4  TPM_RC
5  TPM2_ECDH_KeyGen(
6      ECDH_KeyGen_In    *in,           // IN: input parameter list
7      ECDH_KeyGen_Out  *out          // OUT: output parameter list
8  )
9  {
10     OBJECT                *eccKey;
11     TPM2B_ECC_PARAMETER    sensitive;
12     TPM_RC                result;
13
14     // Input Validation
15
16     eccKey = ObjectGet(in->keyHandle);
17
18     // Input key must be a non-restricted, decrypt ECC key
19     if( eccKey->publicArea.type != TPM_ALG_ECC
20         || eccKey->publicArea.objectAttributes.restricted == SET
21         || eccKey->publicArea.objectAttributes.decrypt != SET
22     )
23         return TPM_RC_KEY + RC_ECDH_KeyGen_keyHandle;
24
25     // Command Output
26     do
27     {
28         // Create ephemeral ECC key
29         CryptNewEccKey(eccKey->publicArea.parameters.eccDetail.curveID,
30                       &out->pubPoint.t.point, &sensitive);
31
32         out->pubPoint.t.size = TPMS_ECC_POINT_Marshal(&out->pubPoint.t.point,
33                                                     NULL, NULL);
34
35         // Compute Z
36         result = CryptEccPointMultiply(&out->zPoint.t.point,
37                                       eccKey->publicArea.parameters.eccDetail.curveID,
38                                       &sensitive, &eccKey->publicArea.unique.ecc);
39         // The point in the key is not on the curve. Indicate that the key is bad.
40         if(result == TPM_RC_ECC_POINT)
41             return TPM_RC_KEY + RC_ECDH_KeyGen_keyHandle;
42         // The other possible error is TPM_RC_NO_RESULT indicating that the
43         // multiplication resulted in the point at infinity, so get a new
44         // random key and start over (hardly ever happens).
45     }
46     while(result != TPM_RC_SUCCESS);
47
48     // Marshal the values to generate the point.
49     out->zPoint.t.size = TPMS_ECC_POINT_Marshal(&out->zPoint.t.point, NULL, NULL);
50
51     return TPM_RC_SUCCESS;
52 }
53 #endif

```

16.5 TPM2_ECDH_ZGen

16.5.1 General Description

This command uses the TPM to recover the Z value from a public point (Q_B) and a private key (d_s). It will perform the multiplication of the provided *inPoint* (Q_B) with the private key (d_s) and return the coordinates of the resultant point ($Z = (x_Z, y_Z) := [hd_s]Q_B$; where h is the cofactor of the curve).

keyHandle shall refer to a loaded, ECC key (TPM_RC_KEY) with the *restricted* attribute CLEAR and the *decrypt* attribute SET (TPM_RC_ATTRIBUTES).

The *scheme* of the key referenced by *keyHandle* is required to be either TPM_ALG_ECDH or TPM_ALG_NULL (TPM_RC_SCHEME).

inPoint is required to be on the curve of the key referenced by *keyHandle* (TPM_RC_ECC_POINT).

The parameters of the key referenced by *keyHandle* are used to perform the point multiplication.

16.5.2 Command and Response

Table 49 — TPM2_ECDH_ZGen Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ECDH_ZGen
TPMI_DH_OBJECT	@keyHandle	handle of a loaded ECC key Auth Index: 1 Auth Role: USER
TPM2B_ECC_POINT	inPoint	a public key

Table 50 — TPM2_ECDH_ZGen Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ECC_POINT	outPoint	X and Y coordinates of the product of the multiplication $Z = (x_Z, y_Z) := [hd_S]Q_B$

16.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ECDH_ZGen_fp.h"
3  #ifdef TPM_ALG_ECC

```

Error Returns	Meaning
TPM_RC_KEY	<i>keyHandle</i> does not reference a non-restricted decryption ECC key
TPM_RC_ECC_POINT	invalid argument
TPM_RC_NO_RESULT	multiplying <i>inPoint</i> resulted in a point at infinity

```

4  TPM_RC
5  TPM2_ECDH_ZGen(
6      ECDH_ZGen_In    *in,           // IN: input parameter list
7      ECDH_ZGen_Out   *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     OBJECT          *eccKey;
12
13     // Input Validation
14
15     eccKey = ObjectGet(in->keyHandle);
16
17     // Input key must be a non-restricted, decrypt ECC key
18     if( eccKey->publicArea.type != TPM_ALG_ECC
19         || eccKey->publicArea.objectAttributes.restricted == SET
20         || eccKey->publicArea.objectAttributes.decrypt != SET
21     )
22         return TPM_RC_KEY + RC_ECDH_ZGen_keyHandle;
23
24     // Command Output
25
26     // Compute Z. TPM_RC_ECC_POINT or TPM_RC_NO_RESULT may be returned here.
27     result = CryptEccPointMultiply(&out->outPoint.t.point,
28                                   eccKey->publicArea.parameters.eccDetail.curveID,
29                                   &eccKey->sensitive.sensitive.ecc,
30                                   &in->inPoint.t.point);
31     if(result != TPM_RC_SUCCESS)
32         return RcSafeAddToResult(result, RC_ECDH_ZGen_inPoint);
33
34     out->outPoint.t.size = TPMS_ECC_POINT_Marshal(&out->outPoint.t.point,
35                                                  NULL, NULL);
36
37     return TPM_RC_SUCCESS;
38 }
39 #endif

```


16.6 TPM2_ECC_Parameters

16.6.1 General Description

This command returns the parameters of an ECC curve identified by its TCG-assigned *curveID*.

16.6.2 Command and Response

Table 51 — TPM2_ECC_Parameters Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ECC_Parameters
TPMI_ECC_CURVE	curveID	parameter set selector

Table 52 — TPM2_ECC_Parameters Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMS_ALGORITHM_DETAIL_ECC	parameters	ECC parameters for the selected curve

16.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ECC_Parameters_fp.h"
3  #ifdef TPM_ALG_ECC

```

Error Returns	Meaning
TPM_RC_VALUE	Unsupported ECC curve ID

```

4  TPM_RC
5  TPM2_ECC_Parameters(
6      ECC_Parameters_In    *in,           // IN: input parameter list
7      ECC_Parameters_Out  *out          // OUT: output parameter list
8  )
9  {
10 // Command Output
11
12 // Get ECC curve parameters
13 if(CryptEccGetParameters(in->curveID, &out->parameters))
14     return TPM_RC_SUCCESS;
15 else
16     return TPM_RC_VALUE + RC_ECC_Parameters_curveID;
17 }
18 #endif

```

16.7 TPM2_ZGen_2Phase

16.7.1 General Description

This command supports two-phase key exchange protocols. The command is used in combination with TPM2_EC_Ephemeral(). TPM2_EC_Ephemeral() generates an ephemeral key and returns the public point of that ephemeral key along with a numeric value that allows the TPM to regenerate the associated private key.

The input parameters for this command are a static public key ($inQsU$), an ephemeral key ($inQeU$) from party B, and the *commitCounter* returned by TPM2_EC_Ephemeral(). The TPM uses the counter value to regenerate the ephemeral private key ($d_{e,v}$) and the associated public key ($Q_{e,v}$). *keyA* provides the static ephemeral elements $d_{s,v}$ and $Q_{s,v}$. This provides the two pairs of ephemeral and static keys that are required for the schemes supported by this command.

The TPM will compute Z or Z_s and Z_e according to the selected scheme. If the scheme is not a two-phase key exchange scheme or if the scheme is not supported, the TPM will return TPM_RC_SCHEME.

It is an error if $inQsB$ or $inQeB$ are not on the curve of *keyA* (TPM_RC_ECC_POINT).

The two-phase key schemes that were assigned an algorithm ID as of the time of the publication of this specification are TPM_ALG_ECDH, TPM_ALG_ECMQV, and TPM_ALG_SM2.

If this command is supported, then support for TPM_ALG_ECDH is required. Support for TPM_ALG_ECMQV or TPM_ALG_SM2 is optional.

NOTE 1 If SM2 is supported and this command is supported, then the implementation is required to support the key exchange protocol of SM2, part 3.

For TPM_ALG_ECDH *outZ1* will be Z_s and *outZ2* will Z_e as defined in 6.1.1.2 of SP800-56A.

NOTE 2 A non-restricted decryption key using ECDH may be used in either TPM2_ECDH_ZGen() or TPM2_ZGen_2Phase as the computation done with the private part of *keyA* is the same in both cases.

For TPM_ALG_ECMQV or TPM_ALG_SM2 *outZ1* will be *Z* and *outZ2* will be an Empty Point.

NOTE 3 An Empty Point has two Empty Buffers as coordinates meaning the minimum *size* value for *outZ2* will be four.

If the input scheme is TPM_ALG_ECDH, then *outZ1* will be Z_s and *outZ2* will be Z_e . For schemes like MQV (including SM2), *outZ1* will contain the computed value and *outZ2* will be an Empty Point.

NOTE The Z values returned by the TPM are a full point and not just an x-coordinate.

If a computation of either Z produces the point at infinity, then the corresponding Z value will be an Empty Point.

16.7.2 Command and Response

Table 53 — TPM2_ZGen_2Phase Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ZGen_2Phase handle of an unrestricted decryption key ECC
TPMI_DH_OBJECT	@keyA	The private key referenced by this handle is used as $d_{S,A}$ Auth Index: 1 Auth Role: USER
TPM2B_ECC_POINT	inQsB	other party's static public key ($Q_{s,B} = (X_{s,B}, Y_{s,B})$)
TPM2B_ECC_POINT	inQeB	other party's ephemeral public key ($Q_{e,B} = (X_{e,B}, Y_{e,B})$)
TPMI_ECC_KEY_EXCHANGE	inScheme	the key exchange scheme
UINT16	counter	value returned by TPM2_EC_Ephemeral()

Table 54 — TPM2_ZGen_2Phase Response

Type	Name	Description
TPM_ST	tag	
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ECC_POINT	outZ1	X and Y coordinates of the computed value (scheme dependent)
TPM2B_ECC_POINT	outZ2	X and Y coordinates of the second computed value (scheme dependent)

16.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ZGen_2Phase_fp.h"
3  #if defined TPM_ALG_ECC && (CC_ZGen_2Phase == YES)

```

This command uses the TPM to recover one or two Z values in a two phase key exchange protocol

Error Returns	Meaning
TPM_RC_ATTRIBUTES	key referenced by <i>keyA</i> is restricted or not a decrypt key
TPM_RC_ECC_POINT	<i>inQsB</i> or <i>inQeB</i> is not on the curve of the key reference by <i>keyA</i>
TPM_RC_KEY	key referenced by <i>keyA</i> is not an ECC key
TPM_RC_SCHEME	the scheme of the key referenced by <i>keyA</i> is not TPM_ALG_NULL, TPM_ALG_ECDH, TPM_ALG_ECMQV or TPM_ALG_SM2

```

4  TPM_RC
5  TPM2_ZGen_2Phase(
6      ZGen_2Phase_In      *in,          // IN: input parameter list
7      ZGen_2Phase_Out    *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC                result;
11     OBJECT                *eccKey;
12     TPM2B_ECC_PARAMETER   r;
13     TPM_ALG_ID            scheme;
14
15     // Input Validation
16
17     eccKey = ObjectGet(in->keyA);
18
19     // keyA must be an ECC key
20     if(eccKey->publicArea.type != TPM_ALG_ECC)
21         return TPM_RC_KEY + RC_ZGen_2Phase_keyA;
22
23     // keyA must not be restricted and must be a decrypt key
24     if( eccKey->publicArea.objectAttributes.restricted == SET
25        || eccKey->publicArea.objectAttributes.decrypt != SET
26        )
27         return TPM_RC_ATTRIBUTES + RC_ZGen_2Phase_keyA;
28
29     // if the scheme of keyA is TPM_ALG_NULL, then use the input scheme; otherwise
30     // the input scheme must be the same as the scheme of keyA
31     scheme = eccKey->publicArea.parameters.asymDetail.scheme.scheme;
32     if(scheme != TPM_ALG_NULL)
33     {
34         if(scheme != in->inScheme)
35             return TPM_RC_SCHEME + RC_ZGen_2Phase_inScheme;
36     }
37     else
38         scheme = in->inScheme;
39     if(scheme == TPM_ALG_NULL)
40         return TPM_RC_SCHEME + RC_ZGen_2Phase_inScheme;
41
42     // Input points must be on the curve of keyA
43     if(!CryptEccIsPointOnCurve(eccKey->publicArea.parameters.eccDetail.curveID,
44                                &in->inQsB.t.point))
45         return TPM_RC_ECC_POINT + RC_ZGen_2Phase_inQsB;
46
47     if(!CryptEccIsPointOnCurve(eccKey->publicArea.parameters.eccDetail.curveID,

```

```
48         &in->inQeB.t.point))
49     return TPM_RC_ECC_POINT + RC_ZGen_2Phase_inQeB;
50
51     if(!CryptGenerateR(&r, &in->counter,
52         eccKey->publicArea.parameters.eccDetail.curveID,
53         NULL))
54         return TPM_RC_VALUE + RC_ZGen_2Phase_counter;
55
56 // Command Output
57
58     result = CryptEcc2PhaseKeyExchange(&out->outZ1.t.point,
59         &out->outZ2.t.point,
60         eccKey->publicArea.parameters.eccDetail.curveID,
61         scheme,
62         &eccKey->sensitive.sensitive.ecc,
63         &r,
64         &in->inQsB.t.point,
65         &in->inQeB.t.point);
66     if(result != TPM_RC_SUCCESS)
67         return result;
68
69     CryptEndCommit(in->counter);
70
71     return TPM_RC_SUCCESS;
72 }
73 #endif
```

17 Symmetric Primitives

17.1 Introduction

The commands in this clause provide low-level primitives for access to the symmetric algorithms implemented in the TPM that operate on blocks of data. These include symmetric encryption and decryption as well as hash and HMAC. All of the commands in this group are stateless. That is, they have no persistent state that is retained in the TPM when the command is complete.

For hashing, HMAC, and Events that require large blocks of data with retained state, the sequence commands are provided (see clause 1).

Some of the symmetric encryption/decryption modes use an IV. When an IV is used, it may be an initiation value or a chained value from a previous stage. The chaining for each mode is:

Table 55 — Symmetric Chaining Process

Mode	Chaining process
TPM_ALG_CTR	<p>The TPM will increment the entire IV provided by the caller. The last encrypted value will be returned to the caller as <i>ivOut</i>. This can be the input value to the next encrypted buffer.</p> <p><i>ivIn</i> is required to be the size of a block encrypted by the selected algorithm and key combination. If the size of <i>ivIn</i> is not correct, the TPM shall return TPM_RC_SIZE.</p> <p>EXAMPLE 1 AES requires that <i>ivIn</i> be 128 bits (16 octets).</p> <p><i>ivOut</i> will be the size of a cipher block and not the size of the last encrypted block.</p> <p>NOTE <i>ivOut</i> will be the value of the counter after the last block is encrypted.</p> <p>EXAMPLE 2 If <i>ivIn</i> were 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00₁₆ and four data blocks were encrypted, <i>ivOut</i> will have a value of 00 00 00 00 00 00 00 00 00 00 00 00 00 00 04₁₆.</p> <p>All the bits of the IV are incremented as if it were an unsigned integer.</p>
TPM_ALG_OFB	<p>In Output Feedback (OFB), the output of the pseudo-random function (the block encryption algorithm) is XORed with a plaintext block to produce a ciphertext block. <i>ivOut</i> will be the value that was XORed with the last plaintext block. That value can be used as the <i>ivIn</i> for a next buffer.</p> <p><i>ivIn</i> is required to be the size of a block encrypted by the selected algorithm and key combination. If the size of <i>ivIn</i> is not correct, the TPM shall return TPM_RC_SIZE.</p> <p><i>ivOut</i> will be the size of a cipher block and not the size of the last encrypted block.</p>
TPM_ALG_CBC	<p>For Cipher Block Chaining (CBC), a block of ciphertext is XORed with the next plaintext block and that block is encrypted. The encrypted block is then input to the encryption of the next block. The last ciphertext block then is used as an IV for the next buffer.</p> <p>Even though the last ciphertext block is evident in the encrypted data, it is also returned in <i>ivOut</i>.</p> <p><i>ivIn</i> is required to be the size of a block encrypted by the selected algorithm and key combination. If the size of <i>ivIn</i> is not correct, the TPM shall return TPM_RC_SIZE.</p> <p><i>inData</i> is required to be an even multiple of the block encrypted by the selected algorithm and key combination. If the size of <i>inData</i> is not correct, the TPM shall return TPM_RC_SIZE.</p>
TPM_ALG_CFB	<p>Similar to CBC in that the last ciphertext block is an input to the encryption of the next block. <i>ivOut</i> will be the value that was XORed with the last plaintext block. That value can be used as the <i>ivIn</i> for a next buffer.</p> <p><i>ivIn</i> is required to be the size of a block encrypted by the selected algorithm and key combination. If the size of <i>ivIn</i> is not correct, the TPM shall return TPM_RC_SIZE.</p> <p><i>ivOut</i> will be the size of a cipher block and not the size of the last encrypted block.</p>
TPM_ALG_ECB	<p>Electronic Codebook (ECB) has no chaining. Each block of plaintext is encrypted using the key. ECB does not support chaining and <i>ivIn</i> shall be the Empty Buffer. <i>ivOut</i> will be the Empty Buffer.</p> <p><i>inData</i> is required to be an even multiple of the block encrypted by the selected algorithm and key combination. If the size of <i>inData</i> is not correct, the TPM shall return TPM_RC_SIZE.</p>

17.2 TPM2_EncryptDecrypt

17.2.1 General Description

This command performs symmetric encryption or decryption.

keyHandle shall reference a symmetric cipher object (TPM_RC_KEY).

For a restricted key, *mode* shall be either the same as the mode of the key, or TPM_ALG_NULL (TPM_RC_VALUE). For an unrestricted key, *mode* may be the same or different from the mode of the key but both shall not be TPM_ALG_NULL (TPM_RC_VALUE).

If the TPM allows this command to be canceled before completion, then the TPM may produce incremental results and return TPM_RC_SUCCESS rather than TPM_RC_CANCEL. In such case, *outData* may be less than *inData*.

17.2.2 Command and Response

Table 56 — TPM2_EncryptDecrypt Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_EncryptDecrypt
TPMI_DH_OBJECT	@keyHandle	the symmetric key used for the operation Auth Index: 1 Auth Role: USER
TPMI_YES_NO	decrypt	if YES, then the operation is decryption; if NO, the operation is encryption
TPMI_ALG_SYM_MODE+	mode	symmetric mode For a restricted key, this field shall match the default mode of the key or be TPM_ALG_NULL.
TPM2B_IV	ivIn	an initial value as required by the algorithm
TPM2B_MAX_BUFFER	inData	the data to be encrypted/decrypted

Table 57 — TPM2_EncryptDecrypt Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_MAX_BUFFER	outData	encrypted output
TPM2B_IV	ivOut	chaining value to use for IV in next round

17.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "EncryptDecrypt_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	is not a symmetric decryption key with both public and private portions loaded
TPM_RC_SIZE	<i>ivIn</i> size is incompatible with the block cipher mode; or <i>inData</i> size is not an even multiple of the block size for CBC or ECB mode
TPM_RC_VALUE	<i>keyHandle</i> is restricted and the argument <i>mode</i> does not match the key's mode

```

3  TPM_RC
4  TPM2_EncryptDecrypt(
5      EncryptDecrypt_In          *in,           // IN: input parameter list
6      EncryptDecrypt_Out        *out          // OUT: output parameter list
7  )
8  {
9      OBJECT                      *symKey;
10     UINT16                       keySize;
11     UINT16                       blockSize;
12     BYTE                          *key;
13     TPM_ALG_ID                   alg;
14
15     // Input Validation
16     symKey = ObjectGet(in->keyHandle);
17
18     // The input key should be a symmetric decrypt key.
19     if( symKey->publicArea.type != TPM_ALG_SYMCIPHER
20         || symKey->attributes.publicOnly == SET)
21         return TPM_RC_KEY + RC_EncryptDecrypt_keyHandle;
22
23     // If the input mode is TPM_ALG_NULL, use the key's mode
24     if( in->mode == TPM_ALG_NULL)
25         in->mode = symKey->publicArea.parameters.symDetail.sym.mode.sym;
26
27     // If the key is restricted, the input sym mode should match the key's sym
28     // mode
29     if( symKey->publicArea.objectAttributes.restricted == SET
30         && symKey->publicArea.parameters.symDetail.sym.mode.sym != in->mode)
31         return TPM_RC_VALUE + RC_EncryptDecrypt_mode;
32
33     // If the mode is null, then we have a problem.
34     // Note: Construction of a TPMT_SYM_DEF does not allow the 'mode' to be
35     // TPM_ALG_NULL so setting in->mode to the mode of the key should have
36     // produced a valid mode. However, this is suspenders.
37     if(in->mode == TPM_ALG_NULL)
38         return TPM_RC_VALUE + RC_EncryptDecrypt_mode;
39
40     // The input iv for ECB mode should be null. All the other modes should
41     // have an iv size same as encryption block size
42
43     keySize = symKey->publicArea.parameters.symDetail.sym.keyBits.sym;
44     alg = symKey->publicArea.parameters.symDetail.sym.algorithm;
45     blockSize = CryptGetSymmetricBlockSize(alg, keySize);
46     if( (in->mode == TPM_ALG_ECB && in->ivIn.t.size != 0)
47         || (in->mode != TPM_ALG_ECB && in->ivIn.t.size != blockSize))
48         return TPM_RC_SIZE + RC_EncryptDecrypt_ivIn;

```

```
49
50 // The input data size of CBC mode or ECB mode must be an even multiple of
51 // the symmetric algorithm's block size
52 if( (in->mode == TPM_ALG_CBC || in->mode == TPM_ALG_ECB)
53     && (in->inData.t.size % blockSize) != 0)
54     return TPM_RC_SIZE + RC_EncryptDecrypt_inData;
55
56 // Copy IV
57 // Note: This is copied here so that the calls to the encrypt/decrypt functions
58 // will modify the output buffer, not the input buffer
59 out->ivOut = in->ivIn;
60
61 // Command Output
62
63
64 key = symKey->sensitive.sensitive.sym.t.buffer;
65 // For symmetric encryption, the cipher data size is the same as plain data
66 // size.
67 out->outData.t.size = in->inData.t.size;
68 if(in->decrypt == YES)
69 {
70     // Decrypt data to output
71     CryptSymmetricDecrypt(out->outData.t.buffer,
72                           alg,
73                           keySize, in->mode, key,
74                           &(out->ivOut),
75                           in->inData.t.size,
76                           in->inData.t.buffer);
77 }
78 else
79 {
80     // Encrypt data to output
81     CryptSymmetricEncrypt(out->outData.t.buffer,
82                           alg,
83                           keySize,
84                           in->mode, key,
85                           &(out->ivOut),
86                           in->inData.t.size,
87                           in->inData.t.buffer);
88 }
89
90 return TPM_RC_SUCCESS;
91 }
```

17.3 TPM2_Hash

17.3.1 General Description

This command performs a hash operation on a data buffer and returns the results.

NOTE If the data buffer to be hashed is larger than will fit into the TPM's input buffer, then the sequence hash commands will need to be used.

If the results of the hash will be used in a signing operation that uses a restricted signing key, then the ticket returned by this command can indicate that the hash is safe to sign.

If the digest is not safe to sign, then the TPM will return a TPMT_TK_HASHCHECK with the hierarchy set to TPM_RH_NULL and *digest* set to the Empty Buffer.

If *hierarchy* is TPM_RH_NULL, then *digest* in the ticket will be the Empty Buffer.

17.3.2 Command and Response

Table 58 — TPM2_Hash Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	Shall have at least one session
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Hash
TPM2B_MAX_BUFFER	data	data to be hashed
TPMI_ALG_HASH	hashAlg	algorithm for the hash being computed – shall not be TPM_ALG_NULL
TPMI_RH_HIERARCHY+	hierarchy	hierarchy to use for the ticket (TPM_RH_NULL allowed)

Table 59 — TPM2_Hash Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DIGEST	outHash	results
TPMT_TK_HASHCHECK	validation	ticket indicating that the sequence of octets used to compute <i>outDigest</i> did not start with TPM_GENERATED_VALUE will be a NULL ticket if the digest may not be signed with a restricted key

17.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "Hash_fp.h"
3  TPM_RC
4  TPM2_Hash(
5      Hash_In      *in,           // IN: input parameter list
6      Hash_Out     *out          // OUT: output parameter list
7  )
8  {
9      HASH_STATE     hashState;
10
11     // Command Output
12
13     // Output hash
14     // Start hash stack
15     out->outHash.t.size = CryptStartHash(in->hashAlg, &hashState);
16     // Adding hash data
17     CryptUpdateDigest2B(&hashState, &in->data.b);
18     // Complete hash
19     CryptCompleteHash2B(&hashState, &out->outHash.b);
20
21     // Output ticket
22     out->validation.tag = TPM_ST_HASHCHECK;
23     out->validation.hierarchy = in->hierarchy;
24
25     if(in->hierarchy == TPM_RH_NULL)
26     {
27         // Ticket is not required
28         out->validation.hierarchy = TPM_RH_NULL;
29         out->validation.digest.t.size = 0;
30     }
31     else if( in->data.t.size >= sizeof(TPM_GENERATED)
32             && !TicketIsSafe(&in->data.b))
33     {
34         // Ticket is not safe
35         out->validation.hierarchy = TPM_RH_NULL;
36         out->validation.digest.t.size = 0;
37     }
38     else
39     {
40         // Compute ticket
41         TicketComputeHashCheck(in->hierarchy, &out->outHash, &out->validation);
42     }
43
44     return TPM_RC_SUCCESS;
45 }
```

17.4 TPM2_HMAC

17.4.1 General Description

This command performs an HMAC on the supplied data using the indicated hash algorithm.

The caller shall provide proper authorization for use of *handle*.

If the sign attribute is not SET in the key referenced by *handle* then the TPM shall return TPM_RC_ATTRIBUTES. If the key type is not TPM_ALG_KEYEDHASH then the TPM shall return TPM_RC_TYPE.

If *handle* references a restricted key, then the hash algorithm specified in the key's *scheme* is used as the hash algorithm for the HMAC and the TPM shall return TPM_RC_VALUE if *hashAlg* is not TPM_ALG_NULL or the same algorithm as selected in the key's scheme.

NOTE 1 A restricted key may only have one of sign or decrypt SET and the default scheme may not be TPM_ALG_NULL. These restrictions are enforced by TPM2_Create() and TPM2_CreatePrimary(),

If the key referenced by *handle* is not restricted, then the TPM will use *hashAlg* for the HMAC. However, if *hashAlg* is TPM_ALG_NULL the TPM will use the default scheme of the key.

If both *hashAlg* and the key default are TPM_ALG_NULL, the TPM shall return TPM_RC_VALUE.

NOTE A key may only have both sign and decrypt SET if the key is unrestricted. When both sign and decrypt are set, there is no default scheme for the key and the hash algorithm must be specified.

17.4.2 Command and Response

Table 60 — TPM2_HMAC Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_DH_OBJECT	commandCode @handle	TPM_CC_HMAC handle for the symmetric signing key providing the HMAC key Auth Index: 1 Auth Role: USER
TPM2B_MAX_BUFFER	buffer	HMAC data
TPMI_ALG_HASH+	hashAlg	algorithm to use for HMAC

Table 61 — TPM2_HMAC Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DIGEST	outHMAC	the returned HMAC in a sized buffer

17.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "HMAC_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	key referenced by <i>handle</i> is not a signing key
TPM_RC_TYPE	key referenced by <i>handle</i> is not an HMAC key
TPM_RC_VALUE	<i>hashAlg</i> specified when the key is restricted is neither TPM_ALG_NULL not equal to that of the key scheme; or both <i>hashAlg</i> and the key scheme's algorithm are TPM_ALG_NULL

```

3  TPM_RC
4  TPM2_HMAC(
5      HMAC_In          *in,          // IN: input parameter list
6      HMAC_Out         *out         // OUT: output parameter list
7  )
8  {
9      HMAC_STATE        hmacState;
10     OBJECT             *hmacObject;
11     TPMT_ALG_HASH      hashAlg;
12     TPMT_PUBLIC        *publicArea;
13
14     // Input Validation
15
16     // Get HMAC key object and public area pointers
17     hmacObject = ObjectGet(in->handle);
18     publicArea = &hmacObject->publicArea;
19
20     // Make sure that the key is an HMAC signing key
21     if(publicArea->type != TPM_ALG_KEYEDHASH)
22         return TPM_RC_TYPE + RC_HMAC_handle;
23     if(publicArea->objectAttributes.sign != SET)
24         return TPM_RC_ATTRIBUTES + RC_HMAC_handle;
25
26
27     // Assume that the key default scheme is used
28     hashAlg = publicArea->parameters.keyedHashDetail.scheme.details.hmac.hashAlg;
29
30     // if the key is restricted, then need to use the scheme of the key and the
31     // input algorithm must be TPM_ALG_NULL or the same as the key scheme
32     if(publicArea->objectAttributes.restricted == SET)
33     {
34         if(in->hashAlg != TPM_ALG_NULL && in->hashAlg != hashAlg)
35             hashAlg = TPM_ALG_NULL;
36     }
37     else
38     {
39         // for a non-restricted key, use hashAlg if it is provided;
40         if(in->hashAlg != TPM_ALG_NULL)
41             hashAlg = in->hashAlg;
42     }
43     // if the hashAlg is TPM_ALG_NULL, then the input hashAlg is not compatible
44     // with the key scheme or type
45     if(hashAlg == TPM_ALG_NULL)
46         return TPM_RC_VALUE + RC_HMAC_hashAlg;
47
48     // Command Output
49

```

```
50     // Start HMAC stack
51     out->outHMAC.t.size = CryptStartHMAC2B(hashAlg,
52                                           &hmacObject->sensitive.sensitive.bits.b,
53                                           &hmacState);
54     // Adding HMAC data
55     CryptUpdateDigest2B(&hmacState, &in->buffer.b);
56
57     // Complete HMAC
58     CryptCompleteHMAC2B(&hmacState, &out->outHMAC.b);
59
60     return TPM_RC_SUCCESS;
61 }
```

18 Random Number Generator

18.1 TPM2_GetRandom

18.1.1 General Description

This command returns the next *bytesRequested* octets from the random number generator (RNG).

NOTE 1 It is recommended that a TPM implement the RNG in a manner that would allow it to return RNG octets such that the frequency of *bytesRequested* being more than the number of octets available is an infrequent occurrence.

If *bytesRequested* is more than will fit into a TPM2B_DIGEST on the TPM, no error is returned but the TPM will only return as much data as will fit into a TPM2B_DIGEST buffer for the TPM.

NOTE 2 TPM2B_DIGEST is large enough to hold the largest digest that may be produced by the TPM. Because that digest size changes according to the implemented hashes, the maximum amount of data returned by this command is TPM implementation-dependent.

18.1.2 Command and Response

Table 62 — TPM2_GetRandom Command

Type	Name	Description
TPML_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_GetRandom
UINT16	bytesRequested	number of octets to return

Table 63 — TPM2_GetRandom Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DIGEST	randomBytes	the random octets

18.1.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "GetRandom_fp.h"
3  TPM_RC
4  TPM2_GetRandom(
5      GetRandom_In      *in,          // IN: input parameter list
6      GetRandom_Out     *out         // OUT: output parameter list
7  )
8  {
9  // Command Output
10
11     // if the requested bytes exceed the output buffer size, generates the
12     // maximum bytes that the output buffer allows
13     if(in->bytesRequested > sizeof(TPMU_HA))
14         out->randomBytes.t.size = sizeof(TPMU_HA);
15     else
16         out->randomBytes.t.size = in->bytesRequested;
17
18     CryptGenerateRandom(out->randomBytes.t.size, out->randomBytes.t.buffer);
19
20     return TPM_RC_SUCCESS;
21 }
```

18.2 TPM2_StirRandom

18.2.1 General Description

This command is used to add "additional information" to the RNG state.

NOTE The "additional information" is as defined in SP800-90A.

The *inData* parameter may not be larger than 128 octets.

18.2.2 Command and Response**Table 64 — TPM2_StirRandom Command**

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_StirRandom {NV}
TPM2B_SENSITIVE_DATA	inData	additional information

Table 65 — TPM2_StirRandom Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

18.2.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "StirRandom_fp.h"
3  TPM_RC
4  TPM2_StirRandom(
5      StirRandom_In    *in                // IN: input parameter list
6  )
7  {
8  // Internal Data Update
9      CryptStirRandom(in->inData.t.size, in->inData.t.buffer);
10
11     return TPM_RC_SUCCESS;
12 }
```

19 Hash/HMAC/Event Sequences

19.1 Introduction

All of the commands in this group are to support sequences for which an intermediate state must be maintained. For a description of sequences, see “Hash, HMAC, and Event Sequences” in Part 1.

19.2 TPM2_HMAC_Start

19.2.1 General Description

This command starts an HMAC sequence. The TPM will create and initialize an HMAC sequence structure, assign a handle to the sequence, and set the *authValue* of the sequence object to the value in *auth*.

NOTE 1 The structure of a sequence object is vendor-dependent.

The caller shall provide proper authorization for use of *handle*.

If the *sign* attribute is not SET in the key referenced by *handle* then the TPM shall return TPM_RC_ATTRIBUTES. If the key type is not TPM_ALG_KEYEDHASH then the TPM shall return TPM_RC_TYPE.

If *handle* references a restricted key, then the hash algorithm specified in the key's *scheme* is used as the hash algorithm for the HMAC and the TPM shall return TPM_RC_VALUE if *hashAlg* is not TPM_ALG_NULL or the same algorithm in the key's scheme.

If the key referenced by *handle* is not restricted, then the TPM will use *hashAlg* for the HMAC; unless *hashAlg* is TPM_ALG_NULL in which case it will use the default scheme of the key.

Table 66 — Hash Selection Matrix

<i>handle</i> → <i>restricted</i> (key's restricted attribute)	<i>handle</i> → <i>scheme</i> (hash algorithm from key's <i>scheme</i>)	<i>hashAlg</i>	hash used
CLEAR (unrestricted)	TPM_ALG_NULL ⁽¹⁾	TPM_ALG_NULL	error ⁽²⁾ (TPM_RC_SCHEME)
CLEAR	don't care	valid hash	<i>hashAlg</i>
CLEAR	valid hash	TPM_ALG_NULL	<i>handle</i> → <i>scheme</i>
SET (restricted)	valid hash ⁽³⁾	TPM_ALG_NULL	<i>handle</i> → <i>scheme</i>
SET	valid hash ⁽³⁾	same as <i>handle</i> → <i>scheme</i>	<i>handle</i> → <i>scheme</i>
SET	valid hash ⁽³⁾	not same as <i>handle</i> → <i>scheme</i>	error ⁽⁴⁾ (TPM_RC_SCHEME)

NOTES:

- 1) The scheme for the handle may only be TPM_ALG_NULL if both *sign* and *decrypt* are SET.
- 2) A hash algorithm is required for the HMAC.
- 3) A restricted key is required to have a scheme with a valid hash algorithm. A restricted key may not have both *sign* and *decrypt* SET.
- 4) The scheme for a restricted key cannot be overridden.

19.2.2 Command and Response

Table 67 — TPM2_HMAC_Start Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_HMAC_Start
TPMI_DH_OBJECT	@handle	handle of an HMAC key Auth Index: 1 Auth Role: USER
TPM2B_AUTH	auth	authorization value for subsequent use of the sequence
TPMI_ALG_HASH+	hashAlg	the hash algorithm to use for the HMAC

Table 68 — TPM2_HMAC_Start Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMI_DH_OBJECT	sequenceHandle	a handle to reference the sequence

19.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "HMAC_Start_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	key referenced by <i>handle</i> is not a signing key
TPM_RC_OBJECT_MEMORY	no space to create an internal object
TPM_RC_TYPE	key referenced by <i>handle</i> is not an HMAC key
TPM_RC_VALUE	<i>hashAlg</i> specified when the key is restricted is neither TPM_ALG_NULL not equal to that of the key scheme; or both <i>hashAlg</i> and the key scheme's algorithm are TPM_ALG_NULL

```

3  TPM_RC
4  TPM2_HMAC_Start(
5      HMAC_Start_In      *in,           // IN: input parameter list
6      HMAC_Start_Out     *out          // OUT: output parameter list
7  )
8  {
9      OBJECT              *hmacObject;
10     TPMT_PUBLIC          *publicArea;
11     TPM_ALG_ID           hashAlg;
12
13     // Input Validation
14
15     // Get HMAC key object and public area pointers
16     hmacObject = ObjectGet(in->handle);
17     publicArea = &hmacObject->publicArea;
18
19     // Make sure that the key is an HMAC signing key
20     if(publicArea->type != TPM_ALG_KEYEDHASH)
21         return TPM_RC_TYPE + RC_HMAC_Start_handle;
22     if(publicArea->objectAttributes.sign != SET)
23         return TPM_RC_ATTRIBUTES + RC_HMAC_Start_handle;
24
25     // Assume that the key default scheme is used
26     hashAlg = publicArea->parameters.keyedHashDetail.scheme.details.hmac.hashAlg;
27
28     // if the key is restricted, then need to use the scheme of the key and the
29     // input algorithm must be TPM_ALG_NULL or the same as the key scheme
30     if(publicArea->objectAttributes.restricted == SET)
31     {
32         if(in->hashAlg != TPM_ALG_NULL && in->hashAlg != hashAlg)
33             hashAlg = TPM_ALG_NULL;
34     }
35     else
36     {
37         // for a non-restricted key, use hashAlg if it is provided;
38         if(in->hashAlg != TPM_ALG_NULL)
39             hashAlg = in->hashAlg;
40     }
41     // if the algorithm selection ended up with TPM_ALG_NULL, then either the
42     // schemes are not compatible or no hash was provided and both conditions
43     // are errors.
44     if(hashAlg == TPM_ALG_NULL)
45         return TPM_RC_VALUE + RC_HMAC_Start_hashAlg;
46
47     // Internal Data Update

```

```
48
49 // Create a HMAC sequence object. A TPM_RC_OBJECT_MEMORY error may be
50 // returned at this point
51 return ObjectCreateHMACSequence(hashAlg,
52                                 in->handle,
53                                 &in->auth,
54                                 &out->sequenceHandle);
55 }
```

19.3 TPM2_HashSequenceStart

19.3.1 General Description

This command starts a hash or an Event sequence. If *hashAlg* is an implemented hash, then a hash sequence is started. If *hashAlg* is TPM_ALG_NULL, then an Event sequence is started. If *hashAlg* is neither an implemented algorithm nor TPM_ALG_NULL, then the TPM shall return TPM_RC_HASH.

Depending on *hashAlg*, the TPM will create and initialize a hash sequence structure or an Event sequence structure. Additionally, it will assign a handle to the sequence and set the *authValue* of the sequence to the value in *auth*. A sequence structure for an Event (*hashAlg* = TPM_ALG_NULL) contains a hash context for each of the PCR banks implemented on the TPM.

19.3.2 Command and Response

Table 69 — TPM2_HashSequenceStart Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_HashSequenceStart
TPM2B_AUTH	auth	authorization value for subsequent use of the sequence
TPMI_ALG_HASH+	hashAlg	the hash algorithm to use for the hash sequence An Event sequence starts if this is TPM_ALG_NULL.

Table 70 — TPM2_HashSequenceStart Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMI_DH_OBJECT	sequenceHandle	a handle to reference the sequence

19.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "HashSequenceStart_fp.h"

```

Error Returns	Meaning
TPM_RC_OBJECT_MEMORY	no space to create an internal object

```

3  TPM_RC
4  TPM2_HashSequenceStart(
5      HashSequenceStart_In      *in,          // IN: input parameter list
6      HashSequenceStart_Out     *out         // OUT: output parameter list
7  )
8  {
9      // Internal Data Update
10
11     if(in->hashAlg == TPM_ALG_NULL)
12         // Start a event sequence. A TPM_RC_OBJECT_MEMORY error may be
13         // returned at this point
14         return ObjectCreateEventSequence(&in->auth, &out->sequenceHandle);
15
16     // Start a hash sequence. A TPM_RC_OBJECT_MEMORY error may be
17     // returned at this point
18     return ObjectCreateHashSequence(in->hashAlg, &in->auth, &out->sequenceHandle);
19 }

```


19.4 TPM2_SequenceUpdate

19.4.1 General Description

This command is used to add data to a hash or HMAC sequence. The amount of data in buffer may be any size up to the limits of the TPM.

NOTE In all TPM, a *buffer* size of 1,024 octets is allowed.

Proper authorization for the sequence object associated with *sequenceHandle* is required. If an authorization or audit of this command requires computation of a *cpHash* and an *rpHash*, the Name associated with *sequenceHandle* will be the Empty Buffer.

If the command does not return TPM_RC_SUCCESS, the state of the sequence is unmodified.

If the sequence is intended to produce a digest that will be signed by a restricted signing key, then the first block of data shall contain sizeof(TPM_GENERATED) octets and the first octets shall not be TPM_GENERATED_VALUE.

NOTE This requirement allows the TPM to validate that the first block is safe to sign without having to accumulate octets over multiple calls.

19.4.2 Command and Response

Table 71 — TPM2_SequenceUpdate Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_SequenceUpdate
TPMI_DH_OBJECT	@sequenceHandle	handle for the sequence object Auth Index: 1 Auth Role: USER
TPM2B_MAX_BUFFER	buffer	data to be added to hash

Table 72 — TPM2_SequenceUpdate Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

19.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "SequenceUpdate_fp.h"

```

Error Returns	Meaning
TPM_RC_MODE	<i>sequenceHandle</i> does not reference a hash or HMAC sequence object

```

3  TPM_RC
4  TPM2_SequenceUpdate(
5      SequenceUpdate_In      *in          // IN: input parameter list
6  )
7  {
8      OBJECT                  *object;
9
10     // Input Validation
11
12     // Get sequence object pointer
13     object = ObjectGet(in->sequenceHandle);
14
15     // Check that referenced object is a sequence object.
16     if(!ObjectIsSequence(object))
17         return TPM_RC_MODE + RC_SequenceUpdate_sequenceHandle;
18
19     // Internal Data Update
20
21     if(object->attributes.eventSeq == SET)
22     {
23         // Update event sequence object
24         UINT32      i;
25         HASH_OBJECT *hashObject = (HASH_OBJECT *)object;
26         for(i = 0; i < HASH_COUNT; i++)
27         {
28             // Update sequence object
29             CryptUpdateDigest2B(&hashObject->state.hashState[i], &in->buffer.b);
30         }
31     }
32     else
33     {
34         HASH_OBJECT *hashObject = (HASH_OBJECT *)object;
35
36         // Update hash/HMAC sequence object
37         if(hashObject->attributes.hashSeq == SET)
38         {
39             // Is this the first block of the sequence
40             if(hashObject->attributes.firstBlock == CLEAR)
41             {
42                 // If so, indicate that first block was received
43                 hashObject->attributes.firstBlock = SET;
44
45                 // Check the first block to see if the first block can contain
46                 // the TPM_GENERATED_VALUE. If it does, it is not safe for
47                 // a ticket.
48                 if(TicketIsSafe(&in->buffer.b))
49                     hashObject->attributes.ticketSafe = SET;
50             }
51             // Update sequence object hash/HMAC stack
52             CryptUpdateDigest2B(&hashObject->state.hashState[0], &in->buffer.b);
53

```

```
54     }
55     else if(object->attributes.hmacSeq == SET)
56     {
57         HASH_OBJECT    *hashObject = (HASH_OBJECT *)object;
58
59         // Update sequence object hash/HMAC stack
60         CryptUpdateDigest2B(&hashObject->state.hmacState, &in->buffer.b);
61     }
62 }
63
64 return TPM_RC_SUCCESS;
65 }
```

19.5 TPM2_SequenceComplete

19.5.1 General Description

This command adds the last part of data, if any, to a hash/HMAC sequence and returns the result.

NOTE 1 This command is not used to complete an Event sequence. TPM2_EventSequenceComplete() is used for that purpose.

For a hash sequence, if the results of the hash will be used in a signing operation that uses a restricted signing key, then the ticket returned by this command can indicate that the hash is safe to sign.

If the *digest* is not safe to sign, then *validation* will be a TPMT_TK_HASHCHECK with the hierarchy set to TPM_RH_NULL and *digest* set to the Empty Buffer.

NOTE 2 Regardless of the contents of the first octets of the hashed message, if the first buffer sent to the TPM had fewer than sizeof(TPM_GENERATED) octets, then the TPM will operate as if *digest* is not safe to sign.

If *sequenceHandle* references an Event sequence, then the TPM shall return TPM_RC_MODE.

Proper authorization for the sequence object associated with *sequenceHandle* is required. If an authorization or audit of this command requires computation of a *cpHash* and an *rpHash*, the Name associated with *sequenceHandle* will be the Empty Buffer.

If this command completes successfully, the *sequenceHandle* object will be flushed.

19.5.2 Command and Response

Table 73 — TPM2_SequenceComplete Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_SequenceComplete {F} authorization for the sequence
TPMI_DH_OBJECT	@sequenceHandle	Auth Index: 1 Auth Role: USER
TPM2B_MAX_BUFFER	buffer	data to be added to the hash/HMAC
TPMI_RH_HIERARCHY+	hierarchy	hierarchy of the ticket for a hash

Table 74 — TPM2_SequenceComplete Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DIGEST	result	the returned HMAC or digest in a sized buffer
TPMT_TK_HASHCHECK	validation	ticket indicating that the sequence of octets used to compute <i>outDigest</i> did not start with TPM_GENERATED_VALUE This is a NULL Ticket when the session is HMAC.

19.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "SequenceComplete_fp.h"
3  #include <Platform.h>

```

Error Returns	Meaning
TPM_RC_TYPE	<i>sequenceHandle</i> does not reference a hash or HMAC sequence object

```

4  TPM_RC
5  TPM2_SequenceComplete(
6      SequenceComplete_In      *in,           // IN: input parameter list
7      SequenceComplete_Out     *out          // OUT: output parameter list
8  )
9  {
10     OBJECT                      *object;
11
12     // Input validation
13
14     // Get hash object pointer
15     object = ObjectGet(in->sequenceHandle);
16
17     // input handle must be a hash or HMAC sequence object.
18     if( object->attributes.hashSeq == CLEAR
19         && object->attributes.hmacSeq == CLEAR)
20         return TPM_RC_MODE + RC_SequenceComplete_sequenceHandle;
21
22     // Command Output
23
24     if(object->attributes.hashSeq == SET)           // sequence object for hash
25     {
26         // Update last piece of data
27         HASH_OBJECT *hashObject = (HASH_OBJECT *)object;
28         CryptUpdateDigest2B(&hashObject->state.hashState[0], &in->buffer.b);
29
30         // Complete hash
31         out->result.t.size
32             = CryptGetHashDigestSize(
33                 CryptGetContextAlg(&hashObject->state.hashState[0]));
34
35         CryptCompleteHash2B(&hashObject->state.hashState[0], &out->result.b);
36
37         // Check if the first block of the sequence has been received
38         if(hashObject->attributes.firstBlock == CLEAR)
39         {
40             // If not, then this is the first block so see if it is 'safe'
41             // to sign.
42             if(TicketIsSafe(&in->buffer.b))
43                 hashObject->attributes.ticketSafe = SET;
44         }
45
46         // Output ticket
47         out->validation.tag = TPM_ST_HASHCHECK;
48         out->validation.hierarchy = in->hierarchy;
49
50         if(in->hierarchy == TPM_RH_NULL)
51         {
52             // Ticket is not required
53             out->validation.digest.t.size = 0;

```

```
54     }
55     else if(object->attributes.ticketSafe == CLEAR)
56     {
57         // Ticket is not safe to generate
58         out->validation.hierarchy = TPM_RH_NULL;
59         out->validation.digest.t.size = 0;
60     }
61     else
62     {
63         // Compute ticket
64         TicketComputeHashCheck(out->validation.hierarchy,
65                               &out->result, &out->validation);
66     }
67 }
68 else
69 {
70     HASH_OBJECT *hashObject = (HASH_OBJECT *)object;
71
72     // Update last piece of data
73     CryptUpdateDigest2B(&hashObject->state.hmacState, &in->buffer.b);
74     // Complete hash/HMAC
75     out->result.t.size =
76         CryptGetHashDigestSize(
77             CryptGetContextAlg(&hashObject->state.hmacState.hashState));
78     CryptCompleteHMAC2B(&(hashObject->state.hmacState), &out->result.b);
79
80     // No ticket is generated for HMAC sequence
81     out->validation.tag = TPM_ST_HASHCHECK;
82     out->validation.hierarchy = TPM_RH_NULL;
83     out->validation.digest.t.size = 0;
84 }
85
86 // Internal Data Update
87
88 // mark sequence object as evict so it will be flushed on the way out
89 object->attributes.evict = SET;
90
91 return TPM_RC_SUCCESS;
92 }
```


19.6 TPM2_EventSequenceComplete

19.6.1 General Description

This command adds the last part of data, if any, to an Event sequence and returns the result in a digest list. If *pcrHandle* references a PCR and not TPM_RH_NULL, then the returned digest list is processed in the same manner as the digest list input parameter to TPM2_PCR_Extend() with the *pcrHandle* in each bank extended with the associated digest value.

If *sequenceHandle* references a hash or HMAC sequence, the TPM shall return TPM_RC_MODE.

Proper authorization for the sequence object associated with *sequenceHandle* is required. If an authorization or audit of this command requires computation of a *cpHash* and an *rpHash*, the Name associated with *sequenceHandle* will be the Empty Buffer.

If this command completes successfully, the *sequenceHandle* object will be flushed.

19.6.2 Command and Response

Table 75 — TPM2_EventSequenceComplete Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_EventSequenceComplete {NV F} PCR to be extended with the Event data
TPMI_DH_PCR+	@ pcrHandle	Auth Index: 1 Auth Role: USER
TPMI_DH_OBJECT	@sequenceHandle	authorization for the sequence Auth Index: 2 Auth Role: USER
TPM2B_MAX_BUFFER	buffer	data to be added to the Event

Table 76 — TPM2_EventSequenceComplete Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPML_DIGEST_VALUES	results	list of digests computed for the PCR

19.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "EventSequenceComplete_fp.h"

```

Error Returns	Meaning
TPM_RC_LOCALITY	PCR extension is not allowed at the current locality
TPM_RC_MODE	input handle is not a valid event sequence object

```

3  TPM_RC
4  TPM2_EventSequenceComplete(
5      EventSequenceComplete_In      *in,          // IN: input parameter list
6      EventSequenceComplete_Out     *out         // OUT: output parameter list
7  )
8  {
9      TPM_RC      result;
10     HASH_OBJECT *hashObject;
11     UINT32      i;
12     TPM_ALG_ID  hashAlg;
13
14     // Input validation
15
16     // get the event sequence object pointer
17     hashObject = (HASH_OBJECT *)ObjectGet(in->sequenceHandle);
18
19     // input handle must reference an event sequence object
20     if(hashObject->attributes.eventSeq != SET)
21         return TPM_RC_MODE + RC_EventSequenceComplete_sequenceHandle;
22
23     // see if a PCR extend is requested in call
24     if(in->pcrHandle != TPM_RH_NULL)
25     {
26         // see if extend of the PCR is allowed at the locality of the command,
27         if(!PCRIsExtendAllowed(in->pcrHandle))
28             return TPM_RC_LOCALITY;
29         // if an extend is going to take place, then check to see if there has
30         // been an orderly shutdown. If so, and the selected PCR is one of the
31         // state saved PCR, then the orderly state has to change. The orderly state
32         // does not change for PCR that are not preserved.
33         // NOTE: This doesn't just check for Shutdown(STATE) because the orderly
34         // state will have to change if this is a state-saved PCR regardless
35         // of the current state. This is because a subsequent Shutdown(STATE) will
36         // check to see if there was an orderly shutdown and not do anything if
37         // there was. So, this must indicate that a future Shutdown(STATE) has
38         // something to do.
39         if(gp.orderlyState != SHUTDOWN_NONE && PCRIsStateSaved(in->pcrHandle))
40         {
41             result = NvIsAvailable();
42             if(result != TPM_RC_SUCCESS) return result;
43             g_clearOrderly = TRUE;
44         }
45     }
46
47     // Command Output
48
49     out->results.count = 0;
50
51     for(i = 0; i < HASH_COUNT; i++)
52     {
53         hashAlg = CryptGetHashAlgByIndex(i);

```

```
54     // Update last piece of data
55     CryptUpdateDigest2B(&hashObject->state.hashState[i], &in->buffer.b);
56     // Complete hash
57     out->results.digests[out->results.count].hashAlg = hashAlg;
58     CryptCompleteHash(&hashObject->state.hashState[i],
59                     CryptGetHashDigestSize(hashAlg),
60                     (BYTE *) &out->results.digests[out->results.count].digest);
61
62     // Extend PCR
63     if(in->pcrHandle != TPM_RH_NULL)
64         PCRExtend(in->pcrHandle, hashAlg,
65                 CryptGetHashDigestSize(hashAlg),
66                 (BYTE *) &out->results.digests[out->results.count].digest);
67     out->results.count++;
68 }
69
70 // Internal Data Update
71
72 // mark sequence object as evict so it will be flushed on the way out
73 hashObject->attributes.evict = SET;
74
75 return TPM_RC_SUCCESS;
76 }
```

20 Attestation Commands

20.1 Introduction

The attestation commands cause the TPM to sign an internally generated data structure. The contents of the data structure vary according to the command.

For all signing commands, provisions are made for the caller to provide a scheme to be used for the signing operation. This scheme will be applied only if the scheme of the key is TPM_ALG_NULL. If the scheme for *signHandle* is not TPM_ALG_NULL, then *inScheme.scheme* shall be TPM_ALG_NULL or the same as *scheme* in the public area of the key. If the scheme for *signHandle* is TPM_ALG_NULL, then *inScheme* will be used for the signing operation and may not be TPM_ALG_NULL. The TPM shall return TPM_RC_SCHEME to indicate that the scheme is not appropriate.

For a signing key that is not restricted, the caller may specify the scheme to be used as long as the scheme is compatible with the family of the key (for example, TPM_ALG_RSAPSS cannot be selected for an ECC key). If the caller sets *scheme* to TPM_ALG_NULL, then the default scheme of the key is used.

If the handle for the signing key (*signHandle*) is TPM_RH_NULL, then all of the actions of the command are performed and the attestation block is “signed” with the NULL Signature.

NOTE 1 This mechanism is provided so that additional commands are not required to access the data that might be in an attestation structure.

NOTE 2 When *signHandle* is TPM_RH_NULL, *scheme* is still required to be a valid signing scheme (may be TPM_ALG_NULL), but the scheme will have no effect on the format of the signature. It will always be the NULL Signature.

TPM2_NV_Certify() is an attestation command that is documented in 1. The remaining attestation commands are collected in the remainder of this clause.

Each of the attestation structures contains a TPMS_CLOCK_INFO structure and a firmware version number. These values may be considered privacy-sensitive, because they would aid in the correlation of attestations by different keys. To provide improved privacy, the *resetCount*, *restartCount*, and *firmwareVersion* numbers are obfuscated when the signing key is not in the Endorsement or Platform hierarchies.

The obfuscation value is computed by:

$$\text{obfuscation} := \text{KDFa}(\text{signHandle} \rightarrow \text{nameAlg}, \text{shProof}, \text{“OBFUSCATE”}, \text{signHandle} \rightarrow \text{QN}, 0, 128) \quad (3)$$

Of the returned 128 bits, 64 bits are added to the *versionNumber* field of the attestation structure; 32 bits are added to the *clockInfo.resetCount* and 32 bits are added to the *clockInfo.restartCount*. The order in which the bits are added is implementation-dependent.

NOTE 3 The obfuscation value for each signing key will be unique to that key in a specific location. That is, each version of a duplicated signing key will have a different obfuscation value.

When the signing key is TPM_RH_NULL, the data structure is produced but not signed; and the values in the signed data structure are obfuscated. When computing the obfuscation value for TPM_RH_NULL, the hash used for context integrity is used.

NOTE 4 The QN for TPM_RH_NULL is TPM_RH_NULL.

If the signing scheme of *signHandle* is an anonymous scheme, then the attestation blocks will not contain the Qualified Name of the *signHandle*.

Each of the attestation structures allows the caller to provide some qualifying data (*qualifyingData*). For most signing schemes, this value will be placed in the TPMS_ATTEST.*extraData* parameter that is then

hashed and signed. However, for some schemes such as ECDSA, the *qualifyingData* is used in a different manner (for details, see “ECDSA” in Part 1).

20.2 TPM2_Certify

20.2.1 General Description

The purpose of this command is to prove that an object with a specific Name is loaded in the TPM. By certifying that the object is loaded, the TPM warrants that a public area with a given Name is self-consistent and associated with a valid sensitive area. If a relying party has a public area that has the same Name as a Name certified with this command, then the values in that public area are correct.

NOTE 1 See 20.1 for description of how the signing scheme is selected.

Authorization for *objectHandle* requires ADMIN role authorization. If performed with a policy session, the session shall have a *policySession*→*commandCode* set to TPM_CC_Certify. This indicates that the policy that is being used is a policy that is for certification, and not a policy that would approve another use. That is, authority to use an object does not grant authority to certify the object.

The object may be any object that is loaded with TPM2_Load() or TPM2_CreatePrimary(). An object that only has its public area loaded cannot be certified.

NOTE 2 The restriction occurs because the Name is used to identify the object being certified. If the TPM has not validated that the public area is associated with a matched sensitive area, then the public area may not represent a valid object and cannot be certified.

The certification includes the Name and Qualified Name of the certified object as well as the Name and the Qualified Name of the certifying object.

20.2.2 Command and Response

Table 77 — TPM2_Certify Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Certify
TPMI_DH_OBJECT	@objectHandle	handle of the object to be certified Auth Index: 1 Auth Role: ADMIN
TPMI_DH_OBJECT+	@signHandle	handle of the key used to sign the attestation structure Auth Index: 2 Auth Role: USER
TPM2B_DATA	qualifyingData	user provided qualifying data
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>signHandle</i> is TPM_ALG_NULL

Table 78 — TPM2_Certify Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	.
TPM2B_ATTEST	certifyInfo	the structure that was signed
TPMT_SIGNATURE	signature	the asymmetric signature over <i>certifyInfo</i> using the key referenced by <i>signHandle</i>

20.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "Certify_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	key referenced by <i>signHandle</i> is not a signing key
TPM_RC_SCHEME	<i>inScheme</i> is not compatible with <i>signHandle</i>
TPM_RC_VALUE	digest generated for <i>inScheme</i> is greater or has larger size than the modulus of <i>signHandle</i> , or the buffer for the result in <i>signature</i> is too small (for an RSA key); invalid commit status (for an ECC key with a split scheme).

```

4  TPM_RC
5  TPM2_Certify(
6      Certify_In      *in,                // IN: input parameter list
7      Certify_Out     *out               // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     TPMS_ATTEST     certifyInfo;
12
13
14     // Command Output
15
16     // Filling in attest information
17     // Common fields
18     result = FillInAttestInfo(in->signHandle,
19                             &in->inScheme,
20                             &in->qualifyingData,
21                             &certifyInfo);
22     if(result != TPM_RC_SUCCESS)
23     {
24         if(result == TPM_RC_KEY)
25             return TPM_RC_KEY + RC_Certify_signHandle;
26         else
27             return RcSafeAddToResult(result, RC_Certify_inScheme);
28     }
29     // Certify specific fields
30     // Attestation type
31     certifyInfo.type = TPM_ST_ATTEST_CERTIFY;
32     // Certified object name
33     certifyInfo.attested.certify.name.t.size =
34         ObjectGetName(in->objectHandle,
35                     &certifyInfo.attested.certify.name.t.name);
36     // Certified object qualified name
37     ObjectGetQualifiedname(in->objectHandle,
38                           &certifyInfo.attested.certify.qualifiedName);
39
40     // Sign attestation structure. A NULL signature will be returned if
41     // signHandle is TPM_RH_NULL. A TPM_RC_NV_UNAVAILABLE, TPM_RC_NV_RATE,
42     // TPM_RC_VALUE, TPM_RC_SCHEME or TPM_RC_ATTRIBUTES error may be returned
43     // by SignAttestInfo()
44     result = SignAttestInfo(in->signHandle,
45                            &in->inScheme,
46                            &certifyInfo,
47                            &in->qualifyingData,
48                            &out->certifyInfo,

```

```
49         &out->signature);
50
51     // TPM_RC_ATTRIBUTES cannot be returned here as FillInAttestInfo would already
52     // have returned TPM_RC_KEY
53     pAssert(result != TPM_RC_ATTRIBUTES);
54
55     if(result != TPM_RC_SUCCESS)
56         return result;
57
58     // orderly state should be cleared because of the reporting of clock info
59     // if signing happens
60     if(in->signHandle != TPM_RH_NULL)
61         g_clearOrderly = TRUE;
62
63     return TPM_RC_SUCCESS;
64 }
```

20.3 TPM2_CertifyCreation

20.3.1 General Description

This command is used to prove the association between an object and its creation data. The TPM will validate that the ticket was produced by the TPM and that the ticket validates the association between a loaded public area and the provided hash of the creation data (*creationHash*).

NOTE 1 See 20.1 for description of how the signing scheme is selected.

The TPM will create a test ticket using the Name associated with *objectHandle* and *creationHash* as:

$$\mathbf{HMAC}(\mathit{proof}, (\text{TPM_ST_CREATION} \parallel \mathit{objectHandle} \rightarrow \mathit{Name} \parallel \mathit{creationHash})) \quad (4)$$

This ticket is then compared to creation ticket. If the tickets are not the same, the TPM shall return TPM_RC_TICKET.

If the ticket is valid, then the TPM will create a TPMS_ATTEST structure and place *creationHash* of the command in the *creationHash* field of the structure. The Name associated with *objectHandle* will be included in the attestation data that is then signed using the key associated with *signHandle*.

NOTE 2 If *signHandle* is TPM_RH_NULL, the TPMS_ATTEST structure is returned and *signature* is a NULL Signature.

ObjectHandle may be any object that is loaded with TPM2_Load() or TPM2_CreatePrimary().

20.3.2 Command and Response

Table 79 — TPM2_CertifyCreation Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_CertifyCreation
TPMI_DH_OBJECT+	@signHandle	handle of the key that will sign the attestation block Auth Index: 1 Auth Role: USER
TPMI_DH_OBJECT	objectHandle	the object associated with the creation data Auth Index: None
TPM2B_DATA	qualifyingData	user-provided qualifying data
TPM2B_DIGEST	creationHash	hash of the creation data produced by TPM2_Create() or TPM2_CreatePrimary()
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>signHandle</i> is TPM_ALG_NULL
TPMT_TK_CREATION	creationTicket	ticket produced by TPM2_Create() or TPM2_CreatePrimary()

Table 80 — TPM2_CertifyCreation Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ATTEST	certifyInfo	the structure that was signed
TPMT_SIGNATURE	signature	the signature over <i>certifyInfo</i>

20.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "CertifyCreation_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	key referenced by <i>signHandle</i> is not a signing key
TPM_RC_SCHEME	<i>inScheme</i> is not compatible with <i>signHandle</i>
TPM_RC_TICKET	<i>creationTicket</i> does not match <i>objectHandle</i>
TPM_RC_VALUE	digest generated for <i>inScheme</i> is greater or has larger size than the modulus of <i>signHandle</i> , or the buffer for the result in <i>signature</i> is too small (for an RSA key); invalid commit status (for an ECC key with a split scheme).

```

4  TPM_RC
5  TPM2_CertifyCreation(
6      CertifyCreation_In  *in,           // IN: input parameter list
7      CertifyCreation_Out *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     TPM2B_NAME      name;
12     TPMT_TK_CREATION ticket;
13     TPMS_ATTEST     certifyInfo;
14
15     // Input Validation
16
17     // CertifyCreation specific input validation
18     // Get certified object name
19     name.t.size = ObjectGetName(in->objectHandle, &name.t.name);
20     // Re-compute ticket
21     TicketComputeCreation(in->creationTicket.hierarchy, &name,
22                          &in->creationHash, &ticket);
23     // Compare ticket
24     if(!Memory2BEqual(&ticket.digest.b, &in->creationTicket.digest.b))
25         return TPM_RC_TICKET + RC_CertifyCreation_creationTicket;
26
27     // Command Output
28     // Common fields
29     result = FillInAttestInfo(in->signHandle, &in->inScheme, &in->qualifyingData,
30                              &certifyInfo);
31     if(result != TPM_RC_SUCCESS)
32     {
33         if(result == TPM_RC_KEY)
34             return TPM_RC_KEY + RC_CertifyCreation_signHandle;
35         else
36             return RcSafeAddToResult(result, RC_CertifyCreation_inScheme);
37     }
38
39     // CertifyCreation specific fields
40     // Attestation type
41     certifyInfo.type = TPM_ST_ATTEST_CREATION;
42     certifyInfo.attested.creation.objectName = name;
43
44     // Copy the creationHash
45     certifyInfo.attested.creation.creationHash = in->creationHash;
46

```

```
47 // Sign attestation structure. A NULL signature will be returned if
48 // signHandle is TPM_RH_NULL. A TPM_RC_NV_UNAVAILABLE, TPM_RC_NV_RATE,
49 // TPM_RC_VALUE, TPM_RC_SCHEME or TPM_RC_ATTRIBUTES error may be returned at
50 // this point
51 result = SignAttestInfo(in->signHandle,
52                       &in->inScheme,
53                       &certifyInfo,
54                       &in->qualifyingData,
55                       &out->certifyInfo,
56                       &out->signature);
57
58 // TPM_RC_ATTRIBUTES cannot be returned here as FillInAttestInfo would already
59 // have returned TPM_RC_KEY
60 pAssert(result != TPM_RC_ATTRIBUTES);
61
62 if(result != TPM_RC_SUCCESS)
63     return result;
64
65 // orderly state should be cleared because of the reporting of clock info
66 // if signing happens
67 if(in->signHandle != TPM_RH_NULL)
68     g_clearOrderly = TRUE;
69
70 return TPM_RC_SUCCESS;
71 }
```

20.4 TPM2_Quote

20.4.1 General Description

This command is used to quote PCR values.

NOTE See 20.1 for description of how the signing scheme is selected.

The TPM will hash the list of PCR selected by *PCRselect* using the hash algorithm associated with *signHandle* (this is the hash algorithm of the signing scheme, not the *nameAlg* of *signHandle*).

The digest is computed as the hash of the concatenation of all of the digest values of the selected PCR.

The concatenation of PCR is described in Part 1, *Selecting Multiple PCR*.

20.4.2 Command and Response

Table 81 — TPM2_Quote Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Quote
TPMI_DH_OBJECT	@signHandle	handle of key that will perform signature Auth Index: 1 Auth Role: USER
TPM2B_DATA	qualifyingData	data supplied by the caller
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>signHandle</i> is TPM_ALG_NULL
TPML_PCR_SELECTION	PCRselect	PCR set to quote

Table 82 — TPM2_Quote Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ATTEST	quoted	the quoted information
TPMT_SIGNATURE	signature	the signature over <i>quoted</i>

20.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "Quote_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	<i>signHandle</i> does not reference a signing key;
TPM_RC_SCHEME	the scheme is not compatible with sign key type, or input scheme is not compatible with default scheme, or the chosen scheme is not a valid sign scheme

```

4  TPM_RC
5  TPM2_Quote(
6      Quote_In          *in,          // IN: input parameter list
7      Quote_Out         *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC              result;
11     TPMI_ALG_HASH      hashAlg;
12     TPMS_ATTEST        quoted;
13
14     // Command Output
15
16     // Filling in attest information
17     // Common fields
18     // FillInAttestInfo will return TPM_RC_SCHEME or TPM_RC_KEY
19     result = FillInAttestInfo(in->signHandle,
20                             &in->inScheme,
21                             &in->qualifyingData,
22                             &quoted);
23     if(result != TPM_RC_SUCCESS)
24     {
25         if(result == TPM_RC_KEY)
26             return TPM_RC_KEY + RC_Quote_signHandle;
27         else
28             return RcSafeAddToResult(result, RC_Quote_inScheme);
29     }
30
31     // Quote specific fields
32     // Attestation type
33     quoted.type = TPM_ST_ATTEST_QUOTE;
34
35     // Get hash algorithm in sign scheme. This hash algorithm is used to
36     // compute PCR digest. If there is no algorithm, then the PCR cannot
37     // be digested and this command returns TPM_RC_SCHEME
38     hashAlg = in->inScheme.details.any.hashAlg;
39
40     if(hashAlg == TPM_ALG_NULL)
41         return TPM_RC_SCHEME + RC_Quote_inScheme;
42
43     // Compute PCR digest
44     PCRComputeCurrentDigest(hashAlg,
45                             &in->PCRselect,
46                             &quoted.attested.quote.pcrDigest);
47
48     // Copy PCR select. "PCRselect" is modified in PCRComputeCurrentDigest
49     // function
50     quoted.attested.quote.pcrSelect = in->PCRselect;
51

```

```
52 // Sign attestation structure. A NULL signature will be returned if
53 // signHandle is TPM_RH_NULL. TPM_RC_VALUE, TPM_RC_SCHEME or TPM_RC_ATTRIBUTES
54 // error may be returned by SignAttestInfo.
55 // NOTE: TPM_RC_ATTRIBUTES means that the key is not a signing key but that
56 // was checked above and TPM_RC_KEY was returned. TPM_RC_VALUE means that the
57 // value to sign is too large but that means that the digest is too big and
58 // that can't happen.
59 result = SignAttestInfo(in->signHandle,
60                        &in->inScheme,
61                        &quoted,
62                        &in->qualifyingData,
63                        &out->quoted,
64                        &out->signature);
65 if(result != TPM_RC_SUCCESS)
66     return result;
67
68 // orderly state should be cleared because of the reporting of clock info
69 // if signing happens
70 if(in->signHandle != TPM_RH_NULL)
71     g_clearOrderly = TRUE;
72
73 return TPM_RC_SUCCESS;
74 }
```

20.5 TPM2_GetSessionAuditDigest

20.5.1 General Description

This command returns a digital signature of the audit session digest.

NOTE 1 See 20.1 for description of how the signing scheme is selected.

If *sessionHandle* is not an audit session, the TPM shall return TPM_RC_TYPE.

NOTE 2 A session does not become an audit session until the successful completion of the command in which the session is first used as an audit session.

This command requires authorization from the privacy administrator of the TPM (expressed with *endorsementAuth*) as well as authorization to use the key associated with *signHandle*.

If this command is audited, then the audit digest that is signed will not include the digest of this command because the audit digest is only updated when the command completes successfully.

This command does not cause the audit session to be closed and does not reset the digest value.

NOTE 3 The audit session digest will be reset if the *sessionHandle* is used as the audit session for the command and the *auditReset* attribute of the session is set; and this command will be the first command in the audit digest.

NOTE 4 A reason for using 'sessionHandle' in this command is so that the *continueSession* attribute may be CLEAR. This will flush the session at the end of the command.

20.5.2 Command and Response

Table 83 — TPM2_GetSessionAuditDigest Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_GetSessionAuditDigest
TPMI_RH_ENDORSEMENT	@privacyAdminHandle	handle of the privacy administrator (TPM_RH_ENDORSEMENT) Auth Index: 1 Auth Role: USER
TPMI_DH_OBJECT+	@signHandle	handle of the signing key Auth Index: 2 Auth Role: USER
TPMI_SH_HMAC	sessionHandle	handle of the audit session Auth Index: None
TPM2B_DATA	qualifyingData	user-provided qualifying data – may be zero-length
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>signHandle</i> is TPM_ALG_NULL

Table 84 — TPM2_GetSessionAuditDigest Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ATTEST	auditInfo	the audit information that was signed
TPMT_SIGNATURE	signature	the signature over <i>auditInfo</i>

20.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "GetSessionAuditDigest_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	key referenced by <i>signHandle</i> is not a signing key
TPM_RC_SCHEME	<i>inScheme</i> is incompatible with <i>signHandle</i> type; or both <i>scheme</i> and key's default scheme are empty; or <i>scheme</i> is empty while key's default scheme requires explicit input scheme (split signing); or non-empty default key scheme differs from <i>scheme</i>
TPM_RC_TYPE	<i>sessionHandle</i> does not reference an audit session
TPM_RC_VALUE	digest generated for the given <i>scheme</i> is greater than the modulus of <i>signHandle</i> (for an RSA key); invalid commit status or failed to generate r value (for an ECC key)

```

4  TPM_RC
5  TPM2_GetSessionAuditDigest(
6      GetSessionAuditDigest_In    *in,           // IN: input parameter list
7      GetSessionAuditDigest_Out   *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     SESSION        *session;
12     TPMS_ATTEST    auditInfo;
13
14     // Input Validation
15
16     // SessionAuditDigest specific input validation
17     // Get session pointer
18     session = SessionGet(in->sessionHandle);
19
20     // session must be an audit session
21     if(session->attributes.isAudit == CLEAR)
22         return TPM_RC_TYPE + RC_GetSessionAuditDigest_sessionHandle;
23
24     // Command Output
25
26     // Filling in attest information
27     // Common fields
28     result = FillInAttestInfo(in->signHandle,
29                             &in->inScheme,
30                             &in->qualifyingData,
31                             &auditInfo);
32     if(result != TPM_RC_SUCCESS)
33     {
34         if(result == TPM_RC_KEY)
35             return TPM_RC_KEY + RC_GetSessionAuditDigest_signHandle;
36         else
37             return RcSafeAddToResult(result, RC_GetSessionAuditDigest_inScheme);
38     }
39
40     // SessionAuditDigest specific fields
41     // Attestation type
42     auditInfo.type = TPM_ST_ATTEST_SESSION_AUDIT;
43
44     // Copy digest

```

```
45     auditInfo.attested.sessionAudit.sessionDigest = session->u2.auditDigest;
46
47     // Exclusive audit session
48     if(g_exclusiveAuditSession == in->sessionHandle)
49         auditInfo.attested.sessionAudit.exclusiveSession = TRUE;
50     else
51         auditInfo.attested.sessionAudit.exclusiveSession = FALSE;
52
53     // Sign attestation structure. A NULL signature will be returned if
54     // signHandle is TPM_RH_NULL. A TPM_RC_NV_UNAVAILABLE, TPM_RC_NV_RATE,
55     // TPM_RC_VALUE, TPM_RC_SCHEME or TPM_RC_ATTRIBUTES error may be returned at
56     // this point
57     result = SignAttestInfo(in->signHandle,
58                             &in->inScheme,
59                             &auditInfo,
60                             &in->qualifyingData,
61                             &out->auditInfo,
62                             &out->signature);
63     if(result != TPM_RC_SUCCESS)
64         return result;
65
66     // orderly state should be cleared because of the reporting of clock info
67     // if signing happens
68     if(in->signHandle != TPM_RH_NULL)
69         g_clearOrderly = TRUE;
70
71     return TPM_RC_SUCCESS;
72 }
```

20.6 TPM2_GetCommandAuditDigest

20.6.1 General Description

This command returns the current value of the command audit digest, a digest of the commands being audited, and the audit hash algorithm. These values are placed in an attestation structure and signed with the key referenced by *signHandle*.

NOTE 1 See 20.1 for description of how the signing scheme is selected.

When this command completes successfully, and *signHandle* is not TPM_RH_NULL, the audit digest is cleared.

NOTE 2 The way that the TPM tracks that the digest is clear is vendor-dependent. The reference implementation resets the size of the digest to zero.

If this command is being audited, then the signed digest produced by the command will not include the command. At the end of this command, the audit digest will be extended with *cpHash* and the *rpHash* of the command which would change the command audit digest signed by the next invocation of this command.

This command requires authorization from the privacy administrator of the TPM (expressed with *endorsementAuth*) as well as authorization to use the key associated with *signHandle*.

20.6.2 Command and Response

Table 85 — TPM2_GetCommandAuditDigest Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_GetCommandAuditDigest {NV}
TPMI_RH_ENDORSEMENT	@privacyHandle	handle of the privacy administrator (TPM_RH_ENDORSEMENT) Auth Index: 1 Auth Role: USER
TPMI_DH_OBJECT+	@signHandle	the handle of the signing key Auth Index: 2 Auth Role: USER
TPM2B_DATA	qualifyingData	other data to associate with this audit digest
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>signHandle</i> is TPM_ALG_NULL

Table 86 — TPM2_GetCommandAuditDigest Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_ATTEST	auditInfo	the auditInfo that was signed
TPMT_SIGNATURE	signature	the signature over <i>auditInfo</i>

20.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "GetCommandAuditDigest_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	key referenced by <i>signHandle</i> is not a signing key
TPM_RC_SCHEME	<i>inScheme</i> is incompatible with <i>signHandle</i> type; or both <i>scheme</i> and key's default scheme are empty; or <i>scheme</i> is empty while key's default scheme requires explicit input scheme (split signing); or non-empty default key scheme differs from <i>scheme</i>
TPM_RC_VALUE	digest generated for the given <i>scheme</i> is greater than the modulus of <i>signHandle</i> (for an RSA key); invalid commit status or failed to generate r value (for an ECC key)

```

4  TPM_RC
5  TPM2_GetCommandAuditDigest(
6      GetCommandAuditDigest_In    *in,           // IN: input parameter list
7      GetCommandAuditDigest_Out   *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     TPMS_ATTEST    auditInfo;
12
13     // Command Output
14
15     // Filling in attest information
16     // Common fields
17     result = FillInAttestInfo(in->signHandle,
18                             &in->inScheme,
19                             &in->qualifyingData,
20                             &auditInfo);
21     if(result != TPM_RC_SUCCESS)
22     {
23         if(result == TPM_RC_KEY)
24             return TPM_RC_KEY + RC_GetCommandAuditDigest_signHandle;
25         else
26             return RcSafeAddToResult(result, RC_GetCommandAuditDigest_inScheme);
27     }
28
29     // CommandAuditDigest specific fields
30     // Attestation type
31     auditInfo.type = TPM_ST_ATTEST_COMMAND_AUDIT;
32
33     // Copy audit hash algorithm
34     auditInfo.attested.commandAudit.digestAlg = gp.auditHashAlg;
35
36     // Copy counter value
37     auditInfo.attested.commandAudit.auditCounter = gp.auditCounter;
38
39     // Copy command audit log
40     auditInfo.attested.commandAudit.auditDigest = gr.commandAuditDigest;
41     CommandAuditGetDigest(&auditInfo.attested.commandAudit.commandDigest);
42
43     // Sign attestation structure. A NULL signature will be returned if
44     // signHandle is TPM_RH_NULL. A TPM_RC_NV_UNAVAILABLE, TPM_RC_NV_RATE,
45     // TPM_RC_VALUE, TPM_RC_SCHEME or TPM_RC_ATTRIBUTES error may be returned at
46     // this point

```

```
47     result = SignAttestInfo(in->signHandle,
48                           &in->inScheme,
49                           &auditInfo,
50                           &in->qualifyingData,
51                           &out->auditInfo,
52                           &out->signature);
53
54     if(result != TPM_RC_SUCCESS)
55         return result;
56
57     // Internal Data Update
58
59     if(in->signHandle != TPM_RH_NULL)
60     {
61         // Reset log
62         gr.commandAuditDigest.t.size = 0;
63
64         // orderly state should be cleared because of the update in
65         // commandAuditDigest, as well as the reporting of clock info
66         g_clearOrderly = TRUE;
67     }
68
69     return TPM_RC_SUCCESS;
70 }
```

20.7 TPM2_GetTime

20.7.1 General Description

This command returns the current values of *Time* and *Clock*.

NOTE 1 See 20.1 for description of how the signing scheme is selected.

The values of *Clock*, *resetCount* and *restartCount* appear in two places in *timeInfo*: once in `TPMS_ATTEST.clockInfo` and again in `TPMS_ATTEST.attested.time.clockInfo`. The firmware version number also appears in two places (`TPMS_ATTEST.firmwareVersion` and `TPMS_ATTEST.attested.time.firmwareVersion`). If *signHandle* is in the endorsement or platform hierarchies, both copies of the data will be the same. However, if *signHandle* is in the storage hierarchy or is `TPM_RH_NULL`, the values in `TPMS_ATTEST.clockInfo` and `TPMS_ATTEST.firmwareVersion` are obfuscated but the values in `TPM_ATTEST.attested.time` are not.

NOTE 2 The purpose of this duplication is to allow an entity who is trusted by the privacy Administrator to correlate the obfuscated values with the clear-text values.

20.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "GetTime_fp.h"

```

Error Returns	Meaning
TPM_RC_KEY	key referenced by <i>signHandle</i> is not a signing key
TPM_RC_SCHEME	<i>inScheme</i> is incompatible with <i>signHandle</i> type; or both <i>scheme</i> and key's default scheme are empty; or <i>scheme</i> is empty while key's default scheme requires explicit input scheme (split signing); or non-empty default key scheme differs from <i>scheme</i>
TPM_RC_VALUE	digest generated for the given <i>scheme</i> is greater than the modulus of <i>signHandle</i> (for an RSA key); invalid commit status or failed to generate r value (for an ECC key)

```

4  TPM_RC
5  TPM2_GetTime (
6      GetTime_In      *in,           // IN: input parameter list
7      GetTime_Out     *out          // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     TPMS_ATTEST     timeInfo;
12
13     // Command Output
14
15     // Filling in attest information
16     // Common fields
17     result = FillInAttestInfo(in->signHandle,
18                             &in->inScheme,
19                             &in->qualifyingData,
20                             &timeInfo);
21     if(result != TPM_RC_SUCCESS)
22     {
23         if(result == TPM_RC_KEY)
24             return TPM_RC_KEY + RC_GetTime_signHandle;
25         else
26             return RcSafeAddToResult(result, RC_GetTime_inScheme);
27     }
28
29     // GetClock specific fields
30     // Attestation type
31     timeInfo.type = TPM_ST_ATTEST_TIME;
32
33     // current clock in plain text
34     timeInfo.attested.time.time.time = g_time;
35     TimeFillInfo(&timeInfo.attested.time.time.clockInfo);
36
37     // Firmware version in plain text
38     timeInfo.attested.time.firmwareVersion
39         = ((UINT64) gp.firmwareV1) << 32;
40     timeInfo.attested.time.firmwareVersion += gp.firmwareV2;
41
42     // Sign attestation structure. A NULL signature will be returned if
43     // signHandle is TPM_RH_NULL. A TPM_RC_NV_UNAVAILABLE, TPM_RC_NV_RATE,
44     // TPM_RC_VALUE, TPM_RC_SCHEME or TPM_RC_ATTRIBUTES error may be returned at
45     // this point
46     result = SignAttestInfo(in->signHandle,

```

```
47         &in->inScheme,  
48         &timeInfo,  
49         &in->qualifyingData,  
50         &out->timeInfo,  
51         &out->signature);  
52     if(result != TPM_RC_SUCCESS)  
53         return result;  
54  
55     // orderly state should be cleared because of the reporting of clock info  
56     // if signing happens  
57     if(in->signHandle != TPM_RH_NULL)  
58         g_clearOrderly = TRUE;  
59  
60     return TPM_RC_SUCCESS;  
61 }
```

21 Ephemeral EC Keys

21.1 Introduction

The TPM generates keys that have different lifetimes. TPM keys in a hierarchy can be persistent for as long as the seed of the hierarchy is unchanged and these keys may be used multiple times. Other TPM-generated keys are only useful for a single operation. Some of these single-use keys are used in the command in which they are created. Examples of this use are TPM2_Duplicate() where an ephemeral key is created for a single pass key exchange with another TPM. However, there are other cases, such as anonymous attestation, where the protocol requires two passes where the public part of the ephemeral key is used outside of the TPM before the final command "consumes" the ephemeral key.

For these uses, TPM2_Commit() or TPM2_EC_Ephemeral() may be used to have the TPM create an ephemeral EC key and return the public part of the key for external use. Then in a subsequent command, the caller provides a reference to the ephemeral key so that the TPM can retrieve or recreate the associated private key.

When an ephemeral EC key is created, it is assigned a number and that number is returned to the caller as the identifier for the key. This number is not a handle. A handle is assigned to a key that may be context saved but these ephemeral EC keys may not be saved and do not have a full key context. When a subsequent command uses the ephemeral key, the caller provides the number of the ephemeral key. The TPM uses that number to either look up or recompute the associated private key. After the key is used, the TPM records the fact that the key has been used so that it cannot be used again.

As mentioned, the TPM can keep each assigned private ephemeral key in memory until it is used. However, this could consume a large amount of memory. To limit the memory size, the TPM is allowed to restrict the number of pending private keys – keys that have been allocated but not used.

NOTE The minimum number of ephemeral keys is determined by a platform specific specification

To further reduce the memory requirements for the ephemeral private keys, the TPM is allowed to use pseudo-random values for the ephemeral keys. Instead of keeping the full value of the key in memory, the TPM can use a counter as input to a KDF. Incrementing the counter will cause the TPM to generate a new pseudo-random value.

Using the counter to generate pseudo-random private ephemeral keys greatly simplifies tracking of key usage. When a counter value is used to create a key, a bit in an array may be set to indicate that the key use is pending. When the ephemeral key is consumed, the bit is cleared. This prevents the key from being used more than once.

Since the TPM is allowed to restrict the number of pending ephemeral keys, the array size can be limited. For example, a 128 bit array would allow 128 keys to be "pending".

The management of the array is described in greater detail in the *Split Operations* clause in Annex C of part 1.

21.2 TPM2_Commit

21.2.1 General Description

TPM2_Commit() performs the first part of an ECC anonymous signing operation. The TPM will perform the point multiplications on the provided points and return intermediate signing values. The *signHandle* parameter shall refer to an ECC key with the sign attribute (TPM_RC_ATTRIBUTES) using an anonymous signing scheme (TPM_RC_SCHEME).

For this command, *p1*, *s2* and *y2* are optional parameters. If *s2* is an Empty Buffer, then the TPM shall return TPM_RC_SIZE if *y2* is not an Empty Buffer. If *p1*, *s2*, and *y2* are all Empty Buffers, the TPM shall return TPM_RC_NO_RESULT.

In the algorithm below, the following additional values are used in addition to the command parameters:

$H_{nameAlg}$	hash function using the <i>nameAlg</i> of the key associated with <i>signHandle</i>
p	field modulus of the curve associated with <i>signHandle</i>
n	order of the curve associated with <i>signHandle</i>
d_s	private key associated with <i>signHandle</i>
c	counter that increments each time a TPM2_Commit() is successfully completed
$A[i]$	array of bits used to indicate when a value of c has been used in a signing operation; values of i are 0 to $2n-1$
k	nonce that is set to a random value on each TPM Reset; nonce size is twice the security strength of any ECDSA key supported by the TPM.

The algorithm is:

- set K , L , and E to be Empty Buffers.
- if $s2$ is not an Empty Buffer, compute $x2 := H_{nameAlg}(s2) \bmod p$, else skip to step (e)
- if $(x2, y2)$ is not a point on the curve of *signHandle*, return TPM_RC_ECC_POINT
- set $K := [d_s](x2, y2)$
- generate or derive r (see the "Commit Random Value" clause in Part 1)
- set $r := r \bmod n$

NOTE 1 $nLen$ is the number of bits in n

- if $p1$ is an Empty Buffer, skip to step i)
- if $(p1)$ is not a point on the curve of *signHandle*, return TPM_RC_ECC_POINT
- set $E := [r](p1)$
- if K is not an Empty Buffer, set $L := [r](x2, y2)$
- if K , L , or E is the point at infinity, return TPM_RC_NO_RESULT
- set *counter* := *commitCount*
- set *commitCount* := *commitCount* + 1

NOTE 2 Depending on the method of generating *r*, it may be necessary to update the tracking array here.

n) output *K, L, E* and *counter*

NOTE 3 Depending on the input parameters *K* and *L* may be Empty Buffers or *E* may be an Empty Buffer

21.2.2 Command and Response

Table 89 — TPM2_Commit Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	paramSize	
TPM_CC	commandCode	TPM_CC_Commit
TPMI_DH_OBJECT	@signHandle	handle of the key that will be used in the signing operation Auth Index: 1 Auth Role: USER
TPM2B_ECC_POINT	P1	a point (M) on the curve used by <i>signHandle</i>
TPM2B_SENSITIVE_DATA	s2	octet array used to derive x-coordinate of a base point
TPM2B_ECC_PARAMETER	y2	y coordinate of the point associated with s2

Table 90 — TPM2_Commit Response

Type	Name	Description
TPM_ST	tag	see 8
UINT32	paramSize	
TPM_RC	responseCode	
TPM2B_ECC_POINT	K	ECC point $K := [d_s](x2, y2)$
TPM2B_ECC_POINT	L	ECC point $L := [r](x2, y2)$
TPM2B_ECC_POINT	E	ECC point $E := [r]P1$
UINT16	counter	least-significant 16 bits of <i>commitCount</i>

21.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Commit_fp.h"
3  #ifdef TPM_ALG_ECC

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>keyHandle</i> references a restricted key that is not a signing key
TPM_RC_ECC_POINT	either <i>P1</i> or the point derived from <i>s2</i> is not on the curve of <i>keyHandle</i>
TPM_RC_HASH	invalid name algorithm in <i>keyHandle</i>
TPM_RC_KEY	<i>keyHandle</i> does not reference an ECC key
TPM_RC_SCHEME	<i>keyHandle</i> references a restricted signing key that does not use an anonymous scheme
TPM_RC_NO_RESULT	<i>K</i> , <i>L</i> or <i>E</i> was a point at infinity; or failed to generate <i>r</i> value
TPM_RC_SIZE	<i>s2</i> is empty but <i>y2</i> is not or <i>s2</i> provided but <i>y2</i> is not

```

4  TPM_RC
5  TPM2_Commit(
6      Commit_In      *in,           // IN: input parameter list
7      Commit_Out     *out          // OUT: output parameter list
8  )
9  {
10     OBJECT                *eccKey;
11     TPMS_ECC_POINT        P2;
12     TPMS_ECC_POINT        *pP2 = NULL;
13     TPMS_ECC_POINT        *pP1 = NULL;
14     TPM2B_ECC_PARAMETER    r;
15     TPM2B                  *p;
16     TPM_RC                 result;
17     UINT16                 hashResults;
18
19     // Input Validation
20
21     eccKey = ObjectGet(in->signHandle);
22
23     // Input key must be an ECC key
24     if(eccKey->publicArea.type != TPM_ALG_ECC)
25         return TPM_RC_KEY + RC_Commit_signHandle;
26
27     // if the key is restricted, it must be a signing key using an anonymous scheme
28     if(eccKey->publicArea.objectAttributes.restricted == SET)
29     {
30         if(eccKey->publicArea.objectAttributes.sign != SET)
31             return TPM_RC_ATTRIBUTES + RC_Commit_signHandle;
32         if(!CryptIsSchemeAnonymous(
33             eccKey->publicArea.parameters.eccDetail.scheme.scheme))
34             return TPM_RC_SCHEME + RC_Commit_signHandle;
35     }
36     else
37     {
38         // if not restricted, s2, and y2 must be an Empty Buffer
39         if(in->s2.t.size)
40             return TPM_RC_SIZE + RC_Commit_s2;
41     }
42     // Make sure that both parts of P2 are present if either is present
43     if((in->s2.t.size == 0) != (in->y2.t.size == 0))

```

```

44     return TPM_RC_SIZE + RC_Commit_y2;
45
46     // Get prime modulus for the curve. This is needed later but getting this now
47     // allows confirmation that the curve exists
48     p = (TPM2B *)CryptEccGetParameter('p',
49                                     eccKey->publicArea.parameters.eccDetail.curveID);
50
51     // if no p, then the curve ID is bad
52     // NOTE: This should never occur if the input unmarshaling code is working
53     // correctly
54     if(p == NULL)
55         return TPM_RC_KEY + RC_Commit_signHandle;
56
57     // Get the random value that will be used in the point multiplications
58     // Note: this does not commit the count.
59     if(!CryptGenerateR(&r,
60                       NULL,
61                       eccKey->publicArea.parameters.eccDetail.curveID,
62                       &eccKey->name))
63         return TPM_RC_NO_RESULT;
64
65     // Set up P2 if s2 and Y2 are provided
66     if(in->s2.t.size != 0)
67     {
68         pP2 = &P2;
69
70         // copy y2 for P2
71         MemoryCopy2B(&P2.y.b, &in->y2.b, sizeof(P2.y.t.buffer));
72         // Compute x2 HnameAlg(s2) mod p
73
74         // do the hash operation on s2 with the size of curve 'p'
75         hashResults = CryptHashBlock(eccKey->publicArea.nameAlg,
76                                     in->s2.t.size,
77                                     in->s2.t.buffer,
78                                     p->size,
79                                     P2.x.t.buffer);
80
81         // If there were error returns in the hash routine, indicate a problem
82         // with the hash in
83         if(hashResults == 0)
84             return TPM_RC_HASH + RC_Commit_signHandle;
85
86         // set the size of the X value to the size of the hash
87         P2.x.t.size = hashResults;
88
89         // set p2.x = hash(s2) mod p
90         if(CryptDivide(&P2.x.b, p, NULL, &P2.x.b) != TPM_RC_SUCCESS)
91             return TPM_RC_NO_RESULT;
92
93         if(!CryptEccIsPointOnCurve(eccKey->publicArea.parameters.eccDetail.curveID,
94                                   pP2))
95             return TPM_RC_ECC_POINT + RC_Commit_s2;
96
97         if(eccKey->attributes.publicOnly == SET)
98             return TPM_RC_KEY + RC_Commit_signHandle;
99     }
100 }
101 else
102
103     // If there is a P1, make sure that it is on the curve
104     // NOTE: an "empty" point has two UINT16 values which are the size values
105     // for each of the coordinates.
106     if(in->P1.t.size > 4)
107     {

```

```
108     pP1 = &in->P1.t.point;
109     if(!CryptEccIsPointOnCurve(eccKey->publicArea.parameters.eccDetail.curveID,
110                               pP1))
111         return TPM_RC_ECC_POINT + RC_Commit_P1;
112 }
113
114 // Pass the parameters to CryptCommit.
115 // The work is not done inline because it does several point multiplies
116 // with the same curve. There is significant optimization by not
117 // having to reload the curve parameters multiple times.
118 result = CryptCommitCompute(&out->K.t.point,
119                             &out->L.t.point,
120                             &out->E.t.point,
121                             eccKey->publicArea.parameters.eccDetail.curveID,
122                             pP1,
123                             pP2,
124                             &eccKey->sensitive.sensitive.ecc,
125                             &r);
126 if(result != TPM_RC_SUCCESS)
127     return result;
128
129 out->K.t.size = TPMS_ECC_POINT_Marshal(&out->K.t.point, NULL, NULL);
130 out->L.t.size = TPMS_ECC_POINT_Marshal(&out->L.t.point, NULL, NULL);
131 out->E.t.size = TPMS_ECC_POINT_Marshal(&out->E.t.point, NULL, NULL);
132
133 // The commit computation was successful so complete the commit by setting
134 // the bit
135 out->counter = CryptCommit();
136
137 return TPM_RC_SUCCESS;
138 }
139 #endif
```

21.3 TPM2_EC_Ephemeral

21.3.1 General Description

TPM2_EC_Ephemeral() creates an ephemeral key for use in a two-phase key exchange protocol.

The TPM will use the commit mechanism to assign an ephemeral key r and compute a public point $Q := [r]G$ where G is the generator point associated with *curveID*.

21.3.2 Command and Response

Table 91 — TPM2_EC_Ephemeral Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	paramSize	
TPM_CC	commandCode	TPM_CC_EC_Ephemeral
TPMI_ECC_CURVE	curveID	The curve for the computed ephemeral point

Table 92 — TPM2_EC_Ephemeral Response

Type	Name	Description
TPM_ST	tag	see 8
UINT32	paramSize	
TPM_RC	responseCode	
TPM2B_ECC_POINT	Q	ephemeral public key $Q := [r]G$
UINT16	counter	least-significant 16 bits of <i>commitCount</i>

21.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "EC_Ephemeral_fp.h"
3  #ifdef TPM_ALG_ECC

```

Error Returns	Meaning
none	...

```

4  TPM_RC
5  TPM2_EC_Ephemeral(
6      EC_Ephemeral_In      *in,          // IN: input parameter list
7      EC_Ephemeral_Out     *out         // OUT: output parameter list
8  )
9  {
10     TPM2B_ECC_PARAMETER    r;
11
12     // Get the random value that will be used in the point multiplications
13     // Note: this does not commit the count.
14     if(!CryptGenerateR(&r,
15                        NULL,
16                        in->curveID,
17                        NULL))
18         return TPM_RC_NO_RESULT;
19
20     CryptEccPointMultiply(&out->Q.t.point, in->curveID, &r, NULL);
21
22     // commit the count value
23     out->counter = CryptCommit();
24
25     return TPM_RC_SUCCESS;
26 }
27 #endif

```


22 Signing and Signature Verification

22.1 TPM2_VerifySignature

22.1.1 General Description

This command uses loaded keys to validate a signature on a message with the message digest passed to the TPM.

If the signature check succeeds, then the TPM will produce a TPMT_TK_VERIFIED. Otherwise, the TPM shall return TPM_RC_SIGNATURE.

NOTE 1 A valid ticket may be used in subsequent commands to provide proof to the TPM that the TPM has validated the signature over the message using the key referenced by *keyHandle*.

If *keyHandle* references an asymmetric key, only the public portion of the key needs to be loaded. If *keyHandle* references a symmetric key, both the public and private portions need to be loaded.

NOTE 2 The sensitive area of the symmetric object is required to allow verification of the symmetric signature (the HMAC).

22.1.2 Command and Response

Table 93 — TPM2_VerifySignature Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_VerifySignature
TPMI_DH_OBJECT	keyHandle	handle of public key that will be used in the validation Auth Index: None
TPM2B_DIGEST	digest	digest of the signed message
TPMT_SIGNATURE	signature	signature to be tested

Table 94 — TPM2_VerifySignature Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMT_TK_VERIFIED	validation	

22.1.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "VerifySignature_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>keyHandle</i> does not reference a signing key
TPM_RC_SIGNATURE	signature is not genuine
TPM_RC_SCHEME	CryptVerifySignature()
TPM_RC_HANDLE	the input handle is not a sign key with private portion loaded

```

3  TPM_RC
4  TPM2_VerifySignature(
5      VerifySignature_In      *in,                // IN: input parameter list
6      VerifySignature_Out     *out               // OUT: output parameter list
7  )
8  {
9      TPM_RC                  result;
10     TPM2B_NAME              name;
11     OBJECT                  *signObject;
12     TPMT_RH_HIERARCHY       hierarchy;
13
14     // Input Validation
15
16     // Get sign object pointer
17     signObject = ObjectGet(in->keyHandle);
18
19     // The object to validate the signature must be a signing key.
20     if(signObject->publicArea.objectAttributes.sign != SET)
21         return TPM_RC_ATTRIBUTES + RC_VerifySignature_keyHandle;
22
23     // If it doesn't have a sensitive area loaded
24     // then it can't be a keyed hash signing key
25     if( signObject->attributes.publicOnly == SET
26         && signObject->publicArea.type == TPM_ALG_KEYEDHASH
27         )
28         return TPM_RC_HANDLE + RC_VerifySignature_keyHandle;
29
30     // Validate Signature. A TPM_RC_BINDING, TPM_RC_SCHEME or TPM_RC_SIGNATURE
31     // error may be returned by CryptCVerifySignatrue()
32     result = CryptVerifySignature(in->keyHandle, &in->digest, &in->signature);
33     if(result != TPM_RC_SUCCESS)
34         return RcSafeAddToResult(result, RC_VerifySignature_signature);
35
36     // Command Output
37
38     hierarchy = ObjectGetHierarchy(in->keyHandle);
39     if( hierarchy == TPM_RH_NULL
40         || signObject->publicArea.nameAlg == TPM_ALG_NULL)
41     {
42         // produce empty ticket if hierarchy is TPM_RH_NULL or nameAlg is
43         // TPM_ALG_NULL
44         out->validation.tag = TPM_ST_VERIFIED;
45         out->validation.hierarchy = TPM_RH_NULL;
46         out->validation.digest.t.size = 0;
47     }
48     else
49     {

```

```
50     // Get object name that verifies the signature
51     name.t.size = ObjectGetName(in->keyHandle, &name.t.name);
52     // Compute ticket
53     TicketComputeVerified(hierarchy, &in->digest, &name, &out->validation);
54 }
55
56 return TPM_RC_SUCCESS;
57 }
```

22.2 TPM2_Sign

22.2.1 General Description

This command causes the TPM to sign an externally provided hash with the specified asymmetric signing key.

NOTE 1 Symmetric “signing” is done with an HMAC.

If *keyHandle* references a restricted signing key, then *validation* shall be provided indicating that the TPM performed the hash of the data and *validation* shall indicate that hashed data did not start with TPM_GENERATED_VALUE.

NOTE 2 If the hashed data did start with TPM_GENERATED_VALUE, then the validation will be a NULL ticket.

If the scheme of *keyHandle* is not TPM_ALG_NULL, then *inScheme* shall either be the same scheme as *keyHandle* or TPM_ALG_NULL.

If the scheme of *keyHandle* is TPM_ALG_NULL, the TPM will sign using *inScheme*; otherwise, it will sign using the scheme of *keyHandle*.

NOTE 3 When the signing scheme requires a hash algorithm, the hash is defined in the qualifying data of the scheme.

If *inScheme* is not a valid signing scheme for the type of *keyHandle* (or TPM_ALG_NULL), then the TPM shall return TPM_RC_SCHEME.

If the scheme of *keyHandle* is an anonymous *scheme*, then *inScheme* shall have the same scheme algorithm as *keyHandle* and *inScheme* will contain a counter value that will be used in the signing process.

As long as it is no larger than allowed, the *digest* parameter is not required to have any specific size but the signature operation may fail if *digest* is too large for the selected scheme.

If the *validation* parameter is not the Empty Buffer, then it will be checked even if the key referenced by *keyHandle* is not a restricted signing key.

22.2.2 Command and Response

Table 95 — TPM2_Sign Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Sign
TPMI_DH_OBJECT	@keyHandle	Handle of key that will perform signing Auth Index: 1 Auth Role: USER
TPM2B_DIGEST	digest	digest to be signed
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>keyHandle</i> is TPM_ALG_NULL
TPMT_TK_HASHCHECK	validation	proof that digest was created by the TPM If <i>keyHandle</i> is not a restricted signing key, then this may be a NULL Ticket with <i>tag</i> = TPM_ST_CHECKHASH.

Table 96 — TPM2_Sign Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMT_SIGNATURE	signature	the signature

22.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Sign_fp.h"
3  #include "Attest_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	key referenced by <i>keyHandle</i> is not a signing key
TPM_RC_BINDING	The public and private portions of the key are not properly bound.
TPM_RC_SCHEME	<i>inScheme</i> is not compatible with <i>keyHandle</i> ; both <i>inScheme</i> and key's default scheme are empty; or <i>inScheme</i> is empty while key's default scheme requires explicit input scheme (split signing); or non-empty default key scheme differs from <i>inScheme</i>
TPM_RC_TICKET	<i>validation</i> is not a valid ticket
TPM_RC_VALUE	the value to sign is larger than allowed for the type of <i>keyHandle</i>

```

4  TPM_RC
5  TPM2_Sign(
6      Sign_In          *in,          // IN: input parameter list
7      Sign_Out         *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC          result;
11     TPMT_TK_HASHCHECK ticket;
12     OBJECT          *signKey;
13
14     // Input Validation
15     // Get sign key pointer
16     signKey = ObjectGet(in->keyHandle);
17
18     // If validation is provided, or the key is restricted, check the ticket
19     if( in->validation.digest.t.size != 0
20         || signKey->publicArea.objectAttributes.restricted == SET)
21     {
22         // Compute and compare ticket
23         TicketComputeHashCheck(in->validation.hierarchy, &in->digest, &ticket);
24
25         if(!Memory2BEqual(&in->validation.digest.b, &ticket.digest.b))
26             return TPM_RC_TICKET + RC_Sign_validation;
27     }
28
29     // Command Output
30
31     // pick a scheme for sign. If the input sign scheme is not compatible with
32     // the default scheme, return an error.
33     result = CryptSelectSignScheme(in->keyHandle, &in->inScheme);
34     if(result != TPM_RC_SUCCESS)
35     {
36         if(result == TPM_RC_KEY)
37             return TPM_RC_KEY + RC_Sign_keyHandle;
38         else
39             return RcSafeAddToResult(result, RC_Sign_inScheme);
40     }
41
42     // Sign the hash. A TPM_RC_VALUE, TPM_RC_SCHEME, or TPM_RC_ATTRIBUTES
43     // error may be returned at this point
44     result = CryptSign(in->keyHandle, &in->inScheme, &in->digest, &out->signature);

```

```
45  
46     return result;  
47 }
```


23 Command Audit

23.1 Introduction

If a command has been selected for command audit, the command audit status will be updated when that command completes successfully. The digest is updated as:

$$commandAuditDigest_{new} := H_{auditAlg}(commandAuditDigest_{old} || cpHash || rpHash) \quad (5)$$

where

$H_{auditAlg}$	hash function using the algorithm of the audit sequence
$commandAuditDigest$	accumulated digest
$cpHash$	the command parameter hash
$rpHash$	the response parameter hash

TPM2_Shutdown() cannot be audited but TPM2_Startup() can be audited. If the $cpHash$ of the TPM2_Startup() is TPM_SU_STATE, that would indicate that a TPM2_Shutdown() had been successfully executed.

TPM2_SetCommandCodeAuditStatus() is always audited.

If the TPM is in Failure mode, command audit is not functional.

23.2 TPM2_SetCommandCodeAuditStatus

23.2.1 General Description

This command may be used by the Privacy Administrator or platform to change the audit status of a command or to set the hash algorithm used for the audit digest, but not both at the same time.

If the *auditAlg* parameter is a supported hash algorithm and not the same as the current algorithm, then the TPM will check both *setList* and *clearList* are empty (zero length). If so, then the algorithm is changed, and the audit digest is cleared. If *auditAlg* is TPM_ALG_NULL or the same as the current algorithm, then the algorithm and audit digest are unchanged and the *setList* and *clearList* will be processed.

NOTE 1 Because the audit digest is cleared, the audit counter will increment the next time that an audited command is executed.

Use of TPM2_SetCommandCodeAuditStatus() to change the list of audited commands is an audited event. If TPM_CC_SetCommandCodeAuditStatus is in *clearList*, it is ignored.

NOTE 2 Use of this command to change the audit hash algorithm is not audited and the digest is reset when the command completes. The change in the audit hash algorithm is the evidence that this command was used to change the algorithm.

The commands in *setList* indicate the commands that to be added to the list of audited commands and the commands in *clearList* indicate the commands that will no longer be audited. It is not an error if a command in *setList* is already audited or is not implemented. It is not an error if a command in *clearList* is not currently being audited or is not implemented.

If a command code is in both *setList* and *clearList*, then it will not be audited (that is, *setList* shall be processed first).

23.2.2 Command and Response

Table 97 — TPM2_SetCommandCodeAuditStatus Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_PROVISION	commandCode @auth	TPM_CC_SetCommandCodeAuditStatus {NV} TPM_RH_ENDORSEMENT or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPMI_ALG_HASH+	auditAlg	hash algorithm for the audit digest; if TPM_ALG_NULL, then the hash is not changed
TPML_CC	setList	list of commands that will be added to those that will be audited
TPML_CC	clearList	list of commands that will no longer be audited

Table 98 — TPM2_SetCommandCodeAuditStatus Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

23.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "SetCommandCodeAuditStatus_fp.h"
3  TPM_RC
4  TPM2_SetCommandCodeAuditStatus(
5      SetCommandCodeAuditStatus_In  *in          // IN: input parameter list
6  )
7  {
8      TPM_RC      result;
9      UINT32     i;
10     BOOL       changed = FALSE;
11
12
13     // The command needs NV update. Check if NV is available.
14     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
15     // this point
16     result = NvIsAvailable();
17     if(result != TPM_RC_SUCCESS)
18         return result;
19
20     // Internal Data Update
21
22     // Update hash algorithm
23     if( in->auditAlg != TPM_ALG_NULL
24         && in->auditAlg != gp.auditHashAlg)
25     {
26         // Can't change the algorithm and command list at the same time
27         if(in->setList.count != 0 || in->clearList.count != 0)
28             return TPM_RC_VALUE + RC_SetCommandCodeAuditStatus_auditAlg;
29
30         // Change the hash algorithm for audit
31         gp.auditHashAlg = in->auditAlg;
32
33         // Set the digest size to a unique value that indicates that the digest
34         // algorithm has been changed. The size will be cleared to zero in the
35         // command audit processing on exit.
36         gr.commandAuditDigest.t.size = 1;
37
38         // Save the change of command audit data (this sets g_updateNV so that NV
39         // will be updagted on exit.)
40         NvWriteReserved(NV_AUDIT_HASH_ALG, &gp.auditHashAlg);
41
42     } else {
43
44         // Process set list
45         for(i = 0; i < in->setList.count; i++)
46
47             // If change is made in CommandAuditSet, set changed flag
48             if(CommandAuditSet(in->setList.commandCodes[i]))
49                 changed = TRUE;
50
51         // Process clear list
52         for(i = 0; i < in->clearList.count; i++)
53             // If change is made in CommandAuditClear, set changed flag
54             if(CommandAuditClear(in->clearList.commandCodes[i]))
55                 changed = TRUE;
56
57         // if change was made to command list, update NV
58         if(changed)
59             // this sets g_updateNV so that NV will be updagted on exit.
60             NvWriteReserved(NV_AUDIT_COMMANDS, &gp.auditComands);

```

```
61     }  
62  
63     return TPM_RC_SUCCESS;  
64 }
```

24 Integrity Collection (PCR)

24.1 Introduction

In TPM 1.2, an Event was hashed using SHA-1 and then the 20-octet digest was extended to a PCR using TPM_Extend(). This specification allows the use of multiple PCR at a given Index, each using a different hash algorithm. Rather than require that the external software generate multiple hashes of the Event with each being extended to a different PCR, the Event data may be sent to the TPM for hashing. This ensures that the resulting digests will properly reflect the algorithms chosen for the PCR even if the calling software is unable to implement the hash algorithm.

NOTE 1 There is continued support for software hashing of events with TPM2_PCR_Extend().

To support recording of an Event that is larger than the TPM input buffer, the caller may use the command sequence described in clause 1.

Change to a PCR requires authorization. The authorization may be with either an authorization value or an authorization policy. The platform-specific specifications determine which PCR may be controlled by policy. All other PCR are controlled by authorization.

If a PCR may be associated with a policy, then the algorithm ID of that policy determines whether the policy is to be applied. If the algorithm ID is not TPM_ALG_NULL, then the policy digest associated with the PCR must match the *policySession*→*policyDigest* in a policy session. If the algorithm ID is TPM_ALG_NULL, then no policy is present and the authorization requires an EmptyAuth.

If a platform-specific specification indicates that PCR are grouped, then all the PCR in the group use the same authorization policy or authorization value.

PcrUpdateCounter counter will be incremented on the successful completion of any command that modifies (Extends or resets) a PCR unless the platform-specific specification explicitly excludes the PCR from being counted.

NOTE 2 If a command causes PCR in multiple banks to change, the PCR Update Counter may be incremented either once or once for each bank.

A platform-specific specification may designate a set of PCR that are under control of the TCB. These PCR may not be modified without the proper authorization. Updates of these PCR shall not cause the PCR Update Counter to increment.

EXAMPLE Updates of the TCB PCR will not cause the PCR update counter to increment because these PCR are changed at the whim of the TCB and are not intended to represent the trust state of the platform.

24.2 TPM2_PCR_Extend

24.2.1 General Description

This command is used to cause an update to the indicated PCR. The *digests* parameter contains one or more tagged digest value identified by an algorithm ID. For each digest, the PCR associated with *pcrHandle* is Extended into the bank identified by the tag (*hashAlg*).

EXAMPLE A SHA1 digest would be Extended into the SHA1 bank and a SHA256 digest would be Extended into a SHA256 bank.

For each list entry, the TPM will check to see if *pcrNum* is implemented for that algorithm. If so, the TPM shall perform the following operation:

$$PCR.digest_{new}[pcrNum][alg] := H_{alg}(PCR.digest_{old}[pcrNum][alg] || data[alg].buffer) \quad (6)$$

where

$H_{alg}()$	hash function using the hash algorithm associated with the PCR instance
<i>PCR.digest</i>	the digest value in a PCR
<i>pcrNum</i>	the PCR numeric selector (equal to <i>pcrHandle</i> – TPM_RH_PCR0)
<i>alg</i>	the PCR algorithm selector for the digest
<i>data[alg].buffer</i>	the bank-specific data to be extended

If no digest value is specified for a bank, then the PCR in that bank are not modified.

NOTE 1 This allows consistent operation of the digests list for all of the Event recording commands.

If a digest is present and the PCR in that bank is not implemented, the digest value is not used.

NOTE 2 If the caller includes digests for algorithms that are not implemented, then the TPM will fail the call because the unmarshalling of *digests* will fail. Each of the entries in the list is a TPMT_HA which is a hash algorithm followed by a digest. If the algorithm is not implemented, unmarshalling of the *hashAlg* will fail and the TPM will return TPM_RC_HASH.

If the TPM unmarshals the *hashAlg* of a list entry and the unmarshaled value is not a hash algorithm implemented on the TPM, the TPM shall return TPM_RC_HASH.

The *pcrHandle* parameter is allowed to reference TPM_RH_NULL. If so, the input parameters are processed but no action is taken by the TPM.

NOTE 3 This command allows a list of digests so that PCR in all banks may be updated in a single command. While the semantics of this command allow multiple extends to a single PCR bank, this is not the preferred use and the limit on the number of entries in the list make this use somewhat impractical.

24.2.2 Command and Response

Table 99 — TPM2_PCR_Extend Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_Extend {NV}
TPMI_DH_PCR+	@pcrHandle	handle of the PCR Auth Handle: 1 Auth Role: USER
TPML_DIGEST_VALUES	digests	list of tagged digest values to be extended

Table 100 — TPM2_PCR_Extend Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	.

24.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PCR_Extend_fp.h"

```

Error Returns	Meaning
TPM_RC_LOCALITY	current command locality is not allowed to extend the PCR referenced by <i>pcrHandle</i>

```

3  TPM_RC
4  TPM2_PCR_Extend(
5      PCR_Extend_In    *in                // IN: input parameter list
6  )
7  {
8      TPM_RC            result;
9      UINT32            i;
10
11     // Input Validation
12
13     // NOTE: This function assumes that the unmarshaling function for 'digests' will
14     // have validated that all of the indicated hash algorithms are valid. If the
15     // hash algorithms are correct, the unmarshaling code will unmarshal a digest
16     // of the size indicated by the hash algorithm. If the overall size is not
17     // consistent, the unmarshaling code will run out of input data or have input
18     // data left over. In either case, it will cause an unmarshaling error and this
19     // function will not be called.
20
21     // For NULL handle, do nothing and return success
22     if(in->pcrHandle == TPM_RH_NULL)
23         return TPM_RC_SUCCESS;
24
25     // Check if the extend operation is allowed by the current command locality
26     if(!PCRIsExtendAllowed(in->pcrHandle))
27         return TPM_RC_LOCALITY;
28
29     // If PCR is state saved and we need to update orderlyState, check NV
30     // availability
31     if(PCRIsStateSaved(in->pcrHandle) && gp.orderlyState != SHUTDOWN_NONE)
32     {
33         result = NvIsAvailable();
34         if(result != TPM_RC_SUCCESS) return result;
35         g_clearOrderly = TRUE;
36     }
37
38     // Internal Data Update
39
40     // Iterate input digest list to extend
41     for(i = 0; i < in->digests.count; i++)
42     {
43         PCRExtend(in->pcrHandle, in->digests.digests[i].hashAlg,
44                 CryptGetHashDigestSize(in->digests.digests[i].hashAlg),
45                 (BYTE *) &in->digests.digests[i].digest);
46     }
47
48     return TPM_RC_SUCCESS;
49 }

```

24.3 TPM2_PCR_Event

24.3.1 General Description

This command is used to cause an update to the indicated PCR.

The data in *eventData* is hashed using the hash algorithm associated with each bank in which the indicated PCR has been allocated. After the data is hashed, the *digests* list is returned. If the *pcrHandle* references an implemented PCR and not TPM_ALG_NULL, *digests* list is processed as in TPM2_PCR_Extend().

A TPM shall support an *Event.size* of zero through 1,024 inclusive (*Event.size* is an octet count). An *Event.size* of zero indicates that there is no data but the indicated operations will still occur,

EXAMPLE 1 If the command implements PCR[2] in a SHA1 bank and a SHA256 bank, then an extend to PCR[2] will cause *eventData* to be hashed twice, once with SHA1 and once with SHA256. The SHA1 hash of *eventData* will be Extended to PCR[2] in the SHA1 bank and the SHA256 hash of *eventData* will be Extended to PCR[2] of the SHA256 bank.

On successful command completion, *digests* will contain the list of tagged digests of *eventData* that was computed in preparation for extending the data into the PCR. At the option of the TPM, the list may contain a digest for each bank, or it may only contain a digest for each bank in which *pcrHandle* is extant.

EXAMPLE 2 Assume a TPM that implements a SHA1 bank and a SHA256 bank and that PCR[22] is only implemented in the SHA1 bank. If *pcrHandle* references PCR[22], then *digests* may contain either a SHA1 and a SHA256 digest or just a SHA1 digest.

24.3.2 Command and Response

Table 101 — TPM2_PCR_Event Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_Event {NV}
TPMI_DH_PCR+	@pcrHandle	Handle of the PCR Auth Handle: 1 Auth Role: USER
TPM2B_EVENT	eventData	Event data in sized buffer

Table 102 — TPM2_PCR_Event Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	.
TPML_DIGEST_VALUES	digests	

24.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PCR_Event_fp.h"

```

Error Returns	Meaning
TPM_RC_LOCALITY	current command locality is not allowed to extend the PCR referenced by <i>pcrHandle</i>

```

3  TPM_RC
4  TPM2_PCR_Event(
5      PCR_Event_In    *in,                // IN: input parameter list
6      PCR_Event_Out   *out               // OUT: output parameter list
7  )
8  {
9      TPM_RC          result;
10     HASH_STATE      hashState;
11     UINT32          i;
12     UINT16          size;
13
14     // Input Validation
15
16     // If a PCR extend is required
17     if(in->pcrHandle != TPM_RH_NULL)
18     {
19         // If the PCR is not allow to extend, return error
20         if(!PCRIsExtendAllowed(in->pcrHandle))
21             return TPM_RC_LOCALITY;
22
23         // If PCR is state saved and we need to update orderlyState, check NV
24         // availability
25         if(PCRIsStateSaved(in->pcrHandle) && gp.orderlyState != SHUTDOWN_NONE)
26         {
27             result = NvIsAvailable();
28             if(result != TPM_RC_SUCCESS) return result;
29             g_clearOrderly = TRUE;
30         }
31     }
32
33     // Internal Data Update
34
35     out->digests.count = HASH_COUNT;
36
37     // Iterate supported PCR bank algorithms to extend
38     for(i = 0; i < HASH_COUNT; i++)
39     {
40         TPM_ALG_ID hash = CryptGetHashAlgByIndex(i);
41         out->digests.digests[i].hashAlg = hash;
42         size = CryptStartHash(hash, &hashState);
43         CryptUpdateDigest2B(&hashState, &in->eventData.b);
44         CryptCompleteHash(&hashState, size,
45             (BYTE *) &out->digests.digests[i].digest);
46         if(in->pcrHandle != TPM_RH_NULL)
47             PCRExtend(in->pcrHandle, hash, size,
48                 (BYTE *) &out->digests.digests[i].digest);
49     }
50
51     return TPM_RC_SUCCESS;
52 }

```

24.4 TPM2_PCR_Read

24.4.1 General Description

This command returns the values of all PCR specified in *pcrSelect*.

The TPM will process the list of TPMS_PCR_SELECTION in *pcrSelectionIn* in order. Within each TPMS_PCR_SELECTION, the TPM will process the bits in the *pcrSelect* array in ascending PCR order (see Part 2 for definition of the PCR order). If a bit is SET, and the indicated PCR is present, then the TPM will add the digest of the PCR to the list of values to be returned in *pcrValue*.

The TPM will continue processing bits until all have been processed or until *pcrValues* would be too large to fit into the output buffer if additional values were added.

The returned *pcrSelectionOut* will have a bit SET in its *pcrSelect* structures for each value present in *pcrValues*.

The current value of the PCR Update Counter is returned in *pcrUpdateCounter*.

The returned list may be empty if none of the selected PCR are implemented.

NOTE If no PCR are returned from a bank, the selector for the bank will be present in *pcrSelectionOut*.

No authorization is required to read a PCR and any implemented PCR may be read from any locality.

24.4.2 Command and Response

Table 103 — TPM2_PCR_Read Command

Type	Name	Description
TPML_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_Read
TPML_PCR_SELECTION	pcrSelectionIn	The selection of PCR to read

Table 104 — TPM2_PCR_Read Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
UINT32	pcrUpdateCounter	the current value of the PCR update counter
TPML_PCR_SELECTION	pcrSelectionOut	the PCR in the returned list
TPML_DIGEST	pcrValues	the contents of the PCR indicated in <i>pcrSelect</i> as tagged digests

24.4.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PCR_Read_fp.h"
3  TPM_RC
4  TPM2_PCR_Read(
5      PCR_Read_In      *in,           // IN: input parameter list
6      PCR_Read_Out     *out          // OUT: output parameter list
7  )
8  {
9  // Command Output
10
11     // Call PCR read function.  input pcrSelectionIn parameter could be changed
12     // to reflect the actual PCR being returned
13     PCRRead(&in->pcrSelectionIn, &out->pcrValues, &out->pcrUpdateCounter);
14
15     out->pcrSelectionOut = in->pcrSelectionIn;
16
17     return TPM_RC_SUCCESS;
18 }
```

24.5 TPM2_PCR_Allocate

24.5.1 General Description

This command is used to set the desired PCR allocation of PCR and algorithms. This command requires *platformAuth*.

The TPM will evaluate the request and, if sufficient memory is available for the requested allocation, the TPM will store the allocation request for use during the next TPM2_Startup(TPM_SU_CLEAR) operation. The PCR allocation in place when this command is executed will be retained until the next TPM2_Startup(TPM_SU_CLEAR).

If no allocation is specified for a bank, then no PCR will be allocated to that bank. If a bank is listed more than once, then the last selection in the *pcrAllocation* list is the one that the TPM will attempt to allocate.

This command shall not allocate more PCR in any bank than there are PCR attribute definitions. The PCR attribute definitions indicate how a PCR is to be managed – if it is resettable, the locality for update, etc. In the response to this command, the TPM returns the maximum number of PCR allowed for any bank.

If the command is properly authorized, it will return SUCCESS even though the request fails. This is to allow the TPM to return information about the size needed for the requested allocation and the size available. If the *sizeNeeded* parameter in the return is less than or equal to the *sizeAvailable* parameter, then the *allocationSuccess* parameter will be YES.

After this command, TPM2_Shutdown() is only allowed to have a *startupType* equal to TPM_SU_CLEAR.

NOTE Even if this command does not cause the PCR allocation to change, the TPM cannot have its state saved. This is done in order to simplify the implementation. There is no need to optimize this command as it is not expected to be used more than once in the lifetime of the TPM (it can be used any number of times but there is no justification for optimization).

24.5.2 Command and Response

Table 105 — TPM2_PCR_Allocate Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_Allocate {NV}
TPMI_RH_PLATFORM	@authHandle	TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPML_PCR_SELECTION	pcrAllocation	the requested allocation

Table 106 — TPM2_PCR_Allocate Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMI_YES_NO	allocationSuccess	YES if the allocation succeeded
UINT32	maxPCR	maximum number of PCR that may be in a bank
UINT32	sizeNeeded	number of octets required to satisfy the request
UINT32	sizeAvailable	Number of octets available. Computed before the allocation.

24.5.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PCR_Allocate_fp.h"
3  TPM_RC
4  TPM2_PCR_Allocate(
5      PCR_Allocate_In    *in,           // IN: input parameter list
6      PCR_Allocate_Out   *out          // OUT: output parameter list
7  )
8  {
9      TPM_RC    result;
10
11     // The command needs NV update. Check if NV is available.
12     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
13     // this point.
14     // Note: These codes are not listed in the return values above because it is
15     // an implementation choice to check in this routine rather than in a common
16     // function that is called before these actions are called. These return values
17     // are described in the Response Code section of Part 3.
18     result = NvIsAvailable();
19     if(result != TPM_RC_SUCCESS)
20         return result;
21
22     // Command Output
23
24     // Call PCR Allocation function.
25     out->allocationSuccess = PCRAAllocate(&in->pcrAllocation, &out->maxPCR,
26                                         &out->sizeNeeded, &out->sizeAvailable);
27
28     // if re-configuration succeeds, set the flag to indicate PCR configuration is
29     // going to be changed in next boot
30     if(out->allocationSuccess == YES)
31         g_pcrReConfig = TRUE;
32
33     return TPM_RC_SUCCESS;
34 }
```

24.6 TPM2_PCR_SetAuthPolicy

24.6.1 General Description

This command is used to associate a policy with a PCR or group of PCR. The policy determines the conditions under which a PCR may be extended or reset.

A policy may only be associated with a PCR that has been defined by a platform-specific specification as allowing a policy. If the TPM implementation does not allow a policy for *pcrNum*, the TPM shall return TPM_RC_VALUE.

A platform-specific specification may group PCR so that they share a common policy. In such case, a *pcrNum* that selects any of the PCR in the group will change the policy for all PCR in the group.

The policy setting is persistent and may only be changed by TPM2_PCR_SetAuthPolicy() or by TPM2_ChangePPS().

Before this command is first executed on a TPM or after TPM2_ChangePPS(), the access control on the PCR will be set to the default value defined in the platform-specific specification.

NOTE 1 It is expected that the typical default will be with the policy hash set to TPM_ALG_NULL and an Empty Buffer for the *authPolicy* value. This will allow an *EmptyAuth* to be used as the authorization value.

If the size of the data buffer in *authPolicy* is not the size of a digest produced by *hashAlg*, the TPM shall return TPM_RC_SIZE.

NOTE 2 If *hashAlg* is TPM_ALG_NULL, then the size is required to be zero.

This command requires platformAuth/platformPolicy.

NOTE 3 If the PCR is in multiple policy sets, the policy will be changed in only one set. The set that is changed will be implementation dependent.

24.6.2 Command and Response

Table 107 — TPM2_PCR_SetAuthPolicy Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_SetAuthPolicy {NV}
TPMI_RH_PLATFORM	@authHandle	TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPM2B_DIGEST	authPolicy	the desired <i>authPolicy</i>
TPMI_ALG_HASH+	policyDigest	the digest of the policy
TPMI_DH_PCR	pcrNum	the PCR for which the policy is to be set

Table 108 — TPM2_PCR_SetAuthPolicy Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

24.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PCR_SetAuthPolicy_fp.h"

```

Error Returns	Meaning
TPM_RC_SIZE	size of <i>authPolicy</i> is not the size of a digest produced by <i>policyDigest</i>
TPM_RC_VALUE	PCR referenced by <i>pcrNum</i> is not a member of a PCR policy group

```

3  TPM_RC
4  TPM2_PCR_SetAuthPolicy(
5      PCR_SetAuthPolicy_In *in           // IN: input parameter list
6  )
7  {
8      UINT32      groupIndex;
9
10     TPM_RC      result;
11
12     // The command needs NV update. Check if NV is available.
13     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
14     // this point
15     result = NvIsAvailable();
16     if(result != TPM_RC_SUCCESS) return result;
17
18     // Input Validation:
19
20     // Check the authPolicy consistent with hash algorithm
21     if(in->authPolicy.t.size != CryptGetHashDigestSize(in->policyDigest))
22         return TPM_RC_SIZE + RC_PCR_SetAuthPolicy_authPolicy;
23
24     // If PCR does not belong to a policy group, return TPM_RC_VALUE
25     if(!PCRBelongsPolicyGroup(in->pcrNum, &groupIndex))
26         return TPM_RC_VALUE + RC_PCR_SetAuthPolicy_pcrNum;
27
28     // Internal Data Update
29
30     // Set PCR policy
31     gp.pcrPolicies.hashAlg[groupIndex] = in->policyDigest;
32     gp.pcrPolicies.policy[groupIndex] = in->authPolicy;
33
34     // Save new policy to NV
35     NvWriteReserved(NV_PCR_POLICIES, &gp.pcrPolicies);
36
37     return TPM_RC_SUCCESS;
38 }

```

24.7 TPM2_PCR_SetAuthValue

24.7.1 General Description

This command changes the *authValue* of a PCR or group of PCR.

An *authValue* may only be associated with a PCR that has been defined by a platform-specific specification as allowing an authorization value. If the TPM implementation does not allow an authorization for *pcrNum*, the TPM shall return TPM_RC_VALUE. A platform-specific specification may group PCR so that they share a common authorization value. In such case, a *pcrNum* that selects any of the PCR in the group will change the *authValue* value for all PCR in the group.

The authorization setting is set to EmptyAuth on each STARTUP(CLEAR) or by TPM2_Clear(). The authorization setting is preserved by SHUTDOWN(STATE).

24.7.2 Command and Response

Table 109 — TPM2_PCR_SetAuthValue Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_SetAuthValue
TPMI_DH_PCR	@pcrHandle	handle for a PCR that may have an authorization value set Auth Index: 1 Auth Role: USER
TPM2B_DIGEST	auth	the desired authorization value

Table 110 — TPM2_PCR_SetAuthValue Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

24.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PCR_SetAuthValue_fp.h"

```

Error Returns	Meaning
TPM_RC_VALUE	PCR referenced by <i>pcrHandle</i> is not a member of a PCR authorization group

```

3  TPM_RC
4  TPM2_PCR_SetAuthValue(
5      PCR_SetAuthValue_In    *in           // IN: input parameter list
6  )
7  {
8      UINT32    groupIndex;
9      TPM_RC    result;
10
11     // Input Validation:
12
13     // If PCR does not belong to an auth group, return TPM_RC_VALUE
14     if(!PCRBelongsAuthGroup(in->pcrHandle, &groupIndex))
15         return TPM_RC_VALUE;
16
17     // The command may cause the orderlyState to be cleared due to the update of
18     // state clear data. If this is the case, Check if NV is available.
19     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
20     // this point
21     if(gp.orderlyState != SHUTDOWN_NONE)
22     {
23         result = NvIsAvailable();
24         if(result != TPM_RC_SUCCESS) return result;
25         g_clearOrderly = TRUE;
26     }
27
28     // Internal Data Update
29
30     // Set PCR authValue
31     gc.pcrAuthValues.auth[groupIndex] = in->auth;
32
33     return TPM_RC_SUCCESS;
34 }

```


24.8 TPM2_PCR_Reset

24.8.1 General Description

If the attribute of a PCR allows the PCR to be reset and proper authorization is provided, then this command may be used to set the PCR to zero. The attributes of the PCR may restrict the locality that can perform the reset operation.

NOTE 1 The definition of TPMI_DH_PCR in Part 2 indicates that if *pcrHandle* is out of the allowed range for PCR, then the appropriate return value is TPM_RC_VALUE.

If *pcrHandle* references a PCR that cannot be reset, the TPM shall return TPM_RC_LOCALITY.

NOTE 2 TPM_RC_LOCALITY is returned because the reset attributes are defined on a per-locality basis.

24.8.2 Command and Response

Table 111 — TPM2_PCR_Reset Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PCR_Reset {NV}
TPMI_DH_PCR	@pcrHandle	the PCR to reset Auth Index: 1 Auth Role: USER

Table 112 — TPM2_PCR_Reset Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

24.8.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PCR_Reset_fp.h"

```

Error Returns	Meaning
TPM_RC_LOCALITY	current command locality is not allowed to reset the PCR referenced by <i>pcrHandle</i>

```

3  TPM_RC
4  TPM2_PCR_Reset(
5      PCR_Reset_In    *in                // IN: input parameter list
6  )
7  {
8      TPM_RC    result;
9
10     // Input Validation
11
12     // Check if the reset operation is allowed by the current command locality
13     if(!PCRIsResetAllowed(in->pcrHandle))
14         return TPM_RC_LOCALITY;
15
16     // If PCR is state saved and we need to update orderlyState, check NV
17     // availability
18     if(PCRIsStateSaved(in->pcrHandle) && gp.orderlyState != SHUTDOWN_NONE)
19     {
20         result = NvIsAvailable();
21         if(result != TPM_RC_SUCCESS)
22             return result;
23         g_clearOrderly = TRUE;
24     }
25
26     // Internal Data Update
27
28     // Reset selected PCR in all banks to 0
29     PCRSetValue(in->pcrHandle, 0);
30
31     // Indicate that the PCR changed so that pcrCounter will be incremented if
32     // necessary.
33     PCRChanged(in->pcrHandle);
34
35     return TPM_RC_SUCCESS;
36 }

```

24.9 `_TPM_Hash_Start`

24.9.1 Description

This indication from the TPM interface indicates the start of a dynamic Core Root of Trust for Measurement (D-CRTM) measurement sequence. On receipt of this indication, the TPM will initialize an Event sequence context.

If no object memory is available for creation of the sequence context, the TPM will flush the context of an object so that creation of the Event sequence context will always succeed.

A platform-specific specification may allow this indication before `TPM2_Startup()`.

NOTE If this indication occurs after `TPM2_Startup()`, it is the responsibility of software to ensure that an object context slot is available or to deal with the consequences of having the TPM select an arbitrary object to be flushed. If this indication occurs before `TPM2_Startup()` then all context slots are available.

24.9.2 Detailed Actions

```
1 #include "InternalRoutines.h"
```

This function is called to process a `_TPM_Hash_Start()` indication.

```
2 void
3 _TPM_Hash_Start(void)
4 {
5     TPM_RC          result;
6     TPMT_DH_OBJECT handle;
7
8     // If a DRTM sequence object exists, terminate it.
9     if(g_DRTMHandle != TPM_DH_UNASSIGNED)
10        ObjectTerminateEvent();
11
12    // Create an event sequence object and store the handle in global
13    // g_DRTMHandle. A TPM_RC_OBJECT_MEMORY error may be returned at this point
14    // The null value for the 'auth' parameter will cause the sequence structure to
15    // be allocated without being set as present. This keeps the sequence from
16    // being left behind if the sequence is terminated early.
17    result = ObjectCreateEventSequence(NULL, &g_DRTMHandle);
18
19    // If a free slot was not available, then free up a slot.
20    if(result != TPM_RC_SUCCESS)
21    {
22        // An implementation does not need to have a fixed relationship between
23        // slot numbers and handle numbers. To handle the general case, scan for
24        // a handle that is assigned an free it for the DRTM sequence.
25        // In the reference implementation, the relationship between handles and
26        // slots is fixed. So, if the call to ObjectCreateEvenSequence()
27        // failed indicating that all slots are occupied, then the first handle we
28        // are going to check (TRANSIENT_FIRST) will be occupied. It will be freed
29        // so that it can be assigned for use as the DRTM sequence object.
30        for(handle = TRANSIENT_FIRST; handle < TRANSIENT_LAST; handle++)
31        {
32            // try to flush the first object
33            if(ObjectIsPresent(handle))
34                break;
35        }
36        // If the first call to find a slot fails but none of the slots is occupied
37        // then there's a big problem
38        pAssert(handle < TRANSIENT_LAST);
39
40        // Free the slot
41        ObjectFlush(handle);
42
43        // Try to create an event sequence object again. This time, we must
44        // succeed.
45        result = ObjectCreateEventSequence(NULL, &g_DRTMHandle);
46        pAssert(result == TPM_RC_SUCCESS);
47    }
48
49    return;
50 }
```

24.10 **_TPM_Hash_Data**

24.10.1 **Description**

This indication from the TPM interface indicates arrival of one or more octets of data that are to be included in the Core Root of Trust for Measurement (CRTM) sequence context created by the `_TPM_Hash_Start` indication. The context holds data for each hash algorithm for each PCR bank implemented on the TPM.

If no DRTM Event Sequence context exists, this indication is discarded and no other action is performed.

24.10.2 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Platform.h"

```

This function is called to process a `_TPM_Hash_Data()` indication.

```

3  void
4  _TPM_Hash_Data(
5      UINT32      dataSize,          // IN: size of data to be extend
6      BYTE        *data             // IN: data buffer
7  )
8  {
9      UINT32      i;
10     HASH_OBJECT *hashObject;
11
12     // If there is no DRTM sequence object, then _TPM_Hash_Start
13     // was not called so this function returns without doing
14     // anything.
15     if(g_DRTMHandle == TPM_RH_UNASSIGNED)
16         return;
17
18     hashObject = (HASH_OBJECT *)ObjectGet(g_DRTMHandle);
19     pAssert(hashObject->attributes.eventSeq);
20
21     // For each of the implemented hash algorithms, update the digest with the
22     // data provided. NOTE: the implementation could be done such that the TPM
23     // only computes the hash for the banks that contain the DRTM PCR.
24     for(i = 0; i < HASH_COUNT; i++)
25     {
26         // Update sequence object
27         CryptUpdateDigest(&hashObject->state.hashState[i], dataSize, data);
28     }
29
30     return;
31 }

```

24.11 _TPM_Hash_End

24.11.1 Description

This indication from the TPM interface indicates the end of the CRTM measurement. This indication is discarded and no other action performed if the TPM does not contain a CRTM Event sequence context.

NOTE A CRTM Event Sequence context is created by `_TPM_Hash_Start()`.

If the CRTM Event sequence occurs after `TPM2_Startup()`, the TPM will set all of the PCR designated in the platform-specific specifications as resettable by this event to the value indicated in the platform specific specification, and increment *restartCount*. The TPM will then Extend the Event Sequence digest/digests into the designated, DRTM PCR.

$$\text{PCR}[\text{DRTM}][\text{hashAlg}] := \mathbf{H}_{\text{hashAlg}}(\text{initial_value} || \mathbf{H}_{\text{hashAlg}}(\text{hash_data})) \quad (7)$$

where

<i>DRTM</i>	index for CRTM PCR designated by a platform-specific specification
<i>hashAlg</i>	hash algorithm associated with a bank of PCR
<i>initial_value</i>	initialization value specified in the platform-specific specification (should be 0...0)
<i>hash_data</i>	all the octets of data received in <code>_TPM_Hash_Data</code> indications

A `_TPM_Hash_End` indication that occurs after `TPM2_Startup()` will increment *pcrUpdateCounter* unless a platform-specific specification excludes modifications of PCR[DRTM] from causing an increment.

A platform-specific specification may allow an H-CRTM Event Sequence before `TPM2_Startup()`. If so, `_TPM_Hash_End` will complete the digest, initialize PCR[0] with a digest-size value of 4, and then extend the H-CRTM Event Sequence data into PCR[0].

$$\text{PCR}[0][\text{hashAlg}] := \mathbf{H}_{\text{hashAlg}}(0\dots04 || \mathbf{H}_{\text{hashAlg}}(\text{hash_data})) \quad (8)$$

NOTE The entire sequence of `_TPM_Hash_Start`, `_TPM_Hash_Data`, and `_TPM_Hash_End` are required to complete before `TPM2_Startup()` or the sequence will have no effect on the TPM.

24.11.2 Detailed Actions

```
1 #include "InternalRoutines.h"
```

This function is called to process a `_TPM_Hash_End()` indication.

```
2 void
3 _TPM_Hash_End(void)
4 {
5
6     UINT32          i;
7     TPM2B_DIGEST    digest;
8     HASH_OBJECT     *hashObject;
9     TPMI_DH_PCR     pcrHandle;
10
11     // If the DRTM handle is not being used, then either _TPM_Hash_Start has not
12     // been called, _TPM_Hash_End was previously called, or some other command
13     // was executed and the sequence was aborted.
14     if(g_DRTMHandle == TPM_RH_UNASSIGNED)
15         return;
16
17     // Get DRTM sequence object
18     hashObject = (HASH_OBJECT *)ObjectGet(g_DRTMHandle);
19
20
21     // Is this _TPM_Hash_End after Startup or before
22     if(TPMIsStarted())
23     {
24         // After
25
26         // Reset the DRTM PCR
27         PCRResetDynamics();
28
29         // Extend the DRTM PCR.
30         pcrHandle = PCR_FIRST + DRTM_PCR;
31
32         // DRTM sequence increments restartCount
33         gr.restartCount++;
34     }
35     else
36     {
37         pcrHandle = PCR_FIRST + HCRIM_PCR;
38     }
39
40
41     // Complete hash and extend PCR, or if this is an HCRIM, complete
42     // the hash and write the PCR
43     for(i = 0; i < HASH_COUNT; i++)
44     {
45         TPMI_ALG_HASH    hash = CryptGetHashAlgByIndex(i);
46
47         // Complete hash
48         digest.t.size = CryptGetHashDigestSize(hash);
49         CryptCompleteHash2B(&hashObject->state.hashState[i], &digest.b);
50
51         // If this is DRTM, extend to zeroed PCR
52         // If this is H-DRTM, copy to HCRM PCR
53         if(TPMIsStarted())
54             // Extend PCR
55             PCRExtend(pcrHandle, hash, digest.t.size, digest.t.buffer);
56         else
57             PcrWrite(pcrHandle, hash, &digest);
```

```
58     }
59
60     // Flush sequence object.
61     ObjectFlush(g_DRTMHandle);
62
63     g_DRTMHandle = TPM_RH_UNASSIGNED;
64
65     g_DrtmPreStartup = TRUE;
66
67     return;
68 }
```

25 Enhanced Authorization (EA) Commands

25.1 Introduction

The commands in this clause 1 are used for policy evaluation. When successful, each command will update the *policySession*→*policyDigest* in a policy session context in order to establish that the authorizations required to use an object have been provided. Many of the commands will also modify other parts of a policy context so that the caller may constrain the scope of the authorization that is provided.

NOTE 1 Many of the terms used in this clause are described in detail in Part 1 and are not redefined in this clause.

The *policySession* parameter of the command is the handle of the policy session context to be modified by the command.

If the *policySession* parameter indicates a trial policy session, then the *policySession*→*policyDigest* will be updated and the indicated validations are not performed.

NOTE 2 A policy session is a trial policy by `TPM2_StartAuthSession(sessionType = TPM_SE_TRIAL)`.

NOTE 3 Unless there is an unmarshaling error in the parameters of the command, these commands will return `TPM_RC_SUCCESS` when *policySession* references a trial session.

NOTE 4 Policy context other than the *policySession*→*policyDigest* may be updated for a trial policy but it is not required.

25.2 Signed Authorization Actions

25.2.1 Introduction

The TPM2_PolicySigned, TPM_PolicySecret, and TPM2_PolicyTicket commands use many of the same functions. This clause consolidates those functions to simplify the document and to ensure uniformity of the operations.

25.2.2 Policy Parameter Checks

These parameter checks will be performed when indicated in the description of each of the commands:

- a) *nonceTPM* – If this parameter is not the Empty Buffer, and it does not match *policySession→nonceTPM*, then the TPM shall return TPM_RC_VALUE.
- b) *expiration* – If this parameter is not zero, then its absolute value is compared to the time in seconds since the *policySession→nonceTPM* was generated. If more time has passed than indicated in *expiration*, the TPM shall return TPM_RC_EXPIRED. If *nonceTPM* is the Empty buffer, and *expiration* is non-zero, then the TPM shall return TPM_RC_EXPIRED.
- c) *timeout* – This parameter is compared to the current TPM time. If *policySession→timeout* is in the past, then the TPM shall return TPM_RC_EXPIRED.

NOTE 1 The *expiration* parameter is present in the TPM2_PolicySigned and TPM2_PolicySecret command and *timeout* is the analogous parameter in the TPM2_PolicyTicket command.

- d) *cpHashA* – If this parameter is not an Empty Buffer

NOTE 2 *CpHashA* is the hash of the command to be executed using this policy session in the authorization. The algorithm used to compute this hash is required to be the algorithm of the policy session.

- 1) the TPM shall return TPM_RC_CPHASH if *policySession→cpHash* does not have its default value or the contents of *policySession→cpHash* are not the same as *cpHashA*; or

NOTE 3 *CpHash* is the expected *cpHash* value held in the policy session context.

- 2) the TPM shall return TPM_RC_SIZE if *cpHashA* is not the same size as *policySession→policyDigest*.

NOTE 4 *PolicySession→policyDigest* is the size of the digest produced by the hash algorithm used to compute *policyDigest*.

25.2.3 PolicyDigest Update Function (PolicyUpdate())

This is the update process for *policySession*→*policyDigest* used by TPM2_PolicySigned(), TPM2_PolicySecret(), TPM2_PolicyTicket(), and TPM2_PolicyAuthorize(). The function prototype for the update function is:

$$\mathbf{PolicyUpdate}(commandCode, arg2, arg3) \quad (9)$$

where

arg2 a TPM2B_NAME

arg3 a TPM2B

These parameters are used to update *policySession*→*policyDigest* by

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || commandCode || arg2.name) \quad (10)$$

followed by

$$policyDigest_{new+1} := H_{policyAlg}(policyDigest_{new} || arg3.buffer) \quad (11)$$

where

$H_{policyAlg}()$ the hash algorithm chosen when the policy session was started

NOTE 1 If *arg3* is a TPM2B_NAME, then *arg3.buffer* will actually be an *arg3.name*.

NOTE 2 The *arg2.size* and *arg3.size* fields are not included in the hashes.

NOTE 3 **PolicyUpdate()** uses two hashes because *arg2* and *arg3* are variable-sized and the concatenation of *arg2* and *arg3* in a single hash could produce the same digest even though *arg2* and *arg3* are different. Processing of the arguments separately in different Extend operation insures that the digest produced by **PolicyUpdate()** will be different if *arg2* and *arg3* are different.

25.2.4 Policy Context Updates

When a policy command modifies some part of the policy session context other than the *policySession*→*policyDigest*, the following rules apply.

- ***cpHash*** – this parameter may only be changed if it contains its initialization value (an Empty String). If *cpHash* is not the Empty String when a policy command attempts to update it, the TPM will return an error (TPM_RC_CPHASH) if the current and update values are not the same.
- ***timeOut*** – this parameter may only be changed to a smaller value. If a command attempts to update this value with a larger value (longer into the future), the TPM will discard the update value. This is not an error condition.
- ***commandCode*** – once set by a policy command, this value may not be change except by TPM2_PolicyRestart(). If a policy command tries to change this to a different value, an error is returned (TPM_RC_POLICY_CC).
- ***pcrUpdateCounter*** – this parameter is updated by TPM2_PolicyPCR(). This value may only be set once during a policy. Each time TPM2_PolicyPCR() executes, it checks to see if *policySession*→*pcrUpdateCounter* has its default state indicating that this is the first TPM2_PolicyPCR(). If it has its default value, then *policySession*→*pcrUpdateCounter* is set to the current value of *pcrUpdateCounter*. If *policySession*→*pcrUpdateCounter* does not have its default value and its value is not the same as *pcrUpdateCounter*, the TPM shall return TPM_RC_PCR_CHANGED.

NOTE If this parameter and *pcrUpdateCounter* are not the same, it indicates that PCR have changed since checked by the previous TPM2_PolicyPCR(). Since they have changed, the previous PCR validation is no longer valid.

- ***commandLocality*** – this parameter is the logical AND of all enabled localities. All localities are enabled for a policy when the policy session is created. TPM2_PolicyLocalities() selectively disables localities. Once use of a policy for a locality has been disabled, it cannot be enabled except by TPM2_PolicyRestart().
- ***isPPRequired*** – once SET, this parameter may only be CLEARED by TPM2_PolicyRestart().
- ***isAuthValueNeeded*** – once SET, this parameter may only be CLEARED by TPM2_PolicyPassword() or TPM2_PolicyRestart().
- ***isPasswordNeeded*** – once SET, this parameter may only be CLEARED by TPM2_PolicyAuthValue() or TPM2_PolicyRestart(),

NOTE Both TPM2_PolicyAuthValue() and TPM2_PolicyPassword() change *policySession*→*policyDigest* in the same way. The different commands simply indicate to the TPM the format used for the *authValue* (HMAC or clear text). Both commands could be in the same policy. The final instance of these commands determines the format.

25.2.5 Policy Ticket Creation

If for TPM2_PolicySigned() or TPM2_PolicySecret() the caller specified a negative value for *expiration*, and the policy update succeeds, then the TPM will return a ticket that includes a value indicating when the authorization expires. The required computation for the digest in the authorization ticket is:

$$\mathbf{HMAC}(proof, H_{policyAlg}(ticketType || timeout || cpHashA || policyRef || authObject \rightarrow Name)) \quad (12)$$

where

proof secret associated with the storage primary seed (SPS) of the TPM

$H_{policyAlg}$ hash function using the hash algorithm associated with the policy session

ticketType either TPM_ST_AUTH_SECRET or TPM_ST_AUTH_SIGNED, used to indicate type of the ticket

NOTE 1 If the ticket is produced by TPM2_PolicySecret() then *ticketType* is TPM_ST_AUTH_SECRET and if produced by TPM2_PolicySigned() then *ticketType* is TPM_ST_AUTH_SIGNED.

timeout implementation-specific representation of the expiration time of the ticket; required to be the implementation equivalent of $policySession \rightarrow startTime$ plus the absolute value of *expiration*

NOTE 2 *Timeout* is not the same as *expiration*. The *expiration* value in the *aHash* is a relative time, using the creation time of the authorization session (TPM2_StartAuthSession()) as its reference. The *timeout* parameter is an absolute time, using TPM *Clock* as the reference.

cpHashA the command parameter digest for the command being authorized; computed using the hash algorithm of the policy session

policyRef the commands that use this function have a *policyRef* parameter and the value of that parameter is used here

authObject \rightarrow Name Name associated with the *authObject* parameter

25.3 TPM2_PolicySigned

25.3.1 General Description

This command includes a signed authorization in a policy. The command ties the policy to a signing key by including the Name of the signing key in the *policyDigest*

If *policySession* is a trial session, the TPM will not check the signature and will update *policySession*→*policyDigest* as described in 25.2.3 as if a properly signed authorization was received; but no ticket will be produced.

If *policySession* is not a trial session, the TPM will validate *auth* and only perform the update if it is a valid signature over the fields of the command.

The authorizing object will sign a digest of the authorization qualifiers: *nonceTPM*, *expiration*, *cpHashA*, and *policyRef*. The digest is computed as:

$$aHash := H_{authAlg}(nonceTPM || expiration || cpHashA || policyRef) \quad (13)$$

where

$H_{authAlg}()$ the hash associated with the auth parameter of this command

NOTE 1 Each signature and key combination indicates the scheme and each scheme has an associated hash.

nonceTPM the nonceTPM parameter from the TPM2_StartAuthSession() response. If the authorization is not limited to this session, the size of this value is zero.

expiration time limit on authorization set by authorizing object. This 32-bit value is set to zero if the expiration time is not being set.

cpHashA digest of the command parameters for the command being approved using the hash algorithm of the policy session. Set to an EmptyAuth if the authorization is not limited to a specific command.

NOTE 2 This is not the *cpHash* of this TPM2_PolicySigned() command.

policyRef an opaque value determined by the authorizing entity. Set to the Empty Buffer if no value is present.

EXAMPLE The computation for an *aHash* if there are no restrictions is:

$$aHash := H_{authAlg}(00\ 00\ 00\ 00_{16})$$

which is the hash of an expiration time of zero.

The *aHash* is signed by the private key associated with key. The signature and signing parameters are combined to create the *auth* parameter.

The TPM will perform the parameter checks listed in 25.2.2

If the parameter checks succeed, the TPM will construct a test digest (*tHash*) over the provided parameters using the same formulation a shown in equation (13) above.

If *tHash* does not match the digest of the signed *aHash*, then the authorization fails and the TPM shall return TPM_RC_POLICY_FAIL and make no change to *policySession*→*policyDigest*.

When all validations have succeeded, *policySession*→*policyDigest* is updated by **PolicyUpdate()** (see 25.2.3).

PolicyUpdate(TPM_CC_PolicySigned, *authObject*→*Name*, *policyRef*) (14)

If the *cpHashA* parameter is not an Empty Buffer, it is copied to *policySession*→*cpHash*.

The TPM will optionally produce a ticket as described in 25.2.5.

Authorization to use *authObject* is not required.

25.3.2 Command and Response

Table 113 — TPM2_PolicySigned Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicySigned
TPMI_DH_OBJECT	authObject	handle for a public key that will validate the signature Auth Index: None
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_NONCE	nonceTPM	the policy nonce for the session If the nonce is not included in the authorization qualification, this field is the Empty Buffer.
TPM2B_DIGEST	cpHashA	digest of the command parameters to which this authorization is limited This is not the <i>cpHash</i> for this command but the <i>cpHash</i> for the command to which this policy session will be applied. If it is not limited, the parameter will be the Empty Buffer.
TPM2B_NONCE	policyRef	a reference to a policy relating to the authorization – may be the Empty Buffer Size is limited to be no larger than the nonce size supported on the TPM.
INT32	expiration	time when authorization will expire, measured in seconds from the time that <i>nonceTPM</i> was generated If <i>expiration</i> is zero, a NULL Ticket is returned.
TPMT_SIGNATURE	auth	signed authorization (not optional)

Table 114 — TPM2_PolicySigned Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_TIMEOUT	timeout	implementation-specific time value, used to indicate to the TPM when the ticket expires NOTE If <i>policyTicket</i> is a NULL Ticket, then this shall be the Empty Buffer.
TPMT_TK_AUTH	policyTicket	produced if the command succeeds and <i>expiration</i> in the command was non-zero; this ticket will use the TPM2B_ST_AUTH_SIGNED structure tag

25.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Policy_spt_fp.h"
3  #include "PolicySigned_fp.h"

```

Error Returns	Meaning
TPM_RC_CPHASH	<i>cpHash</i> was previously set to a different value
TPM_RC_EXPIRED	<i>expiration</i> indicates a time in the past or <i>expiration</i> is non-zero but no <i>nonceTPM</i> is present
TPM_RC_HANDLE	<i>authObject</i> need to have sensitive portion loaded
TPM_RC_KEY	<i>authObject</i> is not a signing scheme
TPM_RC_NONCE	<i>nonceTPM</i> is not the nonce associated with the <i>policySession</i>
TPM_RC_SCHEME	the signing scheme of <i>auth</i> is not supported by the TPM
TPM_RC_SIGNATURE	the signature is not genuine
TPM_RC_SIZE	input <i>cpHash</i> has wrong size
TPM_RC_VALUE	input <i>policyID</i> or <i>expiration</i> does not match the internal data in policy session

```

4  TPM_RC
5  TPM2_PolicySigned(
6      PolicySigned_In      *in,          // IN: input parameter list
7      PolicySigned_Out     *out         // OUT: output parameter list
8  )
9  {
10     TPM_RC                result = TPM_RC_SUCCESS;
11     SESSION               *session;
12     OBJECT                *authObject;
13     TPM2B_NAME            entityName;
14     TPM2B_DIGEST          authHash;
15     HASH_STATE            hashState;
16     UINT32                expiration = (in->expiration < 0)
17                                 ? -(in->expiration) : in->expiration;
18     UINT64                authTimeout = 0;
19
20     // Input Validation
21
22     // Set up local pointers
23     session = SessionGet(in->policySession); // the session structure
24     authObject = ObjectGet(in->authObject); // pointer for the object
25                                             // providing authorization
26                                             // signature
27
28     // Only do input validation if this is not a trial policy session
29     if(session->attributes.isTrialPolicy == CLEAR)
30     {
31         if(expiration != 0)
32             authTimeout = expiration * 1000 + session->startTime;
33
34         result = PolicyParameterChecks(session, authTimeout,
35                                     &in->cpHashA, &in->nonceTPM,
36                                     RC_PolicySigned_nonceTPM,
37                                     RC_PolicySigned_cpHashA,
38                                     RC_PolicySigned_expiration);
39         if(result != TPM_RC_SUCCESS)

```

```

40         return result;
41
42     // Re-compute the digest being signed
43     /*(See part 3 specification)
44     // The digest is computed as:
45     //     aHash := hash ( nonceTPM | expiration | cpHashA | policyRef)
46     // where:
47     //     hash()     the hash associated with the signed auth
48     //     nonceTPM   the nonceTPM value from the TPM2_StartAuthSession .
49     //               response If the authorization is not limited to this
50     //               session, the size of this value is zero.
51     //     expiration time limit on authorization set by authorizing object.
52     //               This 32-bit value is set to zero if the expiration
53     //               time is not being set.
54     //     cpHashA    hash of the command parameters for the command being
55     //               approved using the hash algorithm of the PSAP session.
56     //               Set to NULLauth if the authorization is not limited
57     //               to a specific command.
58     //     policyRef  hash of an opaque value determined by the authorizing
59     //               object. Set to the NULLdigest if no hash is present.
60     */
61     // Start hash
62     authHash.t.size = CryptStartHash(CryptGetSignHashAlg(&in->auth),
63                                     &hashState);
64
65     // add nonceTPM
66     CryptUpdateDigest2B(&hashState, &in->nonceTPM.b);
67
68     // add expiration
69     CryptUpdateDigestInt(&hashState, sizeof(UINT32), (BYTE*) &in->expiration);
70
71     // add cpHashA
72     CryptUpdateDigest2B(&hashState, &in->cpHashA.b);
73
74     // add policyRef
75     CryptUpdateDigest2B(&hashState, &in->policyRef.b);
76
77     // Complete digest
78     CryptCompleteHash2B(&hashState, &authHash.b);
79
80     // Validate Signature. A TPM_RC_SCHEME, TPM_RC_TYPE or TPM_RC_SIGNATURE
81     // error may be returned at this point
82     result = CryptVerifySignature(in->authObject, &authHash, &in->auth);
83     if(result != TPM_RC_SUCCESS)
84         return RcSafeAddToResult(result, RC_PolicySigned_auth);
85 }
86 // Internal Data Update
87 // Need the Name of the signing entity
88 entityName.t.size = EntityGetName(in->authObject, &entityName.t.name);
89
90 // Update policy with input policyRef and name of auth key
91 // These values are updated even if the session is a trial session
92 PolicyContextUpdate(TPM_CC_PolicySigned, &entityName, &in->policyRef,
93                   &in->cpHashA, authTimeout, session);
94
95 // Command Output
96
97 // Create ticket and timeout buffer if in->expiration < 0 and this is not
98 // a trial session.
99 // NOTE: PolicyParameterChecks() makes sure that nonceTPM is present
100 // when expiration is non-zero.
101 if( in->expiration < 0
102     && session->attributes.isTrialPolicy == CLEAR
103 )

```

```
104     {
105         // Generate timeout buffer. The format of output timeout buffer is
106         // TPM-specific.
107         // Note: can't do a direct copy because the output buffer is a byte
108         // array and it may not be aligned to accept a 64-bit value. The method
109         // used has the side-effect of making the returned value a big-endian,
110         // 64-bit value that is byte aligned.
111         out->timeout.t.size = sizeof(UINT64);
112         UINT64_TO_BYTE_ARRAY(authTimeout, out->timeout.t.buffer);
113
114         // Compute policy ticket
115         TicketComputeAuth(TPM_ST_AUTH_SIGNED, EntityGetHierarchy(in->authObject),
116                          authTimeout, &in->cpHashA, &in->policyRef, &entityName,
117                          &out->policyTicket);
118     }
119     else
120     {
121         // Generate a null ticket.
122         // timeout buffer is null
123         out->timeout.t.size = 0;
124
125         // auth ticket is null
126         out->policyTicket.tag = TPM_ST_AUTH_SIGNED;
127         out->policyTicket.hierarchy = TPM_RH_NULL;
128         out->policyTicket.digest.t.size = 0;
129     }
130
131     return TPM_RC_SUCCESS;
132 }
```

25.4 TPM2_PolicySecret

25.4.1 General Description

This command includes a secret-based authorization to a policy. The caller proves knowledge of the secret value using an authorization session using the *authValue* associated with *authHandle*. A password session, an HMAC session, or a policy session containing `TPM2_PolicyAuthValue()` or `TPM2_PolicyPassword()` will satisfy this requirement.

“If a policy session is used and use of the *authValue* of *authHandle* is not required, the TPM will return `TPM_RC_MODE`.”

The secret is the *authValue* of *authObject*, which may be any TPM entity with a handle and an associated *authValue*. This includes the reserved handles (for example, Platform, Storage, and Endorsement), NV Indexes, and loaded objects.

NOTE 1 The authorization value for a hierarchy cannot be used in this command if the hierarchy is disabled.

If the authorization check fails, then the normal dictionary attack logic is invoked.

If the authorization provided by the authorization session is valid, the command parameters are checked as described in 25.2.2.

When all validations have succeeded, *policySession*→*policyDigest* is updated by `PolicyUpdate()` (see 25.2.3).

PolicyUpdate(`TPM_CC_PolicySecret`, *authObject*→*Name*, *policyRef*) (15)

If the *cpHashA* command parameter is not an Empty Buffer, it is copied to *cpHash* in the session context.

The TPM will optionally produce a ticket as described in 25.2.5.

If the session is a trial session, *policySession*→*policyDigest* is updated as if the authorization is valid but no check is performed.

NOTE 2 If an HMAC is used to convey the authorization, a separate session is needed for the authorization. Because the HMAC in that authorization will include a nonce that prevents replay of the authorization, the value of the *nonceTPM* parameter in this command is limited. It is retained mostly to provide processing consistency with `TPM2_PolicySigned()`.

25.4.2 Command and Response

Table 115 — TPM2_PolicySecret Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	see clause 8
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicySecret
TPMI_DH_ENTITY	@authHandle	handle for an entity providing the authorization Auth Index: 1 Auth Role: USER
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_NONCE	nonceTPM	the policy nonce for the session If the nonce is not included in the authorization qualification, this field is the Empty Buffer.
TPM2B_DIGEST	cpHashA	digest of the command parameters to which this authorization is limited This not the <i>cpHash</i> for this command but the <i>cpHash</i> for the command to which this policy session will be applied. If it is not limited, the parameter will be the Empty Buffer.
TPM2B_NONCE	policyRef	a reference to a policy relating to the authorization – may be the Empty Buffer Size is limited to be no larger than the nonce size supported on the TPM.
INT32	expiration	time when authorization will expire, measured in seconds from the time that <i>nonceTPM</i> was generated If <i>expiration</i> is zero, a NULL Ticket is returned.

Table 116 — TPM2_PolicySecret Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_TIMEOUT	timeout	implementation-specific time value used to indicate to the TPM when the ticket expires; this ticket will use the TPMT_ST_AUTH_SECRET structure tag
TPMT_TK_AUTH	policyTicket	produced if the command succeeds and <i>expiration</i> in the command was non-zero

25.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicySecret_fp.h"
3  #include "Policy_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_CPHASH	<i>cpHash</i> for policy was previously set to a value that is not the same as <i>cpHashA</i>
TPM_RC_EXPIRED	<i>expiration</i> indicates a time in the past
TPM_RC_NONCE	<i>nonceTPM</i> does not match the nonce associated with <i>policySession</i>
TPM_RC_SIZE	<i>cpHashA</i> is not the size of a digest for the hash associated with <i>policySession</i>
TPM_RC_VALUE	input <i>policyID</i> or <i>expiration</i> does not match the internal data in policy session

```

4  TPM_RC
5  TPM2_PolicySecret(
6      PolicySecret_In      *in,    // IN: input parameter list
7      PolicySecret_Out    *out    // OUT: output parameter list
8  )
9  {
10     TPM_RC                result;
11     SESSION               *session;
12     TPM2B_NAME            entityName;
13     UINT32                expiration = (in->expiration < 0)
14                             ? -(in->expiration) : in->expiration;
15     UINT64                authTimeout = 0;
16
17     // Input Validation
18
19     // Get pointer to the session structure
20     session = SessionGet(in->policySession);
21
22     //Only do input validation if this is not a trial policy session
23     if(session->attributes.isTrialPolicy == CLEAR)
24     {
25
26         if(expiration != 0)
27             authTimeout = expiration * 1000 + session->startTime;
28
29         result = PolicyParameterChecks(session, authTimeout,
30                                     &in->cpHashA, &in->nonceTPM,
31                                     RC_PolicySecret_nonceTPM,
32                                     RC_PolicySecret_cpHashA,
33                                     RC_PolicySecret_expiration);
34         if(result != TPM_RC_SUCCESS)
35             return result;
36     }
37
38     // Internal Data Update
39     // Need the name of the authorizing entity
40     entityName.t.size = EntityGetName(in->authHandle, &entityName.t.name);
41
42     // Update policy context with input policyRef and name of auth key
43     // This value is computed even for trial sessions. Possibly update the cpHash
44     PolicyContextUpdate(TPM_CC_PolicySecret, &entityName, &in->policyRef,

```



```
45         &in->cpHashA, authTimeout, session);
46
47 // Command Output
48
49 // Create ticket and timeout buffer if in->expiration < 0 and this is not
50 // a trial session.
51 // NOTE: PolicyParameterChecks() makes sure that nonceTPM is present
52 // when expiration is non-zero.
53 if( in->expiration < 0
54     && session->attributes.isTrialPolicy == CLEAR
55     )
56     {
57         // Generate timeout buffer. The format of output timeout buffer is
58         // TPM-specific.
59         // Note: can't do a direct copy because the output buffer is a byte
60         // array and it may not be aligned to accept a 64-bit value. The method
61         // used has the side-effect of making the returned value a big-endian,
62         // 64-bit value that is byte aligned.
63         out->timeout.t.size = sizeof(UINT64);
64         UINT64_TO_BYTE_ARRAY(authTimeout, out->timeout.t.buffer);
65
66         // Compute policy ticket
67         TicketComputeAuth(TPM_ST_AUTH_SECRET, EntityGetHierarchy(in->authHandle),
68                          authTimeout, &in->cpHashA, &in->policyRef,
69                          &entityName, &out->policyTicket);
70     }
71 else
72     {
73         // timeout buffer is null
74         out->timeout.t.size = 0;
75
76         // auth ticket is null
77         out->policyTicket.tag = TPM_ST_AUTH_SECRET;
78         out->policyTicket.hierarchy = TPM_RH_NULL;
79         out->policyTicket.digest.t.size = 0;
80     }
81
82 return TPM_RC_SUCCESS;
83 }
```

25.5 TPM2_PolicyTicket

25.5.1 General Description

This command is similar to TPM2_PolicySigned() except that it takes a ticket instead of a signed authorization. The ticket represents a validated authorization that had an expiration time associated with it.

The parameters of this command are checked as described in 25.2.2.

If the checks succeed, the TPM uses the *timeout*, *cpHashA*, *policyRef*, and *keyName* to construct a ticket to compare with the value in *ticket*. If these tickets match, then the TPM will create a TPM2B_NAME (*objectName*) using *authName* and update the context of *policySession* by **PolicyUpdate()** (see 25.2.3).

PolicyUpdate(*commandCode*, *authName*, *policyRef*) (16)

If the structure tag of ticket is TPM_ST_AUTH_SECRET, then *commandCode* will be TPM_CC_PolicySecret. If the structure tag of ticket is TPM_ST_AUTH_SIGNED, then *commandCode* will be TPM_CC_PolicySigned.

If the *cpHashA* command parameter is not an Empty Buffer, it may be copied to *cpHash* in the session context as described in 25.2.1.

25.5.2 Command and Response

Table 117 — TPM2_PolicyTicket Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	see clause 8
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyTicket
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_TIMEOUT	timeout	time when authorization will expire The contents are TPM specific. This shall be the value returned when ticket was produced.
TPM2B_DIGEST	cpHashA	digest of the command parameters to which this authorization is limited If it is not limited, the parameter will be the Empty Buffer.
TPM2B_NONCE	policyRef	reference to a qualifier for the policy – may be the Empty Buffer
TPM2B_NAME	authName	name of the object that provided the authorization
TPMT_TK_AUTH	ticket	an authorization ticket returned by the TPM in response to a TPM2_PolicySigned() or TPM2_PolicySecret()

Table 118 — TPM2_PolicyTicket Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyTicket_fp.h"
3  #include "Policy_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_CPHASH	policy's <i>cpHash</i> was previously set to a different value
TPM_RC_EXPIRED	<i>timeout</i> value in the ticket is in the past and the ticket has expired
TPM_RC_SIZE	<i>timeout</i> or <i>cpHash</i> has invalid size for the
TPM_RC_TICKET	<i>ticket</i> is not valid

```

4  TPM_RC
5  TPM2_PolicyTicket(
6      PolicyTicket_In      *in          // IN: input parameter list
7  )
8  {
9      TPM_RC                result;
10     SESSION               *session;
11     UINT64                timeout;
12     TPMT_TK_AUTH          ticketToCompare;
13     TPM_CC                commandCode = TPM_CC_PolicySecret;
14
15     // Input Validation
16
17     // Get pointer to the session structure
18     session = SessionGet(in->policySession);
19
20     // NOTE: A trial policy session is not allowed to use this command.
21     // A ticket is used in place of a previously given authorization. Since
22     // a trial policy doesn't actually authenticate, the validated
23     // ticket is not necessary and, in place of using a ticket, one
24     // should use the intended authorization for which the ticket
25     // would be a substitute.
26     if(session->attributes.isTrialPolicy)
27         return TPM_RCS_ATTRIBUTES + RC_PolicyTicket_policySession;
28
29     // Restore timeout data. The format of timeout buffer is TPM-specific.
30     // In this implementation, we simply copy the value of timeout to the
31     // buffer.
32     if(in->timeout.t.size != sizeof(UINT64))
33         return TPM_RC_SIZE + RC_PolicyTicket_timeout;
34     timeout = BYTE_ARRAY_TO_UINT64(in->timeout.t.buffer);
35
36     // Do the normal checks on the cpHashA and timeout values
37     result = PolicyParameterChecks(session, timeout,
38                                   &in->cpHashA, NULL,
39                                   0, // no bad nonce return
40                                   RC_PolicyTicket_cpHashA,
41                                   RC_PolicyTicket_timeout);
42     if(result != TPM_RC_SUCCESS)
43         return result;
44
45
46     // Validate Ticket
47     // Re-generate policy ticket by input parameters
48     TicketComputeAuth(in->ticket.tag, in->ticket.hierarchy, timeout, &in->cpHashA,
49                      &in->policyRef, &in->authName, &ticketToCompare);

```

```
50
51     // Compare generated digest with input ticket digest
52     if(!Memory2BEqual(&in->ticket.digest.b, &ticketToCompare.digest.b))
53         return TPM_RC_TICKET + RC_PolicyTicket_ticket;
54
55 // Internal Data Update
56
57 // Is this ticket to take the place of a TPM2_PolicySigned() or
58 // a TPM2_PolicySecret()?
59 if(in->ticket.tag == TPM_ST_AUTH_SIGNED)
60     commandCode = TPM_CC_PolicySigned;
61 else if(in->ticket.tag == TPM_ST_AUTH_SECRET)
62     commandCode = TPM_CC_PolicySecret;
63 else
64     // There could only be two possible tag values. Any other value should
65     // be caught by the ticket validation process.
66     pAssert(FALSE);
67
68 // Update policy context
69 PolicyContextUpdate(commandCode, &in->authName, &in->policyRef,
70                     &in->cpHashA, timeout, session);
71
72 return TPM_RC_SUCCESS;
73 }
```

25.6 TPM2_PolicyOR

25.6.1 General Description

This command allows options in authorizations without requiring that the TPM evaluate all of the options. If a policy may be satisfied by different sets of conditions, the TPM need only evaluate one set that satisfies the policy. This command will indicate that one of the required sets of conditions has been satisfied.

PolicySession→*policyDigest* is compared against the list of provided values. If the current *policySession*→*policyDigest* does not match any value in the list, the TPM shall return TPM_RC_VALUE. Otherwise, it will replace *policySession*→*policyDigest* with the digest of the concatenation of all of the digests and return TPM_RC_SUCCESS.

If *policySession* is a trial session, the TPM will assume that *policySession*→*policyDigest* matches one of the list entries and compute the new value of *policyDigest*.

The algorithm for computing the new value for *policyDigest* of *policySession* is:

- a) Concatenate all the digest values in *pHashList*:

$$digests := pHashList.digests[1].buffer || \dots || pHashList.digests[n].buffer \quad (17)$$

NOTE 1 The TPM makes no check to see if the size of an entry matches the size of the digest of the policy.

- b) Reset *policyDigest* to a Zero Digest.

- c) Extend the command code and the hashes computed in step a) above:

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyOR || digests) \quad (18)$$

NOTE 2 The computation in b) and c) above is equivalent to:

$$policyDigest_{new} := H_{policyAlg}(0\dots0 || TPM_CC_PolicyOR || digests)$$

A TPM shall support a list with at least eight tagged digest values.

NOTE 3 If policies are to be portable between TPMs, then they should not use more than eight values.

25.6.2 Command and Response

Table 119 — TPM2_PolicyOR Command

Type	Name	Description
TPML_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyOR.
TPML_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPML_DIGEST	pHashList	the list of hashes to check for a match

Table 120 — TPM2_PolicyOR Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyOR_fp.h"
3  #include "Policy_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_VALUE	no digest in <i>pHashList</i> matched the current value of <i>policyDigest</i> for <i>policySession</i>

```

4  TPM_RC
5  TPM2_PolicyOR(
6      PolicyOR_In *in          // IN: input parameter list
7  )
8  {
9      SESSION      *session;
10     UINT32        i;
11
12     // Input Validation and Update
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     // Compare and Update Internal Session policy if match
18     for(i = 0; i < in->pHashList.count; i++)
19     {
20         if( session->attributes.isTrialPolicy == SET
21             || (Memory2BEqual(&session->u2.policyDigest.b,
22                               &in->pHashList.digests[i].b))
23             )
24         {
25             // Found a match
26             HASH_STATE      hashState;
27             TPM_CC          commandCode = TPM_CC_PolicyOR;
28
29             // Start hash
30             session->u2.policyDigest.t.size = CryptStartHash(session->authHashAlg,
31                                                               &hashState);
32             // Set policyDigest to 0 string and add it to hash
33             MemorySet(session->u2.policyDigest.t.buffer, 0,
34                       session->u2.policyDigest.t.size);
35             CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
36
37             // add command code
38             CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
39
40             // Add each of the hashes in the list
41             for(i = 0; i < in->pHashList.count; i++)
42             {
43                 // Extend policyDigest
44                 CryptUpdateDigest2B(&hashState, &in->pHashList.digests[i].b);
45             }
46             // Complete digest
47             CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
48
49             return TPM_RC_SUCCESS;
50         }
51     }
52     // None of the values in the list matched the current policyDigest
53     return TPM_RC_VALUE + RC_PolicyOR_pHashList;

```


54 }

25.7 TPM2_PolicyPCR

25.7.1 General Description

This command is used to cause conditional gating of a policy based on PCR. This allows one group of authorizations to occur when PCR are in one state and a different set of authorizations when the PCR are in a different state. If this command is used for a trial *policySession*, *policySession*→*policyDigest* will be updated using the values from the command rather than the values from digest of the TPM PCR.

The TPM will modify the *pcrs* parameter so that bits that correspond to unimplemented PCR are CLEAR. If *policySession* is not a trial policy session, the TPM will use the modified value of *pcrs* to select PCR values to hash according to Part 1, *Selecting Multiple PCR*. The hash algorithm of the policy session is used to compute a digest (*digestTPM*) of the selected PCR. If *pcrDigest* does not have a length of zero, then it is compared to *digestTPM*; and if the values do not match, the TPM shall return TPM_RC_VALUE and make no change to *policySession*→*policyDigest*. If the values match, or if the length of *pcrDigest* is zero, then *policySession*→*policyDigest* is extended by:

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyPCR || pcrs || digestTPM) \quad (19)$$

where

<i>pcrs</i>	the <i>pcrs</i> parameter with bits corresponding to unimplemented PCR set to 0
<i>digestTPM</i>	the digest of the selected PCR using the hash algorithm of the policy session

NOTE 1 If the caller provides the expected PCR value, the intention is that the policy evaluation stop at that point if the PCR do not match. If the caller does not provide the expected PCR value, then the validity of the settings will not be determined until an attempt is made to use the policy for authorization. If the policy is constructed such that the PCR check comes before user authorization checks, this early termination would allow software to avoid unnecessary prompts for user input to satisfy a policy that would fail later due to incorrect PCR values.

After this command completes successfully, the TPM shall return TPM_RC_PCR_CHANGED if the policy session is used for authorization and the PCR are not known to be correct.

The TPM uses a “generation” number (*pcrUpdateCounter*) that is incremented each time PCR are updated (unless the PCR being changed is specified not to cause a change to this counter). The value of this counter is stored in the policy session context (*policySession*→*pcrUpdateCounter*) when this command is executed. When the policy is used for authorization, the current value of the counter is compared to the value in the policy session context and the authorization will fail if the values are not the same.

When this command is executed, *policySession*→*pcrUpdateCounter* is checked to see if it has been previously set (in the reference implementation, it has a value of zero if not previously set). If it has been set, it will be compared with the current value of *pcrUpdateCounter* to determine if any PCR changes have occurred. If the values are different, the TPM shall return TPM_RC_PCR_CHANGED. If *policySession*→*pcrUpdateCounter* has not been set, then it is set to the current value of *pcrUpdateCounter*.

If *policySession* is a trial policy session, the TPM will not check any PCR and will compute:

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyPCR || pcrs || pcrDigest) \quad (20)$$

In this computation, *pcrs* is the input parameter without modification.

NOTE 2 The *pcrs* parameter is expected to match the configuration of the TPM for which the policy is being computed which may not be the same as the TPM on which the trial policy is being computed.

25.7.2 Command and Response

Table 121 — TPM2_PolicyPCR Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyPCR
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_DIGEST	pcrDigest	expected digest value of the selected PCR using the hash algorithm of the session; may be zero length
TPML_PCR_SELECTION	pcrs	the PCR to include in the check digest

Table 122 — TPM2_PolicyPCR Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyPCR_fp.h"

```

Error Returns	Meaning
TPM_RC_VALUE	if provided, <i>pcrDigest</i> does not match the current PCR settings
TPM_RC_PCR_CHANGED	a previous TPM2_PolicyPCR() set <i>pcrCounter</i> and it has changed

```

3  TPM_RC
4  TPM2_PolicyPCR(
5      PolicyPCR_In    *in          // IN: input parameter list
6  )
7  {
8      SESSION          *session;
9      TPM2B_DIGEST     pcrDigest;
10     BYTE              pcrcs[sizeof(TPML_PCR_SELECTION)];
11     UINT32            pcrSize;
12     BYTE              *buffer;
13     TPM_CC             commandCode = TPM_CC_PolicyPCR;
14     HASH_STATE        hashState;
15
16     // Input Validation
17
18     // Get pointer to the session structure
19     session = SessionGet(in->policySession);
20
21     // Do validation for non trial session
22     if(session->attributes.isTrialPolicy == CLEAR)
23     {
24         // Make sure that this is not going to invalidate a previous PCR check
25         if(session->pcrCounter != 0 && session->pcrCounter != gr.pcrCounter)
26             return TPM_RC_PCR_CHANGED;
27
28         // Compute current PCR digest
29         PCRComputeCurrentDigest(session->authHashAlg, &in->pcrcs, &pcrDigest);
30
31         // If the caller specified the PCR digest and it does not
32         // match the current PCR settings, return an error..
33         if(in->pcrDigest.t.size != 0)
34         {
35             if(!Memory2BEqual(&in->pcrDigest.b, &pcrDigest.b))
36                 return TPM_RC_VALUE + RC_PolicyPCR_pcrDigest;
37         }
38     }
39     else
40     {
41         // For trial session, just use the input PCR digest
42         pcrDigest = in->pcrDigest;
43     }
44     // Internal Data Update
45
46     // Update policy hash
47     // policyDigestnew = hash( policyDigestold || TPM_CC_PolicyPCR
48     //                          || pcrcs || pcrDigest)
49     // Start hash
50     CryptStartHash(session->authHashAlg, &hashState);
51
52     // add old digest
53     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);

```

```
54
55     // add commandCode
56     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
57
58     // add PCRS
59     buffer = pcrs;
60     pcrSize = TPML_PCR_SELECTION_Marshal(&in->pcrs, &buffer, NULL);
61     CryptUpdateDigest(&hashState, pcrSize, pcrs);
62
63     // add PCR digest
64     CryptUpdateDigest2B(&hashState, &pcrDigest.b);
65
66     // complete the hash and get the results
67     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
68
69     // update pcrCounter in session context for non trial session
70     if(session->attributes.isTrialPolicy == CLEAR)
71     {
72         session->pcrCounter = gr.pcrCounter;
73     }
74
75     return TPM_RC_SUCCESS;
76 }
```

25.8 TPM2_PolicyLocality

25.8.1 General Description

This command indicates that the authorization will be limited to a specific locality.

policySession→*commandLocality* is a parameter kept in the session context. It is initialized when the policy session is started to allow the policy to apply to any locality.

If *locality* has a value greater than 31, then an extended locality is indicated. For an extended locality, the TPM will validate that *policySession*→*commandLocality* has not previously been set or that the current value of *policySession*→*commandLocality* is the same as *locality* (TPM_RC_RANGE).

When *locality* is not an extended locality, the TPM will validate that the *policySession*→*commandLocality* is not set or is not set to an extended locality value (TPM_RC_RANGE). If not the TPM will disable any locality not SET in the *locality* parameter. If the result of disabling localities results in no locality being enabled, the TPM will return TPM_RC_RANGE.

If no error occurred in the validation of *locality*, *policySession*→*policyDigest* is extended with

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyLocality || locality) \quad (21)$$

Then *policySession*→*commandLocality* is updated to indicate which localities are still allowed after execution of TPM2_PolicyLocality().

When the policy session is used to authorize a command, the authorization will fail if the locality used for the command is not one of the enabled localities in *policySession*→*commandLocality*.

25.8.2 Command and Response

Table 123 — TPM2_PolicyLocality Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyLocality
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPMA_LOCALITY	locality	the allowed localities for the policy

Table 124 — TPM2_PolicyLocality Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.8.3 Detailed Actions

```

1 #include "InternalRoutines.h"
2 #include "PolicyLocality_fp.h"

```

Limit a policy to a specific locality

Error Returns	Meaning
TPM_RC_RANGE	all the locality values selected by <i>locality</i> have been disabled by previous TPM2_PolicyLocality() calls.

```

3 TPM_RC
4 TPM2_PolicyLocality(
5     PolicyLocality_In *in          // IN: input parameter list
6 )
7 {
8     SESSION *session;
9     BYTE marshalBuffer[sizeof(TPMA_LOCALITY)];
10    BYTE prevSetting[sizeof(TPMA_LOCALITY)];
11    UINT32 marshalSize;
12    BYTE *buffer;
13    TPM_CC commandCode = TPM_CC_PolicyLocality;
14    HASH_STATE hashState;
15
16    // Input Validation
17
18    // Get pointer to the session structure
19    session = SessionGet(in->policySession);
20
21    // Get new locality setting in canonical form
22    buffer = marshalBuffer;
23    marshalSize = TPMA_LOCALITY_Marshal(&in->locality, &buffer, NULL);
24
25    // Its an error if the locality parameter is zero
26    if(marshalBuffer[0] == 0)
27        return TPM_RC_RANGE + RC_PolicyLocality_locality;
28
29    // Get existing locality setting in canonical form
30    buffer = prevSetting;
31    TPMA_LOCALITY_Marshal(&session->commandLocality, &buffer, NULL);
32
33    // If the locality has been previously set, then it needs to be the same
34    // type as the input locality (i.e. both extended or both normal
35    if(prevSetting[0] != 0 && ((prevSetting[0] <= 0) != (marshalBuffer[0] <= 0)))
36        return TPM_RC_RANGE + RC_PolicyLocality_locality;
37
38
39    // See if the input is a regular or extended locality
40    if(marshalBuffer[0] < 32)
41    {
42        // For regular locality
43        // The previous setting must not be an extended locality
44        if(prevSetting[0] > 31)
45            return TPM_RC_RANGE + RC_PolicyLocality_locality;
46
47        // if there was no previous setting, start with all normal localities
48        // enabled
49        if(prevSetting[0] == 0)
50            prevSetting[0] = 0x1F;
51
52        // AND the new setting with the previous setting and store it in prevSetting

```



```
53     prevSetting[0] &= marshalBuffer[0];
54
55     // The result setting can not be 0
56     if(prevSetting[0] == 0)
57         return TPM_RC_RANGE + RC_PolicyLocality_locality;
58     }
59     else
60     {
61         // for extended locality
62         // if the locality has already been set, then it must match the
63         if(prevSetting[0] != 0 && prevSetting[0] != marshalBuffer[0])
64             return TPM_RC_RANGE + RC_PolicyLocality_locality;
65
66         // Setting is OK
67         prevSetting[0] = marshalBuffer[0];
68     }
69 }
70
71 // Internal Data Update
72
73 // Update policy hash
74 // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyLocality || locality)
75 // Start hash
76 CryptStartHash(session->authHashAlg, &hashState);
77
78 // add old digest
79 CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
80
81 // add commandCode
82 CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
83
84 // add input locality
85 CryptUpdateDigest(&hashState, marshalSize, marshalBuffer);
86
87 // complete the digest
88 CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
89
90 // update session locality by unmarshal function. The function must succeed
91 // because both input and existing locality setting have been validated.
92 buffer = prevSetting;
93 TPMA_LOCALITY_Unmarshal(&session->commandLocality, &buffer,
94                        (INT32 *) &marshalSize);
95
96 return TPM_RC_SUCCESS;
97 }
```

25.9 TPM2_PolicyNV

25.9.1 General Description

This command is used to cause conditional gating of a policy based on the contents of an NV Index.

If *policySession* is a trial policy session, the TPM will update *policySession*→*policyDigest* as shown in equations (22) and (23) below and return TPM_RC_SUCCESS. It will not perform any validation. The remainder of this general description would apply only if *policySession* is not a trial policy session.

An authorization session providing authorization to read the NV Index shall be provided.

NOTE 1 If read access is controlled by policy, the policy should include a branch that authorizes a TPM2_PolicyNV().

If TPMA_NV_WRITTEN is not SET in the NV Index, the TPM shall return TPM_RC_NV_UNINITIALIZED.

The TPM will validate that the size of *operandB* plus offset is not greater than the size of the NV Index. If it is, the TPM shall return TPM_RC_SIZE.

The TPM will perform the indicated arithmetic check on the indicated portion of the selected NV Index. If the check fails, the TPM shall return TPM_RC_POLICY and not change *policySession*→*policyDigest*. If the check succeeds, the TPM will hash the arguments:

$$args := H_{policyAlg}(operand.buffer || offset || operation) \quad (22)$$

where

$H_{policyAlg}()$	hash function using the algorithm of the policy session
<i>operandB</i>	the value used for the comparison
<i>offset</i>	offset from the start of the NV Index data to start the comparison
<i>operation</i>	the operation parameter indicating the comparison being performed

The value of *args* and the Name of the NV Index are extended to *policySession*→*policyDigest* by

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyNV || args || nvIndex \rightarrow Name) \quad (23)$$

where

$H_{policyAlg}()$	hash function using the algorithm of the policy session
<i>args</i>	value computed in equation (22)
<i>nvIndex</i> → <i>Name</i>	the Name of the NV Index

The signed arithmetic operations are performed using twos-compliment.

Magnitude comparisons assume that the octet at offset zero in the referenced NV location and in *operandB* contain the most significant octet of the data.

NOTE 2 When an Index is written, it has a different authorization name than an Index that has not been written. It is possible to use this change in the NV Index to create a write-once Index.

25.9.2 Command and Response

Table 125 — TPM2_PolicyNV Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyNV
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index of the area to read Auth Index: None
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_OPERAND	operandB	the second operand
UINT16	offset	the offset in the NV Index for the start of operand A
TPM_EO	operation	the comparison to make

Table 126 — TPM2_PolicyNV Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.9.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyNV_fp.h"
3  #include "Policy_spt_fp.h"
4  #include "NV_spt_fp.h"           // Include NV support routine for read access check

```

Error Returns	Meaning
TPM_RC_AUTH_TYPE	NV index authorization type is not correct
TPM_RC_NV_LOCKED	NV index read locked
TPM_RC_NV_UNINITIALIZED	the NV index has not been initialized
TPM_RC_POLICY	the comparison to the NV contents failed
TPM_RC_SIZE	the size of <i>nvIndex</i> data starting at <i>offset</i> is less than the size of <i>operandB</i>

```

5  TPM_RC
6  TPM2_PolicyNV(
7      PolicyNV_In      *in          // IN: input parameter list
8  )
9  {
10     TPM_RC          result;
11     SESSION        *session;
12     NV_INDEX       nvIndex;
13     BYTE           nvBuffer[sizeof(in->operandB.t.buffer)];
14     TPM2B_NAME     nvName;
15     TPM_CC         commandCode = TPM_CC_PolicyNV;
16     HASH_STATE     hashState;
17     TPM2B_DIGEST   argHash;
18
19     // Input Validation
20
21     // Get NV index information
22     NvGetIndexInfo(in->nvIndex, &nvIndex);
23
24     // Get pointer to the session structure
25     session = SessionGet(in->policySession);
26
27     //If this is a trial policy, skip all validations and the operation
28     if(session->attributes.isTrialPolicy == CLEAR)
29     {
30         // NV Read access check. NV index should be allowed for read. A
31         // TPM_RC_AUTH_TYPE or TPM_RC_NV_LOCKED error may be return at this
32         // point
33         result = NvReadAccessChecks(in->authHandle, in->nvIndex);
34         if(result != TPM_RC_SUCCESS) return result;
35
36         // Valid NV data size should not be smaller than input operandB size
37         if((nvIndex.publicArea.dataSize - in->offset) < in->operandB.t.size)
38             return TPM_RC_SIZE + RC_PolicyNV_operandB;
39
40         // Arithmetic Comparison
41
42         // Get NV data. The size of NV data equals the input operand B size
43         NvGetIndexData(in->nvIndex, &nvIndex, in->offset,
44             in->operandB.t.size, nvBuffer);
45
46         switch(in->operation)

```

```

47     {
48     case TPM_EO_EQ:
49         // compare A = B
50         if (CryptCompare(in->operandB.t.size, nvBuffer,
51                         in->operandB.t.size, in->operandB.t.buffer) != 0)
52             return TPM_RC_POLICY;
53         break;
54     case TPM_EO_NEQ:
55         // compare A != B
56         if (CryptCompare(in->operandB.t.size, nvBuffer,
57                         in->operandB.t.size, in->operandB.t.buffer) == 0)
58             return TPM_RC_POLICY;
59         break;
60     case TPM_EO_SIGNED_GT:
61         // compare A > B signed
62         if (CryptCompareSigned(in->operandB.t.size, nvBuffer,
63                               in->operandB.t.size, in->operandB.t.buffer) <= 0)
64             return TPM_RC_POLICY;
65         break;
66     case TPM_EO_UNSIGNED_GT:
67         // compare A > B unsigned
68         if (CryptCompare(in->operandB.t.size, nvBuffer,
69                         in->operandB.t.size, in->operandB.t.buffer) <= 0)
70             return TPM_RC_POLICY;
71         break;
72     case TPM_EO_SIGNED_LT:
73         // compare A < B signed
74         if (CryptCompareSigned(in->operandB.t.size, nvBuffer,
75                               in->operandB.t.size, in->operandB.t.buffer) >= 0)
76             return TPM_RC_POLICY;
77         break;
78     case TPM_EO_UNSIGNED_LT:
79         // compare A < B unsigned
80         if (CryptCompare(in->operandB.t.size, nvBuffer,
81                         in->operandB.t.size, in->operandB.t.buffer) >= 0)
82             return TPM_RC_POLICY;
83         break;
84     case TPM_EO_SIGNED_GE:
85         // compare A >= B signed
86         if (CryptCompareSigned(in->operandB.t.size, nvBuffer,
87                               in->operandB.t.size, in->operandB.t.buffer) < 0)
88             return TPM_RC_POLICY;
89         break;
90     case TPM_EO_UNSIGNED_GE:
91         // compare A >= B unsigned
92         if (CryptCompare(in->operandB.t.size, nvBuffer,
93                         in->operandB.t.size, in->operandB.t.buffer) < 0)
94             return TPM_RC_POLICY;
95         break;
96     case TPM_EO_SIGNED_LE:
97         // compare A <= B signed
98         if (CryptCompareSigned(in->operandB.t.size, nvBuffer,
99                               in->operandB.t.size, in->operandB.t.buffer) > 0)
100             return TPM_RC_POLICY;
101         break;
102     case TPM_EO_UNSIGNED_LE:
103         // compare A <= B unsigned
104         if (CryptCompare(in->operandB.t.size, nvBuffer,
105                         in->operandB.t.size, in->operandB.t.buffer) > 0)
106             return TPM_RC_POLICY;
107         break;
108     case TPM_EO_BITSET:
109         // All bits SET in B are SET in A. ((A&B)=B)
110     {

```

```

111         UINT32 i;
112         for (i = 0; i < in->operandB.t.size; i++)
113             if((nvBuffer[i] & in->operandB.t.buffer[i])
114                 != in->operandB.t.buffer[i])
115                 return TPM_RC_POLICY;
116     }
117     break;
118     case TPM_EO_BITCLEAR:
119         // All bits SET in B are CLEAR in A. ((A&B)=0)
120         {
121             UINT32 i;
122             for (i = 0; i < in->operandB.t.size; i++)
123                 if((nvBuffer[i] & in->operandB.t.buffer[i]) != 0)
124                     return TPM_RC_POLICY;
125         }
126     break;
127     default:
128         pAssert(FALSE);
129         break;
130     }
131 }
132
133 // Internal Data Update
134
135 // Start argument hash
136 argHash.t.size = CryptStartHash(session->authHashAlg, &hashState);
137
138 // add operandB
139 CryptUpdateDigest2B(&hashState, &in->operandB.b);
140
141 // add offset
142 CryptUpdateDigestInt(&hashState, sizeof(UINT16), &in->offset);
143
144 // add operation
145 CryptUpdateDigestInt(&hashState, sizeof(TPM_EO), &in->operation);
146
147 // complete argument digest
148 CryptCompleteHash2B(&hashState, &argHash.b);
149
150 // Update policyDigest
151 // Start digest
152 CryptStartHash(session->authHashAlg, &hashState);
153
154 // add old digest
155 CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
156
157 // add commandCode
158 CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
159
160 // add argument digest
161 CryptUpdateDigest2B(&hashState, &argHash.b);
162
163 // Adding nvName
164 nvName.t.size = EntityGetName(in->nvIndex, &nvName.t.name);
165 CryptUpdateDigest2B(&hashState, &nvName.b);
166
167 // complete the digest
168 CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
169
170 return TPM_RC_SUCCESS;
171 }

```

25.10 TPM2_PolicyCounterTimer

25.10.1 General Description

This command is used to cause conditional gating of a policy based on the contents of the TPMS_TIME_INFO structure.

If *policySession* is a trial policy session, the TPM will update *policySession*→*policyDigest* as shown in equations (24) and (25) below and return TPM_RC_SUCCESS. It will not perform any validation. The remainder of this general description would apply only if *policySession* is not a trial policy session.

The TPM will perform the indicated arithmetic check on the indicated portion of the TPMS_TIME_INFO structure. If the check fails, the TPM shall return TPM_RC_POLICY and not change *policySession*→*policyDigest*. If the check succeeds, the TPM will hash the arguments:

$$args := H_{policyAlg}(operandB.buffer || offset || operation) \quad (24)$$

where

$H_{policyAlg}()$	hash function using the algorithm of the policy session
<i>operandB.buffer</i>	the value used for the comparison
<i>offset</i>	offset from the start of the TPMS_TIME_INFO structure at which the comparison starts
<i>operation</i>	the operation parameter indicating the comparison being performed

The value of *args* is extended to *policySession*→*policyDigest* by

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyCounterTimer || args) \quad (25)$$

where

$H_{policyAlg}()$	hash function using the algorithm of the policy session
<i>args</i>	value computed in equation (24)

The signed arithmetic operations are performed using twos-compliment.

Magnitude comparisons assume that the octet at offset zero in the referenced location and in *operandB* contain the most significant octet of the data.

25.10.2 Command and Response

Table 127 — TPM2_PolicyCounterTimer Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyCounterTimer
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_OPERAND	operandB	the second operand
UINT16	offset	the offset in TPMS_TIME_INFO structure for the start of operand A
TPM_EO	operation	the comparison to make

Table 128 — TPM2_PolicyCounterTimer Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.10.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyCounterTimer_fp.h"
3  #include "Policy_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_POLICY	the comparison of the selected portion of the TPMS_TIME_INFO with <i>operandB</i> failed
TPM_RC_RANGE	<i>offset + size</i> exceed size of TPMS_TIME_INFO structure

```

4  TPM_RC
5  TPM2_PolicyCounterTimer(
6      PolicyCounterTimer_In  *in          // IN: input parameter list
7  )
8  {
9      TPM_RC          result;
10     SESSION         *session;
11     TIME_INFO       infoData;          // data buffer of TPMS_TIME_INFO
12     TPM_CC          commandCode = TPM_CC_PolicyCounterTimer;
13     HASH_STATE      hashState;
14     TPM2B_DIGEST    argHash;
15
16     // Input Validation
17
18     // If the command is going to use any part of the counter or timer, need
19     // to verify that time is advancing.
20     // The time and clock vales are the first two 64-bit values in the clock
21     if(in->offset < <K>sizeof(UINT64) + sizeof(UINT64))
22     {
23         // Using Clock or Time so see if clock is running. Clock doesn't run while
24         // NV is unavailable.
25         // TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned here.
26         result = NvIsAvailable();
27         if(result != TPM_RC_SUCCESS)
28             return result;
29     }
30     // Get pointer to the session structure
31     session = SessionGet(in->policySession);
32
33     //If this is a trial policy, skip all validations and the operation
34     if(session->attributes.isTrialPolicy == CLEAR)
35     {
36         // Get time data info. The size of time info data equals the input
37         // operand B size. A TPM_RC_RANGE error may be returned at this point
38         result = TimeGetRange(in->offset, in->operandB.t.size, &infoData);
39         if(result != TPM_RC_SUCCESS) return result;
40
41         // Arithmetic Comparison
42         switch(in->operation)
43         {
44             case TPM_EO_EQ:
45                 // compare A = B
46                 if(CryptCompare(in->operandB.t.size, infoData,
47                                 in->operandB.t.size, in->operandB.t.buffer) != 0)
48                     return TPM_RC_POLICY;
49                 break;
50             case TPM_EO_NEQ:
51                 // compare A != B
52                 if(CryptCompare(in->operandB.t.size, infoData,

```

```

53             in->operandB.t.size, in->operandB.t.buffer) == 0)
54         return TPM_RC_POLICY;
55     break;
56 case TPM_EO_SIGNED_GT:
57     // compare A > B signed
58     if(CryptCompareSigned(in->operandB.t.size, infoData,
59         in->operandB.t.size, in->operandB.t.buffer) <= 0)
60         return TPM_RC_POLICY;
61     break;
62 case TPM_EO_UNSIGNED_GT:
63     // compare A > B unsigned
64     if(CryptCompare(in->operandB.t.size, infoData,
65         in->operandB.t.size, in->operandB.t.buffer) <= 0)
66         return TPM_RC_POLICY;
67     break;
68 case TPM_EO_SIGNED_LT:
69     // compare A < B signed
70     if(CryptCompareSigned(in->operandB.t.size, infoData,
71         in->operandB.t.size, in->operandB.t.buffer) >= 0)
72         return TPM_RC_POLICY;
73     break;
74 case TPM_EO_UNSIGNED_LT:
75     // compare A < B unsigned
76     if(CryptCompare(in->operandB.t.size, infoData,
77         in->operandB.t.size, in->operandB.t.buffer) >= 0)
78         return TPM_RC_POLICY;
79     break;
80 case TPM_EO_SIGNED_GE:
81     // compare A >= B signed
82     if(CryptCompareSigned(in->operandB.t.size, infoData,
83         in->operandB.t.size, in->operandB.t.buffer) < 0)
84         return TPM_RC_POLICY;
85     break;
86 case TPM_EO_UNSIGNED_GE:
87     // compare A >= B unsigned
88     if(CryptCompare(in->operandB.t.size, infoData,
89         in->operandB.t.size, in->operandB.t.buffer) < 0)
90         return TPM_RC_POLICY;
91     break;
92 case TPM_EO_SIGNED_LE:
93     // compare A <= B signed
94     if(CryptCompareSigned(in->operandB.t.size, infoData,
95         in->operandB.t.size, in->operandB.t.buffer) > 0)
96         return TPM_RC_POLICY;
97     break;
98 case TPM_EO_UNSIGNED_LE:
99     // compare A <= B unsigned
100    if(CryptCompare(in->operandB.t.size, infoData,
101        in->operandB.t.size, in->operandB.t.buffer) > 0)
102        return TPM_RC_POLICY;
103    break;
104 case TPM_EO_BITSET:
105     // All bits SET in B are SET in A. ((A&B)=B)
106     {
107         UINT32 i;
108         for (i = 0; i < in->operandB.t.size; i++)
109             if( (infoData[i] & in->operandB.t.buffer[i])
110                 != in->operandB.t.buffer[i])
111                 return TPM_RC_POLICY;
112     }
113     break;
114 case TPM_EO_BITCLEAR:
115     // All bits SET in B are CLEAR in A. ((A&B)=0)
116     {

```

```
117         UINT32 i;
118         for (i = 0; i < in->operandB.t.size; i++)
119             if((infoData[i] & in->operandB.t.buffer[i]) != 0)
120                 return TPM_RC_POLICY;
121     }
122     break;
123     default:
124         pAssert(FALSE);
125         break;
126     }
127 }
128
129 // Internal Data Update
130
131 // Start argument list hash
132 argHash.t.size = CryptStartHash(session->authHashAlg, &hashState);
133 // add operandB
134 CryptUpdateDigest2B(&hashState, &in->operandB.b);
135 // add offset
136 CryptUpdateDigestInt(&hashState, sizeof(UINT16), &in->offset);
137 // add operation
138 CryptUpdateDigestInt(&hashState, sizeof(TPM_EO), &in->operation);
139 // complete argument hash
140 CryptCompleteHash2B(&hashState, &argHash.b);
141
142 // update policyDigest
143 // start hash
144 CryptStartHash(session->authHashAlg, &hashState);
145
146 // add old digest
147 CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
148
149 // add commandCode
150 CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
151
152 // add argument digest
153 CryptUpdateDigest2B(&hashState, &argHash.b);
154
155 // complete the digest
156 CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
157
158 return TPM_RC_SUCCESS;
159 }
```

25.11 TPM2_PolicyCommandCode

25.11.1 General Description

This command indicates that the authorization will be limited to a specific command code.

If *policySession*→*commandCode* has its default value, then it will be set to *code*. If *policySession*→*commandCode* does not have its default value, then the TPM will return TPM_RC_VALUE if the two values are not the same.

If *code* is not implemented, the TPM will return TPM_RC_POLICY_CC.

If the TPM does not return an error, it will update *policySession*→*policyDigest* by

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyCommandCode || code) \quad (26)$$

NOTE 1 If a previous TPM2_PolicyCommandCode() had been executed, then it is probable that the policy expression is improperly formed but the TPM does not return an error.

NOTE 2 A TPM2_PolicyOR() would be used to allow an authorization to be used for multiple commands.

When the policy session is used to authorize a command, the TPM will fail the command if the *commandCode* of that command does not match *policySession*→*commandCode*.

This command, or TPM2_PolicyDuplicationSelect(), is required to enable the policy to be used for ADMIN role authorization.

EXAMPLE Before TPM2_Certify() can be executed, TPM2_PolicyCommandCode() with *code* set to TPM_CC_Certify is required.

25.11.2 Command and Response

Table 129 — TPM2_PolicyCommandCode Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyCommandCode
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM_CC	code	the allowed <i>commandCode</i>

Table 130 — TPM2_PolicyCommandCode Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.11.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyCommandCode_fp.h"

```

Error Returns	Meaning
TPM_RC_VALUE	<i>commandCode</i> of <i>policySession</i> previously set to a different value

```

3  TPM_RC
4  TPM2_PolicyCommandCode(
5      PolicyCommandCode_In *in          // IN: input parameter list
6  )
7  {
8      SESSION      *session;
9      TPM_CC       commandCode = TPM_CC_PolicyCommandCode;
10     HASH_STATE   hashState;
11
12     // Input validation
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     if(session->commandCode != 0 && session->commandCode != in->code)
18         return TPM_RC_VALUE + RC_PolicyCommandCode_code;
19     if(!CommandIsImplemented(in->code))
20         return TPM_RC_POLICY_CC + RC_PolicyCommandCode_code;
21
22     // Internal Data Update
23     // Update policy hash
24     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyCommandCode || code)
25     // Start hash
26     CryptStartHash(session->authHashAlg, &hashState);
27
28     // add old digest
29     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
30
31     // add commandCode
32     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
33
34     // add input commandCode
35     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &in->code);
36
37     // complete the hash and get the results
38     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
39
40     // update commandCode value in session context
41     session->commandCode = in->code;
42
43     return TPM_RC_SUCCESS;
44 }

```

25.12 TPM2_PolicyPhysicalPresence

25.12.1 General Description

This command indicates that physical presence will need to be asserted at the time the authorization is performed.

If this command is successful, *policySession*→*isPPRequired* will be SET to indicate that this check is required when the policy is used for authorization. Additionally, *policySession*→*policyDigest* is extended with

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyPhysicalPresence) \quad (27)$$

25.12.2 Command and Response

Table 131 — TPM2_PolicyPhysicalPresence Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyPhysicalPresence
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None

Table 132 — TPM2_PolicyPhysicalPresence Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.12.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PolicyPhysicalPresence_fp.h"
3  TPM_RC
4  TPM2_PolicyPhysicalPresence(
5      PolicyPhysicalPresence_In *in          // IN: input parameter list
6  )
7  {
8      SESSION      *session;
9      TPM_CC      commandCode = TPM_CC_PolicyPhysicalPresence;
10     HASH_STATE   hashState;
11
12     // Internal Data Update
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     // Update policy hash
18     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyPhysicalPresence)
19     // Start hash
20     CryptStartHash(session->authHashAlg, &hashState);
21
22     // add old digest
23     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
24
25     // add commandCode
26     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
27
28     // complete the digest
29     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
30
31     // update session attribute
32     session->attributes.isPPRequired = SET;
33
34     return TPM_RC_SUCCESS;
35 }
```

25.13 TPM2_PolicyCpHash

25.13.1 General Description

This command is used to allow a policy to be bound to a specific command and command parameters.

TPM2_PolicySigned(), TPM2_PolicySecret(), and TPM2_PolicyTicket() are designed to allow an authorizing entity to execute an arbitrary command as the *cpHashA* parameter of those commands is not included in *policySession*→*policyDigest*. TPM2_PolicyCommandCode() allows the policy to be bound to a specific Command Code so that only certain entities may authorize specific command codes. This command allows the policy to be restricted such that an entity may only authorize a command with a specific set of parameters.

If *policySession*→*cpHash* is already set and not the same as *cpHashA*, then the TPM shall return TPM_RC_VALUE. If *cpHashA* does not have the size of the *policySession*→*policyDigest*, the TPM shall return TPM_RC_SIZE.

If the *cpHashA* checks succeed, *policySession*→*cpHash* is set to *cpHashA* and *policySession*→*policyDigest* is updated with

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyCpHash || cpHashA) \quad (28)$$

25.13.2 Command and Response

Table 133 — TPM2_PolicyCpHash Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyCpHash
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_DIGEST	cpHashA	the <i>cpHash</i> added to the policy

Table 134 — TPM2_PolicyCpHash Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.13.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyCpHash_fp.h"

```

Error Returns	Meaning
TPM_RC_CPHASH	<i>cpHash</i> of <i>policySession</i> has previously been set to a different value
TPM_RC_SIZE	<i>cpHashA</i> is not the size of a digest produced by the hash algorithm associated with <i>policySession</i>

```

3  TPM_RC
4  TPM2_PolicyCpHash(
5      PolicyCpHash_In *in          // IN: input parameter list
6  )
7  {
8      SESSION      *session;
9      TPM_CC       commandCode = TPM_CC_PolicyCpHash;
10     HASH_STATE   hashState;
11
12     // Input Validation
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     // A new cpHash is given in input parameter, but cpHash in session context
18     // is not empty, or is not the same as the new cpHash
19     if( in->cpHashA.t.size != 0
20         && session->u1.cpHash.t.size != 0
21         && !Memory2BEqual(&in->cpHashA.b, &session->u1.cpHash.b)
22     )
23         return TPM_RC_CPHASH;
24
25     // A valid cpHash must have the same size as session hash digest
26     if(in->cpHashA.t.size != CryptGetHashDigestSize(session->authHashAlg))
27         return TPM_RC_SIZE + RC_PolicyCpHash_cpHashA;
28
29     // Internal Data Update
30
31     // Update policy hash
32     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyCpHash || cpHashA)
33     // Start hash
34     CryptStartHash(session->authHashAlg, &hashState);
35
36     // add old digest
37     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
38
39     // add commandCode
40     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
41
42     // add cpHashA
43     CryptUpdateDigest2B(&hashState, &in->cpHashA.b);
44
45     // complete the digest and get the results
46     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
47
48     // update cpHash in session context
49     session->u1.cpHash = in->cpHashA;
50     session->attributes.iscpHashDefined = SET;
51
52     return TPM_RC_SUCCESS;

```

53 }

25.14 TPM2_PolicyNameHash

25.14.1 General Description

This command allows a policy to be bound to a specific set of TPM entities without being bound to the parameters of the command. This is most useful for commands such as TPM2_Duplicate() and for TPM2_PCR_Event() when the referenced PCR requires a policy.

The *nameHash* parameter should contain the digest of the Names associated with the handles to be used in the authorized command.

EXAMPLE For the TPM2_Duplicate() command, two handles are provided. One is the handle of the object being duplicated and the other is the handle of the new parent. For that command, *nameHash* would contain:

$$nameHash := H_{policyAlg}(objectHandle \rightarrow Name || newParentHandle \rightarrow Name)$$

If *policySession*→*cpHash* is already set, the TPM shall return TPM_RC_VALUE. If the size of *nameHash* is not the size of *policySession*→*policyDigest*, the TPM shall return TPM_RC_SIZE. Otherwise, *policySession*→*cpHash* is set to *nameHash*.

If this command completes successfully, the *cpHash* of the authorized command will not be used for validation. Only the digest of the Names associated with the handles in the command will be used.

NOTE 1 This allows the space normally used to hold *policySession*→*cpHash* to be used for *policySession*→*nameHash* instead.

The *policySession*→*policyDigest* will be updated with

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyNameHash || nameHash) \quad (29)$$

NOTE 2 This command will often be used with TPM2_PolicyAuthorize() where the owner of the object being duplicated provides approval for their object to be migrated to a specific new parent.

25.14.2 Command and Response

Table 135 — TPM2_PolicyNameHash Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyNameHash
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_DIGEST	nameHash	the digest to be added to the policy

Table 136 — TPM2_PolicyNameHash Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.14.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyNameHash_fp.h"

```

Error Returns	Meaning
TPM_RC_CPHASH	<i>nameHash</i> has been previously set to a different value
TPM_RC_SIZE	<i>nameHash</i> is not the size of the digest produced by the hash algorithm associated with <i>policySession</i>

```

3  TPM_RC
4  TPM2_PolicyNameHash(
5      PolicyNameHash_In  *in      // IN: input parameter list
6  )
7  {
8      SESSION              *session;
9      TPM_CC               commandCode = TPM_CC_PolicyNameHash;
10     HASH_STATE           hashState;
11
12     // Input Validation
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     // A new nameHash is given in input parameter, but cpHash in session context
18     // is not empty
19     if(in->nameHash.t.size != 0 && session->ul.cpHash.t.size != 0)
20         return TPM_RC_CPHASH;
21
22     // A valid nameHash must have the same size as session hash digest
23     if(in->nameHash.t.size != CryptGetHashDigestSize(session->authHashAlg))
24         return TPM_RC_SIZE + RC_PolicyNameHash_nameHash;
25
26     // Internal Data Update
27
28     // Update policy hash
29     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyNameHash || nameHash)
30     // Start hash
31     CryptStartHash(session->authHashAlg, &hashState);
32
33     // add old digest
34     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
35
36     // add commandCode
37     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
38
39     // add nameHash
40     CryptUpdateDigest2B(&hashState, &in->nameHash.b);
41
42     // complete the digest
43     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
44
45     // clear iscpHashDefined bit to indicate now this field contains a nameHash
46     session->attributes.iscpHashDefined = CLEAR;
47
48     // update nameHash in session context
49     session->ul.cpHash = in->nameHash;
50
51     return TPM_RC_SUCCESS;
52 }

```


25.15 TPM2_PolicyDuplicationSelect

25.15.1 General Description

This command allows qualification of duplication to allow duplication to a selected new parent.

If this command not used in conjunction with TPM2_PolicyAuthorize(), then only the new parent is selected.

EXAMPLE When an object is created when the list of allowed duplication targets is known, the policy would be created with *includeObject* CLEAR.

NOTE 1 Only the new parent may be selected because, without TPM2_PolicyAuthorize(), the Name of the Object to be duplicated would need to be known at the time that Object's policy is created. However, since the Name of the Object includes its policy, the Name is not known.

If used in conjunction with TPM2_PolicyAuthorize(), then the authorizer of the new policy has the option of selecting just the new parent or of selecting both the new parent and the duplication Object..

NOTE 2 If the authorizing entity for an TPM2_PolicyAuthorize() only specifies the new parent, then that authorization may be applied to the duplication of any number of other Objects. If the authorizing entity specifies both a new parent and the duplicated Object, then the authorization only applies to that pairing of Object and new parent.

If either *policySession*→*cpHash* or *policySession*→*nameHash* has been previously set, the TPM shall return TPM_RC_CPHASH. Otherwise, *policySession*→*nameHash* will be set to:

$$nameHash := H_{policyAlg}(objectName || newParentName) \quad (30)$$

NOTE 3 It is allowed that *policySession*→*nameHash* and *policySession*→*cpHash* share the same memory space.

The *policySession*→*policyDigest* will be updated according to the setting of *includeObject*. If equal to YES, *policySession*→*policyDigest* is updated by:

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyDuplicationSelect || objectName || newParentName || includeObject) \quad (31)$$

If *includeObject* is NO, *policySession*→*policyDigest* is updated by:

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyDuplicationSelect || newParentName || includeObject) \quad (32)$$

NOTE 4 *PolicySession*→*CpHash* receives the digest of both Names so that the check performed in TPM2_Duplicate() may be the same regardless of which Names are included in *policySession*→*policyDigest*. This means that, when TPM2_PolicyDuplicationSelect() is executed, it is only valid for a specific pair of duplication object and new parent.

If the command succeeds, *commandCode* in the policy session context is set to TPM_CC_Duplicate.

NOTE 5 The normal use of this command is before a TPM2_PolicyAuthorize(). An authorized entity would approve a *policyDigest* that allowed duplication to a specific new parent. The authorizing entity may want to limit the authorization so that the approval allows only a specific object to be duplicated to the new parent. In that case, the authorizing entity would approve the *policyDigest* of equation (31).

25.15.2 Command and Response

Table 137 — TPM2_PolicyDuplicationSelect Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyDuplicationSelect
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_NAME	objectName	the Name of the object to be duplicated
TPM2B_NAME	newParentName	the Name of the new parent
TPMI_YES_NO	includeObject	if YES, the <i>objectName</i> will be included in the value in <i>policySession</i> → <i>policyDigest</i>

Table 138 — TPM2_PolicyDuplicationSelect Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.15.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyDuplicationSelect_fp.h"

```

Error Returns	Meaning
TPM_RC_COMMAND_CODE	<i>commandCode</i> of <i>policySession</i> ; is not empty
TPM_RC_CPHASH	<i>cpHash</i> of <i>policySession</i> is not empty

```

3  TPM_RC
4  TPM2_PolicyDuplicationSelect(
5      PolicyDuplicationSelect_In *in           // IN: input parameter list
6  )
7  {
8      SESSION          *session;
9      HASH_STATE       hashState;
10     TPM_CC           commandCode = TPM_CC_PolicyDuplicationSelect;
11
12     // Input Validation
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     // cpHash in session context must be empty
18     if(session->u1.cpHash.t.size != 0)
19         return TPM_RC_CPHASH;
20
21     // commandCode in session context must be empty
22     if(session->commandCode != 0)
23         return TPM_RC_COMMAND_CODE;
24
25     // Internal Data Update
26
27     // Update name hash
28     session->u1.cpHash.t.size = CryptStartHash(session->authHashAlg, &hashState);
29
30     // add objectName
31     CryptUpdateDigest2B(&hashState, &in->objectName.b);
32
33     // add new parent name
34     CryptUpdateDigest2B(&hashState, &in->newParentName.b);
35
36     // complete hash
37     CryptCompleteHash2B(&hashState, &session->u1.cpHash.b);
38
39     // update policy hash
40     // Old policyDigest size should be the same as the new policyDigest size since
41     // they are using the same hash algorithm
42     session->u2.policyDigest.t.size
43         = CryptStartHash(session->authHashAlg, &hashState);
44
45     // add old policy
46     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
47
48     // add command code
49     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
50
51     // add objectName
52     if(in->includeObject == YES)
53         CryptUpdateDigest2B(&hashState, &in->objectName.b);

```

```
54
55     // add new parent name
56     CryptUpdateDigest2B(&hashState, &in->newParentName.b);
57
58     // add includeObject
59     CryptUpdateDigestInt(&hashState, sizeof(TPMI_YES_NO), &in->includeObject);
60
61     // complete digest
62     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
63
64     // clear iscpHashDefined bit to indicate now this field contains a nameHash
65     session->attributes.iscpHashDefined = CLEAR;
66
67     // set commandCode in session context
68     session->commandCode = TPM_CC_Duplicate;
69
70     return TPM_RC_SUCCESS;
71 }
```

25.16 TPM2_PolicyAuthorize

25.16.1 General Description

This command allows policies to change. If a policy were static, then it would be difficult to add users to a policy. This command lets a policy authority sign a new policy so that it may be used in an existing policy.

The authorizing entity signs a structure that contains

$$aHash := H_{aHashAlg}(approvedPolicy || policyRef) \quad (33)$$

The *aHashAlg* is required to be the *nameAlg* of the key used to sign the *aHash*. The *aHash* value is then signed (symmetric or asymmetric) by *keySign*. That signature is then checked by the TPM in TPM2_VerifySignature() which produces a ticket by

$$HMAC(proof, (TPM_ST_VERIFIED || aHash || keySign \rightarrow Name)) \quad (34)$$

NOTE The reason for the validation is because of the expectation that the policy will be used multiple times and it is more efficient to check a ticket than to load an object each time to check a signature.

The ticket is then used in TPM2_PolicyAuthorize() to validate the parameters.

The *keySign* parameter is required to be a valid object name using *nameAlg* other than TPM_ALG_NULL. If the first two octets of *keySign* are not a valid hash algorithm, the TPM shall return TPM_RC_HASH. If the remainder of the Name is not the size of the indicated digest, the TPM shall return TPM_RC_SIZE.

The TPM validates that the *approvedPolicy* matches the current value of *policySession*→*policyDigest* and if not, shall return TPM_RC_VALUE.

The TPM then validates that the parameters to TPM2_PolicyAuthorize() match the values used to generate the ticket. If so, the TPM will reset *policySession*→*policyDigest* to a Zero Digest. Then it will create a TPM2B_NAME (*keyName*) using *keySign* and update *policySession*→*policyDigest* with **PolicyUpdate()** (see 25.2.3).

$$\mathbf{PolicyUpdate}(TPM_CC_PolicyAuthorize, keyName, policyRef) \quad (35)$$

If the ticket is not valid, the TPM shall return TPM_RC_POLICY.

If *policySession* is a trial session, *policySession*→*policyDigest* is extended as if the ticket is valid without actual verification.

NOTE The unmarshaling process requires that a proper TPMT_TK_VERIFIED be provided for *checkTicket* but it may be a NULL Ticket.

25.16.2 Command and Response

Table 139 — TPM2_PolicyAuthorize Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyAuthorize
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPM2B_DIGEST	approvedPolicy	digest of the policy being approved
TPM2B_NONCE	policyRef	a policy qualifier
TPM2B_NAME	keySign	Name of a key that can sign a policy addition
TPMT_TK_VERIFIED	checkTicket	ticket validating that <i>approvedPolicy</i> and <i>policyRef</i> were signed by <i>keySign</i>

Table 140 — TPM2_PolicyAuthorize Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.16.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyAuthorize_fp.h"
3  #include "Policy_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_HASH	hash algorithm in <i>keyName</i> is not supported
TPM_RC_SIZE	<i>keyName</i> is not the correct size for its hash algorithm
TPM_RC_VALUE	the current <i>policyDigest</i> of <i>policySession</i> does not match <i>approvedPolicy</i> ; or <i>checkTicket</i> doesn't match the provided values

```

4  TPM_RC
5  TPM2_PolicyAuthorize(
6      PolicyAuthorize_In      *in      // IN: input parameter list
7  )
8  {
9      SESSION                  *session;
10     TPM2B_DIGEST              authHash;
11     HASH_STATE                hashState;
12     TPMT_TK_VERIFIED          ticket;
13     TPM_ALG_ID                hashAlg;
14     UINT16                    digestSize;
15
16     // Input Validation
17
18     // Get pointer to the session structure
19     session = SessionGet(in->policySession);
20
21     // Extract from the Name of the key, the algorithm used to compute it's Name
22     hashAlg = BYTE_ARRAY_TO_UINT16(in->keySign.t.name);
23
24     // 'keySign' parameter needs to use a supported hash algorithm, otherwise
25     // can't tell how large the digest should be
26     digestSize = CryptGetHashDigestSize(hashAlg);
27     if(digestSize == 0)
28         return TPM_RC_HASH + RC_PolicyAuthorize_keySign;
29
30     if(digestSize != (in->keySign.t.size - 2))
31         return TPM_RC_SIZE + RC_PolicyAuthorize_keySign;
32
33     //If this is a trial policy, skip all validations
34     if(session->attributes.isTrialPolicy == CLEAR)
35     {
36         // Check that "approvedPolicy" matches the current value of the
37         // policyDigest in policy session
38         if(!Memory2BEqual(&session->u2.policyDigest.b,
39                          &in->approvedPolicy.b))
40             return TPM_RC_VALUE + RC_PolicyAuthorize_approvedPolicy;
41
42         // Validate ticket TPMT_TK_VERIFIED
43         // Compute aHash. The authorizing object sign a digest
44         // aHash := hash(approvedPolicy || policyRef).
45         // Start hash
46         authHash.t.size = CryptStartHash(hashAlg, &hashState);
47
48         // add approvedPolicy
49         CryptUpdateDigest2B(&hashState, &in->approvedPolicy.b);
50

```

```
51     // add policyRef
52     CryptUpdateDigest2B(&hashState, &in->policyRef.b);
53
54     // complete hash
55     CryptCompleteHash2B(&hashState, &authHash.b);
56
57     // re-compute TPMT_TK_VERIFIED
58     TicketComputeVerified(in->checkTicket.hierarchy, &authHash,
59                          &in->keySign, &ticket);
60
61     // Compare ticket digest. If not match, return error
62     if(!Memory2BEqual(&in->checkTicket.digest.b, &ticket.digest.b))
63         return TPM_RC_VALUE+ RC_PolicyAuthorize_checkTicket;
64 }
65
66 // Internal Data Update
67
68 // Set policyDigest to zero digest
69 MemorySet(session->u2.policyDigest.t.buffer, 0,
70          session->u2.policyDigest.t.size);
71
72 // Update policyDigest
73 PolicyContextUpdate(TPM_CC_PolicyAuthorize, &in->keySign, &in->policyRef,
74                   NULL, 0, session);
75
76 return TPM_RC_SUCCESS;
77
78 }
```


25.17 TPM2_PolicyAuthValue

25.17.1 General Description

This command allows a policy to be bound to the authorization value of the authorized object.

When this command completes successfully, *policySession*→*isAuthValueNeeded* is SET to indicate that the *authValue* will be included in *hmacKey* when the authorization HMAC is computed for this session. Additionally, *policySession*→*isPasswordNeeded* will be CLEAR.

NOTE If a policy does not use this command, then the *hmacKey* for the authorized command would only use *sessionKey*. If *sessionKey* is not present, then the *hmacKey* is an Empty Buffer and no HMAC would be computed.

If successful, *policySession*→*policyDigest* will be updated with

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyAuthValue) \quad (36)$$

25.17.2 Command and Response

Table 141 — TPM2_PolicyAuthValue Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyAuthValue
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None

Table 142 — TPM2_PolicyAuthValue Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.17.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PolicyAuthValue_fp.h"
3  #include "Policy_spt_fp.h"
4  TPM_RC
5  TPM2_PolicyAuthValue(
6      PolicyAuthValue_In *in          // IN: input parameter list
7  )
8  {
9      SESSION          *session;
10     TPM_CC            commandCode = TPM_CC_PolicyAuthValue;
11     HASH_STATE        hashState;
12
13     // Internal Data Update
14
15     // Get pointer to the session structure
16     session = SessionGet(in->policySession);
17
18     // Update policy hash
19     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyAuthValue)
20     // Start hash
21     CryptStartHash(session->authHashAlg, &hashState);
22
23     // add old digest
24     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
25
26     // add commandCode
27     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
28
29     // complete the hash and get the results
30     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
31
32     // update isAuthValueNeeded bit in the session context
33     session->attributes.isAuthValueNeeded = SET;
34     session->attributes.isPasswordNeeded = CLEAR;
35
36     return TPM_RC_SUCCESS;
37 }
```

25.18 TPM2_PolicyPassword

25.18.1 General Description

This command allows a policy to be bound to the authorization value of the authorized object.

When this command completes successfully, *policySession*→*isPasswordNeeded* is SET to indicate that *authValue* of the authorized object will be checked when the session is used for authorization. The caller will provide the *authValue* in clear text in the *hmac* parameter of the authorization. The comparison of *hmac* to *authValue* is performed as if the authorization is a password.

NOTE 1 The parameter field in the policy session where the authorization value is provided is called *hmac*. If TPM2_PolicyPassword() is part of the sequence, then the field will contain a password and not an HMAC.

If successful, *policySession*→*policyDigest* will be updated with

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyAuthValue) \quad (37)$$

NOTE 2 This is the same extend value as used with TPM2_PolicyAuthValue so that the evaluation may be done using either an HMAC or a password with no change to the *authPolicy* of the object. The reason that two commands are present is to indicate to the TPM if the *hmac* field in the authorization will contain an HMAC or a password value.

When this command is successful, *policySession*→*isAuthValueNeeded* will be CLEAR.

25.18.2 Command and Response

Table 143 — TPM2_PolicyPassword Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyPassword
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None

Table 144 — TPM2_PolicyPassword Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.18.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PolicyPassword_fp.h"
3  #include "Policy_spt_fp.h"
4  TPM_RC
5  TPM2_PolicyPassword(
6      PolicyPassword_In  *in      // IN: input parameter list
7  )
8  {
9      SESSION            *session;
10     TPM_CC              commandCode = TPM_CC_PolicyAuthValue;
11     HASH_STATE          hashState;
12
13     // Internal Data Update
14
15     // Get pointer to the session structure
16     session = SessionGet(in->policySession);
17
18     // Update policy hash
19     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyAuthValue)
20     // Start hash
21     CryptStartHash(session->authHashAlg, &hashState);
22
23     // add old digest
24     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
25
26     // add commandCode
27     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
28
29     // complete the digest
30     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
31
32     // Update isPasswordNeeded bit
33     session->attributes.isPasswordNeeded = SET;
34     session->attributes.isAuthValueNeeded = CLEAR;
35
36     return TPM_RC_SUCCESS;
37 }
```

25.19 TPM2_PolicyGetDigest

25.19.1 General Description

This command returns the current *policyDigest* of the session. This command allows the TPM to be used to perform the actions required to pre-compute the *authPolicy* for an object.

25.19.2 Command and Response

Table 145 — TPM2_PolicyGetDigest Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyGetDigest
TPMI_SH_POLICY	policySession	handle for the policy session Auth Index: None

Table 146 — TPM2_PolicyGetDigest Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_DIGEST	policyDigest	the current value of the <i>policySession</i> → <i>policyDigest</i>

25.19.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PolicyGetDigest_fp.h"
3  TPM_RC
4  TPM2_PolicyGetDigest(
5      PolicyGetDigest_In      *in,           // IN: input parameter list
6      PolicyGetDigest_Out     *out          // OUT: output parameter list
7  )
8  {
9      SESSION      *session;
10
11  // Command Output
12
13  // Get pointer to the session structure
14  session = SessionGet(in->policySession);
15
16  out->policyDigest = session->u2.policyDigest;
17
18  return TPM_RC_SUCCESS;
19 }
```

25.20 TPM2_PolicyNvWritten

25.20.1 General Description

This command allows a policy to be bound to the TPMA_NV_WRITTEN attributes. This is a deferred assertion. Values are stored in the policy session context and checked when the policy is used for authorization.

If *policySession*→*checkNVWritten* is CLEAR, it is SET and *policySession*→*nvWrittenState* is set to *writtenSet*. If *policySession*→*checkNVWritten* is SET, the TPM will return TPM_RC_VALUE if *policySession*→*nvWrittenState* and *writtenSet* are not the same.

If the TPM does not return an error, it will update *policySession*→*policyDigest* by

$$policyDigest_{new} := H_{policyAlg}(policyDigest_{old} || TPM_CC_PolicyNvWritten || writtenSet) \quad (38)$$

When the policy session is used to authorize a command, the TPM will fail the command if *policySession*→*checkNVWritten* is SET and *nvIndex*→*attributes*→*TPMA_NV_WRITTEN* does not match *policySession*→*nvWrittenState*.

NOTE A typical use case is a simple policy for the first write during manufacturing provisioning that would require TPMA_NV_WRITTEN CLEAR and a more complex policy for later use that would require TPMA_NV_WRITTEN SET.

25.20.2 Command and Response

Table 147 — TPM2_PolicyNvWritten Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	Tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PolicyNVWritten
TPMI_SH_POLICY	policySession	handle for the policy session being extended Auth Index: None
TPMI_YES_NO	writtenSet	YES if NV Index is required to have been written NO if NV Index is required not to have been written

Table 148 — TPM2_PolicyNvWritten Response

Type	Name	Description
TPM_ST	Tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

25.20.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "PolicyNvWritten_fp.h"

```

Make an NV Index policy dependent on the state of the TPMA_NV_WRITTEN attribute of the index.

Error Returns	Meaning
TPM_RC_VALUE	a conflicting request for the attribute has already been processed

```

3  TPM_RC
4  TPM2_PolicyNvWritten(
5      PolicyNvWritten_In  *in      // IN: input parameter list
6  )
7  {
8      SESSION      *session;
9      TPM_CC       commandCode = TPM_CC_PolicyNvWritten;
10     HASH_STATE   hashState;
11
12     // Input Validation
13
14     // Get pointer to the session structure
15     session = SessionGet(in->policySession);
16
17     // If already set is this a duplicate (the same setting)? If it
18     // is a conflicting setting, it is an error
19     if(session->attributes.checkNvWritten == SET)
20     {
21         if(( (session->attributes.nvWrittenState == SET)
22             != (in->writtenSet == YES)))
23             return TPM_RC_VALUE + RC_PolicyNvWritten_writtenSet;
24     }
25
26
27     // Internal Data Update
28
29     // Set session attributes so that the NV Index needs to be checked
30     session->attributes.checkNvWritten = SET;
31     session->attributes.nvWrittenState = (in->writtenSet == YES);
32
33     // Update policy hash
34     // policyDigestnew = hash(policyDigestold || TPM_CC_PolicyNvWritten
35     //                        || writtenSet)
36     // Start hash
37     CryptStartHash(session->authHashAlg, &hashState);
38
39     // add old digest
40     CryptUpdateDigest2B(&hashState, &session->u2.policyDigest.b);
41
42     // add commandCode
43     CryptUpdateDigestInt(&hashState, sizeof(TPM_CC), &commandCode);
44
45     // add the byte of writtenState
46     CryptUpdateDigestInt(&hashState, sizeof(TPMI_YES_NO), &in->writtenSet);
47
48     // complete the digest
49     CryptCompleteHash2B(&hashState, &session->u2.policyDigest.b);
50
51     return TPM_RC_SUCCESS;
52 }

```


26 Hierarchy Commands

26.1 TPM2_CreatePrimary

26.1.1 General Description

This command is used to create a Primary Object under one of the Primary Seeds or a Temporary Object under TPM_RH_NULL. The command uses a TPM2B_PUBLIC as a template for the object to be created. The command will create and load a Primary Object. The sensitive area is not returned.

NOTE: Since the sensitive data is not returned, the key cannot be reloaded. It can either be made persistent or it can be recreated.

Any type of object and attributes combination that is allowed by TPM2_Create() may be created by this command. The constraints on templates and parameters are the same as TPM2_Create() except that a Primary Storage Key and a Temporary Storage Key are not constrained to use the algorithms of their parents.

For setting of the attributes of the created object, *fixedParent*, *fixedTPM*, *userWithAuth*, *adminWithPolicy*, *encrypt*, and *restricted* are implied to be SET in the parent (a Permanent Handle). The remaining attributes are implied to be CLEAR.

The TPM will derive the object from the Primary Seed indicated in *primaryHandle* using an approved KDF. All of the bits of the template are used in the creation of the Primary Key. Methods for creating a Primary Object from a Primary Seed are described in Part 1 of this specification and implemented in Part 4.

If this command is called multiple times with the same *inPublic* parameter, *inSensitive.data*, and Primary Seed, the TPM shall produce the same Primary Object.

NOTE If the Primary Seed is changed, the Primary Objects generated with the new seed shall be statistically unique even if the parameters of the call are the same.

This command requires authorization. Authorization for a Primary Object attached to the Platform Primary Seed (PPS) shall be provided by *platformAuth* or *platformPolicy*. Authorization for a Primary Object attached to the Storage Primary Seed (SPS) shall be provided by *ownerAuth* or *ownerPolicy*. Authorization for a Primary Key attached to the Endorsement Primary Seed (EPS) shall be provided by *endorsementAuth* or *endorsementPolicy*.

26.1.2 Command and Response

Table 149 — TPM2_CreatePrimary Command

Type	Name	Description
TPML_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_HIERARCHY+	commandCode @primaryHandle	TPM_CC_CreatePrimary TPM_RH_ENDORSEMENT, TPM_RH_OWNER, TPM_RH_PLATFORM+{PP}, or TPM_RH_NULL Auth Index: 1 Auth Role: USER
TPM2B_SENSITIVE_CREATE	inSensitive	the sensitive data, see Part 1 Sensitive Values
TPM2B_PUBLIC	inPublic	the public template
TPM2B_DATA	outsideInfo	data that will be included in the creation data for this object to provide permanent, verifiable linkage between this object and some object owner data
TPML_PCR_SELECTION	creationPCR	PCR that will be used in creation data

Table 150 — TPM2_CreatePrimary Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC TPM_HANDLE	responseCode objectHandle Handle for created Primary Object
TPM2B_PUBLIC	outPublic	the public portion of the created object
TPM2B_CREATION_DATA	creationData	contains a TPMT_CREATION_DATA
TPM2B_DIGEST	creationHash	digest of <i>creationData</i> using <i>nameAlg</i> of <i>outPublic</i>
TPMT_TK_CREATION	creationTicket	ticket used by TPM2_CertifyCreation() to validate that the creation data was produced by the TPM
TPM2B_NAME	name	the name of the created object

26.1.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "CreatePrimary_fp.h"
3  #include "Object_spt_fp.h"
4  #include <Platform.h>

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	<i>sensitiveDataOrigin</i> is CLEAR when 'sensitive. data' is an Empty Buffer, or is SET when 'sensitive. data' is not empty; <i>fixedTPM</i> , <i>fixedParent</i> , or <i>encryptedDuplication</i> attributes are inconsistent between themselves or with those of the parent object; inconsistent <i>restricted</i> , <i>decrypt</i> and <i>sign</i> attributes; attempt to inject sensitive data for an asymmetric key; attempt to create a symmetric cipher key that is not a decryption key
TPM_RC_KDF	incorrect KDF specified for decrypting keyed hash object
TPM_RC_OBJECT_MEMORY	there is no free slot for the object
TPM_RC_SCHEME	inconsistent attributes <i>decrypt</i> , <i>sign</i> , <i>restricted</i> and key's scheme ID; or hash algorithm is inconsistent with the scheme ID for keyed hash object
TPM_RC_SIZE	size of public auth policy or sensitive auth value does not match digest size of the name algorithm sensitive data size for the keyed hash object is larger than is allowed for the scheme
TPM_RC_SYMMETRIC	a storage key with no symmetric algorithm specified; or non-storage key with symmetric algorithm different from TPM_ALG_NULL
TPM_RC_TYPE	unknown object type;

```

5  TPM_RC
6  TPM2_CreatePrimary(
7      CreatePrimary_In  *in,          // IN: input parameter list
8      CreatePrimary_Out *out         // OUT: output parameter list
9  )
10 {
11     // Local variables
12     TPM_RC      result = TPM_RC_SUCCESS;
13     TPMT_SENSITIVE sensitive;
14
15     // Input Validation
16     // The sensitiveDataOrigin attribute must be consistent with the setting of
17     // the size of the data object in inSensitive.
18     if( (in->inPublic.t.publicArea.objectAttributes.sensitiveDataOrigin == SET)
19         != (in->inSensitive.t.sensitive.data.t.size == 0) )
20         // Mismatch between the object attributes and the parameter.
21         return TPM_RC_ATTRIBUTES + RC_CreatePrimary_inSensitive;
22
23     // Check attributes in input public area. TPM_RC_ATTRIBUTES, TPM_RC_KDF,
24     // TPM_RC_SCHEME, TPM_RC_SIZE, TPM_RC_SYMMETRIC, or TPM_RC_TYPE error may
25     // be returned at this point.
26     result = PublicAttributesValidation(FALSE, in->primaryHandle,
27                                       &in->inPublic.t.publicArea);
28     if(result != TPM_RC_SUCCESS)
29         return RcSafeAddToResult(result, RC_CreatePrimary_inPublic);
30
31     // Validate the sensitive area values
32     if( MemoryRemoveTrailingZeros(&in->inSensitive.t.sensitive.userAuth)
33         > CryptGetHashDigestSize(in->inPublic.t.publicArea.nameAlg) )

```



```
34     return TPM_RC_SIZE + RC_CreatePrimary_inSensitive;
35
36 // Command output
37
38 // Generate Primary Object
39 // The primary key generation process uses the Name of the input public
40 // template to compute the key. The keys are generated from the template
41 // before anything in the template is allowed to be changed.
42 // A TPM_RC_KDF, TPM_RC_SIZE error may be returned at this point
43 result = CryptCreateObject(in->primaryHandle, &in->inPublic.t.publicArea,
44                          &in->inSensitive.t.sensitive, &sensitive);
45 if(result != TPM_RC_SUCCESS)
46     return result;
47
48 // Fill in creation data
49 FillInCreationData(in->primaryHandle, in->inPublic.t.publicArea.nameAlg,
50                  &in->creationPCR, &in->outsideInfo, &out->creationData,
51                  &out->creationHash);
52
53 // Copy public area
54 out->outPublic = in->inPublic;
55
56 // Fill in private area for output
57 ObjectComputeName(&(out->outPublic.t.publicArea), &out->name);
58
59 // Compute creation ticket
60 TicketComputeCreation(EntityGetHierarchy(in->primaryHandle), &out->name,
61                               &out->creationHash, &out->creationTicket);
62
63 // Create a internal object. A TPM_RC_OBJECT_MEMORY error may be returned
64 // at this point.
65 result = ObjectLoad(in->primaryHandle, &in->inPublic.t.publicArea, &sensitive,
66                  &out->name, in->primaryHandle, TRUE, &out->objectHandle);
67
68 return result;
69 }
```

26.2 TPM2_HierarchyControl

26.2.1 General Description

This command enables and disables use of a hierarchy and its associated NV storage. The command allows *phEnable*, *phEnableNV*, *shEnable*, and *ehEnable* to be changed when the proper authorization is provided.

This command may be used to CLEAR *phEnable* and *phEnableNV* if *platformAuth/platformPolicy* is provided. *phEnable* may not be SET using this command.

This command may be used to CLEAR *shEnable* if either *platformAuth/platformPolicy* or *ownerAuth/ownerPolicy* is provided. *shEnable* may be SET if *platformAuth/platformPolicy* is provided.

This command may be used to CLEAR *ehEnable* if either *platformAuth/platformPolicy* or *endorsementAuth/endorsementPolicy* is provided. *ehEnable* may be SET if *platformAuth/platformPolicy* is provided.

When this command is used to CLEAR *phEnable*, *shEnable*, or *ehEnable*, the TPM will disable use of any persistent entity associated with the disabled hierarchy and will flush any transient objects associated with the disabled hierarchy.

When this command is used to CLEAR *shEnable*, the TPM will disable access to any NV index that has TPMA_NV_PLATFORMCREATE CLEAR (indicating that the NV Index was defined using *ownerAuth*). As long as *shEnable* is CLEAR, the TPM will return an error in response to any command that attempts to operate upon an NV index that has TPMA_NV_PLATFORMCREATE CLEAR.

When this command is used to CLEAR *phEnableNV*, the TPM will disable access to any NV index that has TPMA_NV_PLATFORMCREATE SET (indicating that the NV Index was defined using *platformAuth*). As long as *phEnableNV* is CLEAR, the TPM will return an error in response to any command that attempts to operate upon an NV index that has TPMA_NV_PLATFORMCREATE SET.

26.2.2 Command and Response

Table 151 — TPM2_HierarchyControl Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_HIERARCHY	commandCode @authHandle	TPM_CC_HierarchyControl {NV E} TPM_RH_ENDORSEMENT, TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPMI_RH_ENABLES	enable	the enable being modified TPM_RH_ENDORSEMENT, TPM_RH_OWNER, TPM_RH_PLATFORM, or TPM_RH_PLATFORM_NV
TPMI_YES_NO	state	YES if the enable should be SET, NO if the enable should be CLEAR

Table 152 — TPM2_HierarchyControl Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "HierarchyControl_fp.h"

```

Error Returns	Meaning
TPM_RC_AUTH_TYPE	<i>authHandle</i> is not applicable to <i>hierarchy</i> in its current state

```

3  TPM_RC
4  TPM2_HierarchyControl(
5      HierarchyControl_In    *in        // IN: input parameter list
6  )
7  {
8      TPM_RC    result;
9      BOOL      select = (in->state == YES);
10     BOOL      *selected = NULL;
11
12     // Input Validation
13     switch(in->enable)
14     {
15         // Platform hierarchy has to be disabled by platform auth
16         // If the platform hierarchy has already been disabled, only a reboot
17         // can enable it again
18         case TPM_RH_PLATFORM:
19         case TPM_RH_PLATFORM_NV:
20             if(in->authHandle != TPM_RH_PLATFORM)
21                 return TPM_RC_AUTH_TYPE;
22             break;
23
24         // ShEnable may be disabled if PlatformAuth/PlatformPolicy or
25         // OwnerAuth/OwnerPolicy is provided. If ShEnable is disabled, then it
26         // may only be enabled if PlatformAuth/PlatformPolicy is provided.
27         case TPM_RH_OWNER:
28             if( in->authHandle != TPM_RH_PLATFORM
29                 && in->authHandle != TPM_RH_OWNER)
30                 return TPM_RC_AUTH_TYPE;
31             if( gc.shEnable == FALSE && in->state == YES
32                 && in->authHandle != TPM_RH_PLATFORM)
33                 return TPM_RC_AUTH_TYPE;
34             break;
35
36         // EhEnable may be disabled if either PlatformAuth/PlatformPolicy or
37         // EndorsementAuth/EndorsementPolicy is provided. If EhEnable is disabled,
38         // then it may only be enabled if PlatformAuth/PlatformPolicy is
39         // provided.
40         case TPM_RH_ENDORSEMENT:
41             if( in->authHandle != TPM_RH_PLATFORM
42                 && in->authHandle != TPM_RH_ENDORSEMENT)
43                 return TPM_RC_AUTH_TYPE;
44             if( gc.ehEnable == FALSE && in->state == YES
45                 && in->authHandle != TPM_RH_PLATFORM)
46                 return TPM_RC_AUTH_TYPE;
47             break;
48         default:
49             pAssert(FALSE);
50             break;
51     }
52
53     // Internal Data Update
54

```

```
55 // Enable or disable the selected hierarchy
56 // Note: the authorization processing for this command may keep these
57 // command actions from being executed. For example, if phEnable is
58 // CLEAR, then platformAuth cannot be used for authorization. This
59 // means that would not be possible to use platformAuth to change the
60 // state of phEnable from CLEAR to SET.
61 // If it is decided that platformPolicy can still be used when phEnable
62 // is CLEAR, then this code could SET phEnable when proper platform
63 // policy is provided.
64 switch(in->enable)
65 {
66     case TPM_RH_OWNER:
67         selected = &gc.shEnable;
68         break;
69     case TPM_RH_ENDORSEMENT:
70         selected = &gc.ehEnable;
71         break;
72     case TPM_RH_PLATFORM:
73         selected = &g_phEnable;
74         break;
75     case TPM_RH_PLATFORM_NV:
76         selected = &gc.phEnableNV;
77         break;
78     default:
79         pAssert(FALSE);
80         break;
81 }
82 if(selected != NULL && *selected != select)
83 {
84     // Before changing the internal state, make sure that NV is available.
85     // Only need to update NV if changing the orderly state
86     if(gp.orderlyState != SHUTDOWN_NONE)
87     {
88         // The command needs NV update. Check if NV is available.
89         // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
90         // this point
91         result = NvIsAvailable();
92         if(result != TPM_RC_SUCCESS)
93             return result;
94     }
95     // state is changing and NV is available so modify
96     *selected = select;
97     // If a hierarchy was just disabled, flush it
98     if(select == CLEAR && in->enable != TPM_RH_PLATFORM_NV)
99         // Flush hierarchy
100         ObjectFlushHierarchy(in->enable);
101
102     // orderly state should be cleared because of the update to state clear data
103     // This gets processed in ExecuteCommand() on the way out.
104     g_clearOrderly = TRUE;
105 }
106 return TPM_RC_SUCCESS;
107 }
```

26.3 TPM2_SetPrimaryPolicy

26.3.1 General Description

This command allows setting of the authorization policy for the platform hierarchy (*platformPolicy*), the storage hierarchy (*ownerPolicy*), and the endorsement hierarchy (*endorsementPolicy*).

The command requires an authorization session. The session shall use the current *authValue* or satisfy the current *authPolicy* for the referenced hierarchy.

The policy that is changed is the policy associated with *authHandle*.

If the enable associated with *authHandle* is not SET, then the associated authorization values (*authValue* or *authPolicy*) may not be used.

26.3.2 Command and Response

Table 153 — TPM2_SetPrimaryPolicy Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_HIERARCHY	commandCode @authHandle	TPM_CC_SetPrimaryPolicy {NV} TPM_RH_ENDORSEMENT, TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPM2B_DIGEST	authPolicy	an authorization policy digest; may be the Empty Buffer If <i>hashAlg</i> is TPM_ALG_NULL, then this shall be an Empty Buffer.
TPMI_ALG_HASH+	hashAlg	the hash algorithm to use for the policy If the <i>authPolicy</i> is an Empty Buffer, then this field shall be TPM_ALG_NULL.

Table 154 — TPM2_SetPrimaryPolicy Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "SetPrimaryPolicy_fp.h"

```

Error Returns	Meaning
TPM_RC_SIZE	size of input <i>authPolicy</i> is not consistent with input hash algorithm

```

3  TPM_RC
4  TPM2_SetPrimaryPolicy(
5      SetPrimaryPolicy_In    *in        // IN: input parameter list
6  )
7  {
8      TPM_RC                result;
9
10     // Input Validation
11
12     // Check the authPolicy consistent with hash algorithm
13     if( in->authPolicy.t.size != 0
14         && in->authPolicy.t.size != CryptGetHashDigestSize(in->hashAlg))
15         return TPM_RC_SIZE + RC_SetPrimaryPolicy_authPolicy;
16
17     // The command need NV update for OWNER and ENDORSEMENT hierarchy, and
18     // might need orderlyState update for PLATFORM hierarchy.
19     // Check if NV is available. A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE
20     // error may be returned at this point
21     result = NvIsAvailable();
22     if(result != TPM_RC_SUCCESS)
23         return result;
24
25     // Internal Data Update
26
27     // Set hierarchy policy
28     switch(in->authHandle)
29     {
30         case TPM_RH_OWNER:
31             gp.ownerAlg = in->hashAlg;
32             gp.ownerPolicy = in->authPolicy;
33             NvWriteReserved(NV_OWNER_ALG, &gp.ownerAlg);
34             NvWriteReserved(NV_OWNER_POLICY, &gp.ownerPolicy);
35             break;
36         case TPM_RH_ENDORSEMENT:
37             gp.endorsementAlg = in->hashAlg;
38             gp.endorsementPolicy = in->authPolicy;
39             NvWriteReserved(NV_ENDORSEMENT_ALG, &gp.endorsementAlg);
40             NvWriteReserved(NV_ENDORSEMENT_POLICY, &gp.endorsementPolicy);
41             break;
42         case TPM_RH_PLATFORM:
43             gc.platformAlg = in->hashAlg;
44             gc.platformPolicy = in->authPolicy;
45             // need to update orderly state
46             g_clearOrderly = TRUE;
47             break;
48         default:
49             pAssert(FALSE);
50             break;
51     }
52
53     return TPM_RC_SUCCESS;
54 }

```


26.4 TPM2_ChangePPS

26.4.1 General Description

This replaces the current PPS with a value from the RNG and sets *platformPolicy* to the default initialization value (the Empty Buffer).

NOTE 1 A policy that is the Empty Buffer can match no policy.

NOTE 2 *platformAuth* is not changed.

All loaded transient and persistent objects in the Platform hierarchy are flushed.

Saved contexts in the Platform hierarchy that were created under the old PPS will no longer be able to be loaded.

The policy hash algorithm for PCR is reset to TPM_ALG_NULL.

This command does not clear any NV Index values.

NOTE 3 Index values belonging to the Platform are preserved because the indexes may have configuration information that will be the same after the PPS changes. The Platform may remove the indexes that are no longer needed using TPM2_NV_UndefineSpace().

This command requires *platformAuth*.

26.4.2 Command and Response

Table 155 — TPM2_ChangePPS Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ChangePPS {NV E}
TPMI_RH_PLATFORM	@authHandle	TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER

Table 156 — TPM2_ChangePPS Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ChangePPS_fp.h"
3  TPM_RC
4  TPM2_ChangePPS(
5      ChangePPS_In      *in          // IN: input parameter list
6  )
7  {
8      UINT32          i;
9      TPM_RC          result;
10
11     // Check if NV is available. A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE
12     // error may be returned at this point
13     result = NvIsAvailable();
14     if(result != TPM_RC_SUCCESS) return result;
15
16     // Input parameter is not reference in command action
17     in = NULL;
18
19     // Internal Data Update
20
21     // Reset platform hierarchy seed from RNG
22     CryptGenerateRandom(PRIMARY_SEED_SIZE, gp.PPSeed.t.buffer);
23
24     // Create a new phProof value from RNG to prevent the saved platform
25     // hierarchy contexts being loaded
26     CryptGenerateRandom(PROOF_SIZE, gp.phProof.t.buffer);
27
28     // Set platform authPolicy to null
29     gc.platformAlg = TPM_ALG_NULL;
30     gc.platformPolicy.t.size = 0;
31
32     // Flush loaded object in platform hierarchy
33     ObjectFlushHierarchy(TPM_RH_PLATFORM);
34
35     // Flush platform evict object and index in NV
36     NvFlushHierarchy(TPM_RH_PLATFORM);
37
38     // Save hierarchy changes to NV
39     NvWriteReserved(NV_PP_SEED, &gp.PPSeed);
40     NvWriteReserved(NV_PH_PROOF, &gp.phProof);
41
42     // Re-initialize PCR policies
43     for(i = 0; i < NUM_POLICY_PCR_GROUP; i++)
44     {
45         gp.pcrPolicies.hashAlg[i] = TPM_ALG_NULL;
46         gp.pcrPolicies.policy[i].t.size = 0;
47     }
48     NvWriteReserved(NV_PCR_POLICIES, &gp.pcrPolicies);
49
50     // orderly state should be cleared because of the update to state clear data
51     g_clearOrderly = TRUE;
52
53     return TPM_RC_SUCCESS;
54 }

```

26.5 TPM2_ChangeEPS

26.5.1 General Description

This replaces the current EPS with a value from the RNG and sets the Endorsement hierarchy controls to their default initialization values: *ehEnable* is SET, *endorsementAuth* and *endorsementPolicy* both equal to the Empty Buffer. It will flush any loaded objects in the EPS hierarchy and not allow objects in the hierarchy associated with the previous EPS to be loaded.

NOTE In the reference implementation, *ehProof* is a non-volatile value from the RNG. It is allowed that the *ehProof* be generated by a KDF using both the EPS and SPS as inputs. If generated with a KDF, the *ehProof* can be generated on an as-needed basis or made a non-volatile value.

This command requires *platformAuth*.

26.5.2 Command and Response

Table 157 — TPM2_ChangeEPS Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ChangeEPS {NV E}
TPMI_RH_PLATFORM	@authHandle	TPM_RH_PLATFORM+{PP} Auth Handle: 1 Auth Role: USER

Table 158 — TPM2_ChangeEPS Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ChangeEPS_fp.h"
3  TPM_RC
4  TPM2_ChangeEPS(
5      ChangeEPS_In      *in          // IN: input parameter list
6  )
7  {
8      TPM_RC      result;
9
10     // The command needs NV update. Check if NV is available.
11     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
12     // this point
13     result = NvIsAvailable();
14     if(result != TPM_RC_SUCCESS) return result;
15
16     // Input parameter is not reference in command action
17     in = NULL;
18
19     // Internal Data Update
20
21     // Reset endorsement hierarchy seed from RNG
22     CryptGenerateRandom(PRIMARY_SEED_SIZE, gp.EPSeed.t.buffer);
23
24     // Create new ehProof value from RNG
25     CryptGenerateRandom(PROOF_SIZE, gp.ehProof.t.buffer);
26
27     // Enable endorsement hierarchy
28     gc.ehEnable = TRUE;
29
30     // set authValue buffer to zeros
31     MemorySet(gp.endorsementAuth.t.buffer, 0, gp.endorsementAuth.t.size);
32     // Set endorsement authValue to null
33     gp.endorsementAuth.t.size = 0;
34
35     // Set endorsement authPolicy to null
36     gp.endorsementAlg = TPM_ALG_NULL;
37     gp.endorsementPolicy.t.size = 0;
38
39     // Flush loaded object in endorsement hierarchy
40     ObjectFlushHierarchy(TPM_RH_ENDORSEMENT);
41
42     // Flush evict object of endorsement hierarchy stored in NV
43     NvFlushHierarchy(TPM_RH_ENDORSEMENT);
44
45     // Save hierarchy changes to NV
46     NvWriteReserved(NV_EP_SEED, &gp.EPSeed);
47     NvWriteReserved(NV_EH_PROOF, &gp.ehProof);
48     NvWriteReserved(NV_ENDORSEMENT_AUTH, &gp.endorsementAuth);
49     NvWriteReserved(NV_ENDORSEMENT_ALG, &gp.endorsementAlg);
50     NvWriteReserved(NV_ENDORSEMENT_POLICY, &gp.endorsementPolicy);
51
52     // orderly state should be cleared because of the update to state clear data
53     g_clearOrderly = TRUE;
54
55     return TPM_RC_SUCCESS;
56 }

```

26.6 TPM2_Clear

26.6.1 General Description

This command removes all TPM context associated with a specific Owner.

The clear operation will:

- flush loaded objects (persistent and volatile) in the Storage and Endorsement hierarchies;
- delete any NV Index with TPMA_NV_PLATFORMCREATE == CLEAR;
- change the SPS to a new value from the TPM's random number generator (RNG),
- change shProof and ehProof,

NOTE The proof values may be set from the RNG or derived from the associated new Primary Seed. If derived from the Primary Seeds, the derivation of *ehProof* shall use both the SPS and EPS. The computation shall use the SPS as an HMAC key and the derived value may then be a parameter in a second HMAC in which the EPS is the HMAC key. The reference design uses values from the RNG.

- SET shEnable and ehEnable;
- set ownerAuth, endorsementAuth, and lockoutAuth to the Empty Buffer;
- set *ownerPolicy* and *endorsementPolicy* to the Empty Buffer;
- set *Clock* to zero;
- set *resetCount* to zero;
- set *restartCount* to zero; and
- set *Safe* to YES.

This command requires *platformAuth* or *lockoutAuth*. If TPM2_ClearControl() has disabled this command, the TPM shall return TPM_RC_DISABLED.

If this command is authorized using *lockoutAuth*, the HMAC in the response shall use the new *lockoutAuth* value (that is, the Empty Buffer) when computing response HMAC.

26.6.2 Command and Response

Table 159 — TPM2_Clear Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_Clear {NV E}
TPMI_RH_CLEAR	@authHandle	TPM_RH_LOCKOUT or TPM_RH_PLATFORM+{PP} Auth Handle: 1 Auth Role: USER

Table 160 — TPM2_Clear Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.6.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Clear_fp.h"

```

Error Returns	Meaning
TPM_RC_DISABLED	Clear command has been disabled

```

3  TPM_RC
4  TPM2_Clear(
5      Clear_In      *in          // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9
10     // Input parameter is not reference in command action
11     in = NULL;
12
13     // The command needs NV update. Check if NV is available.
14     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
15     // this point
16     result = NvIsAvailable();
17     if(result != TPM_RC_SUCCESS) return result;
18
19     // Input Validation
20
21     // If Clear command is disabled, return an error
22     if(gp.disableClear)
23         return TPM_RC_DISABLED;
24
25     // Internal Data Update
26
27     // Reset storage hierarchy seed from RNG
28     CryptGenerateRandom(PRIMARY_SEED_SIZE, gp.SPSeed.t.buffer);
29
30     // Create new shProof and ehProof value from RNG
31     CryptGenerateRandom(PROOF_SIZE, gp.shProof.t.buffer);
32     CryptGenerateRandom(PROOF_SIZE, gp.ehProof.t.buffer);
33
34     // Enable storage and endorsement hierarchy
35     gc.shEnable = gc.ehEnable = TRUE;
36
37     // set the authValue buffers to zero
38     MemorySet(gp.ownerAuth.t.buffer, 0, gp.ownerAuth.t.size);
39     MemorySet(gp.endorsementAuth.t.buffer, 0, gp.endorsementAuth.t.size);
40     MemorySet(gp.lockoutAuth.t.buffer, 0, gp.lockoutAuth.t.size);
41     // Set storage, endorsement and lockout authValue to null
42     gp.ownerAuth.t.size = gp.endorsementAuth.t.size = gp.lockoutAuth.t.size = 0;
43
44     // Set storage and endorsement authPolicy to null
45     gp.ownerAlg = gp.endorsementAlg = TPM_ALG_NULL;
46     gp.ownerPolicy.t.size = gp.endorsementPolicy.t.size = 0;
47
48     // Flush loaded object in storage and endorsement hierarchy
49     ObjectFlushHierarchy(TPM_RH_OWNER);
50     ObjectFlushHierarchy(TPM_RH_ENDORSEMENT);
51
52     // Flush owner and endorsement object and owner index in NV
53     NvFlushHierarchy(TPM_RH_OWNER);
54     NvFlushHierarchy(TPM_RH_ENDORSEMENT);

```

```
55
56 // Save hierarchy changes to NV
57 NvWriteReserved(NV_SP_SEED, &gp.SPSeed);
58 NvWriteReserved(NV_SH_PROOF, &gp.shProof);
59 NvWriteReserved(NV_EH_PROOF, &gp.ehProof);
60 NvWriteReserved(NV_OWNER_AUTH, &gp.ownerAuth);
61 NvWriteReserved(NV_ENDORSEMENT_AUTH, &gp.endorsementAuth);
62 NvWriteReserved(NV_LOCKOUT_AUTH, &gp.lockoutAuth);
63 NvWriteReserved(NV_OWNER_ALG, &gp.ownerAlg);
64 NvWriteReserved(NV_ENDORSEMENT_ALG, &gp.endorsementAlg);
65 NvWriteReserved(NV_OWNER_POLICY, &gp.ownerPolicy);
66 NvWriteReserved(NV_ENDORSEMENT_POLICY, &gp.endorsementPolicy);
67
68 // Initialize dictionary attack parameters
69 DAPreInstall_Init();
70
71 // Reset clock
72 go.clock = 0;
73 go.clockSafe = YES;
74 // Update the DRBG state whenever writing orderly state to NV
75 CryptDrbgGetPutState(GET_STATE);
76 NvWriteReserved(NV_ORDERLY_DATA, &go);
77
78 // Reset counters
79 gp.resetCount = gr.restartCount = gr.clearCount = 0;
80 gp.auditCounter = 0;
81 NvWriteReserved(NV_RESET_COUNT, &gp.resetCount);
82 NvWriteReserved(NV_AUDIT_COUNTER, &gp.auditCounter);
83
84 // orderly state should be cleared because of the update to state clear data
85 g_clearOrderly = TRUE;
86
87 return TPM_RC_SUCCESS;
88 }
```

26.7 TPM2_ClearControl

26.7.1 General Description

TPM2_ClearControl() disables and enables the execution of TPM2_Clear().

The TPM will SET the TPM's TPMA_PERMANENT.*disableClear* attribute if *disable* is YES and will CLEAR the attribute if *disable* is NO. When the attribute is SET, TPM2_Clear() may not be executed.

NOTE This is to simplify the logic of TPM2_Clear(). TPM2_ClearControl() can be called using *platformAuth* to CLEAR the *disableClear* attribute and then execute TPM2_Clear().

LockoutAuth may be used to SET *disableClear* but not to CLEAR it.

PlatformAuth may be used to SET or CLEAR *disableClear*.

26.7.2 Command and Response

Table 161 — TPM2_ClearControl Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_CLEAR	commandCode @auth	TPM_CC_ClearControl {NV} TPM_RH_LOCKOUT or TPM_RH_PLATFORM+{PP} Auth Handle: 1 Auth Role: USER
TPMI_YES_NO	disable	YES if the <i>disableOwnerClear</i> flag is to be SET, NO if the flag is to be CLEAR.

Table 162 — TPM2_ClearControl Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ClearControl_fp.h"

```

Error Returns	Meaning
TPM_RC_AUTH_FAIL	authorization is not properly given

```

3  TPM_RC
4  TPM2_ClearControl(
5      ClearControl_In      *in          // IN: input parameter list
6  )
7  {
8      TPM_RC      result;
9
10     // The command needs NV update. Check if NV is available.
11     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
12     // this point
13     result = NvIsAvailable();
14     if(result != TPM_RC_SUCCESS) return result;
15
16     // Input Validation
17
18     // LockoutAuth may be used to set disableLockoutClear to TRUE but not to FALSE
19     if(in->auth == TPM_RH_LOCKOUT && in->disable == NO)
20         return TPM_RC_AUTH_FAIL;
21
22     // Internal Data Update
23
24     if(in->disable == YES)
25         gp.disableClear = TRUE;
26     else
27         gp.disableClear = FALSE;
28
29     // Record the change to NV
30     NvWriteReserved(NV_DISABLE_CLEAR, &gp.disableClear);
31
32     return TPM_RC_SUCCESS;
33 }

```

26.8 TPM2_HierarchyChangeAuth

26.8.1 General Description

This command allows the authorization secret for a hierarchy or lockout to be changed using the current authorization value as the command authorization.

If *authHandle* is TPM_RH_PLATFORM, then *platformAuth* is changed. If *authHandle* is TPM_RH_OWNER, then *ownerAuth* is changed. If *authHandle* is TPM_RH_ENDORSEMENT, then *endorsementAuth* is changed. If *authHandle* is TPM_RH_LOCKOUT, then *lockoutAuth* is changed.

If *authHandle* is TPM_RH_PLATFORM, then Physical Presence may need to be asserted for this command to succeed (see 28.2, “TPM2_PP_Commands”).

The authorization value may be no larger than the digest produced by the hash algorithm used for context integrity.

EXAMPLE If SHA384 is used in the computation of the integrity values for saved contexts, then the largest authorization value is 48 octets.

26.8.2 Command and Response

Table 163 — TPM2_HierarchyChangeAuth Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_HIERARCHY_AUTH	commandCode @authHandle	TPM_CC_HierarchyChangeAuth {NV} TPM_RH_LOCKOUT, TPM_RH_ENDORSEMENT, TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPM2B_AUTH	newAuth	new authorization value

Table 164 — TPM2_HierarchyChangeAuth Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

26.8.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "HierarchyChangeAuth_fp.h"
3  #include "Object_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_SIZE	<i>newAuth</i> size is greater than that of integrity hash digest

```

4  TPM_RC
5  TPM2_HierarchyChangeAuth(
6      HierarchyChangeAuth_In      *in          // IN: input parameter list
7  )
8  {
9      TPM_RC      result;
10
11     // The command needs NV update. Check if NV is available.
12     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
13     // this point
14     result = NvIsAvailable();
15     if(result != TPM_RC_SUCCESS) return result;
16
17     // Make sure the the auth value is a reasonable size (not larger than
18     // the size of the digest produced by the integrity hash. The integrity
19     // hash is assumed to produce the longest digest of any hash implemented
20     // on the TPM.
21     if( MemoryRemoveTrailingZeros(&in->newAuth)
22         > CryptGetHashDigestSize(CONTEXT_INTEGRITY_HASH_ALG))
23         return TPM_RC_SIZE + RC_HierarchyChangeAuth_newAuth;
24
25     // Set hierarchy authValue
26     switch(in->authHandle)
27     {
28     case TPM_RH_OWNER:
29         gp.ownerAuth = in->newAuth;
30         NvWriteReserved(NV_OWNER_AUTH, &gp.ownerAuth);
31         break;
32     case TPM_RH_ENDORSEMENT:
33         gp.endorsementAuth = in->newAuth;
34         NvWriteReserved(NV_ENDORSEMENT_AUTH, &gp.endorsementAuth);
35         break;
36     case TPM_RH_PLATFORM:
37         gc.platformAuth = in->newAuth;
38         // orderly state should be cleared
39         g_clearOrderly = TRUE;
40         break;
41     case TPM_RH_LOCKOUT:
42         gp.lockoutAuth = in->newAuth;
43         NvWriteReserved(NV_LOCKOUT_AUTH, &gp.lockoutAuth);
44         break;
45     default:
46         pAssert(FALSE);
47         break;
48     }
49
50     return TPM_RC_SUCCESS;
51 }

```


27 Dictionary Attack Functions

27.1 Introduction

A TPM is required to have support for logic that will help prevent a dictionary attack on an authorization value. The protection is provided by a counter that increments when a password authorization or an HMAC authorization fails. When the counter reaches a predefined value, the TPM will not accept, for some time interval, further requests that require authorization and the TPM is in Lockout mode. While the TPM is in Lockout mode, the TPM will return `TPM_RC_LOCKED` if the command requires use of an object's or Index's *authValue* unless the authorization applies to an entry in the Platform hierarchy.

NOTE Authorizations for objects and NV Index values in the Platform hierarchy are never locked out. However, a command that requires multiple authorizations will not be accepted when the TPM is in Lockout mode unless all of the authorizations reference objects and indexes in the Platform hierarchy.

If the TPM is continuously powered for the duration of *newRecoveryTime* and no authorization failures occur, the authorization failure counter will be decremented by one. This property is called "self-healing." Self-healing shall not cause the count of failed attempts to decrement below zero.

The count of failed attempts, the lockout interval, and self-healing interval are settable using `TPM2_DictionaryAttackParameters()`. The lockout parameters and the current value of the lockout counter can be read with `TPM2_GetCapability()`.

Dictionary attack protection does not apply to an entity associated with a permanent handle (handle type == `TPM_HT_PERMANENT`).

27.2 TPM2_DictionaryAttackLockReset

27.2.1 General Description

This command cancels the effect of a TPM lockout due to a number of successive authorization failures. If this command is properly authorized, the lockout counter is set to zero.

Only one authorization failure is allowed for this command during a *lockoutRecovery* interval (set using `TPM2_DictionaryAttackParameters()`).

27.2.2 Command and Response

Table 165 — TPM2_DictionaryAttackLockReset Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_DictionaryAttackLockReset {NV}
TPMI_RH_LOCKOUT	@lockHandle	TPM_RH_LOCKOUT Auth Index: 1 Auth Role: USER

Table 166 — TPM2_DictionaryAttackLockReset Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

27.2.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "DictionaryAttackLockReset_fp.h"
3  TPM_RC
4  TPM2_DictionaryAttackLockReset(
5      DictionaryAttackLockReset_In    *in           // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9
10     // Input parameter is not reference in command action
11     in = NULL;
12
13     // The command needs NV update. Check if NV is available.
14     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
15     // this point
16     result = NvIsAvailable();
17     if(result != TPM_RC_SUCCESS) return result;
18
19     // Internal Data Update
20
21     // Set failed tries to 0
22     gp.failedTries = 0;
23
24     // Record the changes to NV
25     NvWriteReserved(NV_FAILED_TRIES, &gp.failedTries);
26
27     return TPM_RC_SUCCESS;
28 }
```

27.3 TPM2_DictionaryAttackParameters

27.3.1 General Description

This command changes the lockout parameters.

The command requires *lockoutAuth*.

The timeout parameters (*newRecoveryTime* and *lockoutRecovery*) indicate values that are measured with respect to the *Time* and not *Clock*.

NOTE Use of *Time* means that the TPM shall be continuously powered for the duration of a timeout.

If *newRecoveryTime* is zero, then DA protection is disabled. Authorizations are checked but authorization failures will not cause the TPM to enter lockout.

If *newMaxTries* is zero, the TPM will be in lockout and use of DA protected entities will be disabled.

If *lockoutRecovery* is zero, then the recovery interval is a boot cycle (*_TPM_Init* followed by *Startup(CLEAR)*).

This command will set the authorization failure count (*failedTries*) to zero.

Only one authorization failure is allowed for this command during a *lockoutRecovery* interval.

27.3.2 Command and Response

Table 167 — TPM2_DictionaryAttackParameters Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_DictionaryAttackParameters {NV}
TPMI_RH_LOCKOUT	@lockHandle	TPM_RH_LOCKOUT Auth Index: 1 Auth Role: USER
UINT32	newMaxTries	count of authorization failures before the lockout is imposed
UINT32	newRecoveryTime	time in seconds before the authorization failure count is automatically decremented A value of zero indicates that DA protection is disabled.
UINT32	lockoutRecovery	time in seconds after a <i>lockoutAuth</i> failure before use of <i>lockoutAuth</i> is allowed A value of zero indicates that a reboot is required.

Table 168 — TPM2_DictionaryAttackParameters Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

27.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "DictionaryAttackParameters_fp.h"
3  TPM_RC
4  TPM2_DictionaryAttackParameters(
5      DictionaryAttackParameters_In    *in          // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9
10     // The command needs NV update. Check if NV is available.
11     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
12     // this point
13     result = NvIsAvailable();
14     if(result != TPM_RC_SUCCESS) return result;
15
16     // Internal Data Update
17
18     // Set dictionary attack parameters
19     gp.maxTries = in->newMaxTries;
20     gp.recoveryTime = in->newRecoveryTime;
21     gp.lockoutRecovery = in->lockoutRecovery;
22
23     // Set failed tries to 0
24     gp.failedTries = 0;
25
26     // Record the changes to NV
27     NvWriteReserved(NV_FAILED_TRIES, &gp.failedTries);
28     NvWriteReserved(NV_MAX_TRIES, &gp.maxTries);
29     NvWriteReserved(NV_RECOVERY_TIME, &gp.recoveryTime);
30     NvWriteReserved(NV_LOCKOUT_RECOVERY, &gp.lockoutRecovery);
31
32     return TPM_RC_SUCCESS;
33 }
```

28 Miscellaneous Management Functions

28.1 Introduction

This clause contains commands that do not logically group with any other commands.

28.2 TPM2_PP_Commands

28.2.1 General Description

This command is used to determine which commands require assertion of Physical Presence (PP) in addition to *platformAuth/platformPolicy*.

This command requires that *auth* is TPM_RH_PLATFORM and that Physical Presence be asserted.

After this command executes successfully, the commands listed in *setList* will be added to the list of commands that require that Physical Presence be asserted when the handle associated with the authorization is TPM_RH_PLATFORM. The commands in *clearList* will no longer require assertion of Physical Presence in order to authorize a command.

If a command is not in either list, its state is not changed. If a command is in both lists, then it will no longer require Physical Presence (for example, *setList* is processed first).

Only commands with handle types of TPML_RH_PLATFORM, TPML_RH_PROVISION, TPML_RH_CLEAR, or TPML_RH_HIERARCHY can be gated with Physical Presence. If any other command is in either list, it is discarded.

When a command requires that Physical Presence be provided, then Physical Presence shall be asserted for either an HMAC or a Policy authorization.

NOTE Physical Presence may be made a requirement of any policy.

TPM2_PP_Commands() always requires assertion of Physical Presence.

28.2.2 Command and Response

Table 169 — TPM2_PP_Commands Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_PP_Commands {NV}
TPMI_RH_PLATFORM	@auth	TPM_RH_PLATFORM+PP Auth Index: 1 Auth Role: USER + Physical Presence
TPML_CC	setList	list of commands to be added to those that will require that Physical Presence be asserted
TPML_CC	clearList	list of commands that will no longer require that Physical Presence be asserted

Table 170 — TPM2_PP_Commands Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

28.2.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "PP_Commands_fp.h"
3  TPM_RC
4  TPM2_PP_Commands(
5      PP_Commands_In  *in          // IN: input parameter list
6  )
7  {
8      UINT32          i;
9
10     TPM_RC          result;
11
12     // The command needs NV update. Check if NV is available.
13     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
14     // this point
15     result = NvIsAvailable();
16     if(result != TPM_RC_SUCCESS) return result;
17
18     // Internal Data Update
19
20     // Process set list
21     for(i = 0; i < in->setList.count; i++)
22         // If command is implemented, set it as PP required. If the input
23         // command is not a PP command, it will be ignored at
24         // PhysicalPresenceCommandSet().
25         if(CommandIsImplemented(in->setList.commandCodes[i]))
26             PhysicalPresenceCommandSet(in->setList.commandCodes[i]);
27
28     // Process clear list
29     for(i = 0; i < in->clearList.count; i++)
30         // If command is implemented, clear it as PP required. If the input
31         // command is not a PP command, it will be ignored at
32         // PhysicalPresenceCommandClear(). If the input command is
33         // TPM2_PP_Commands, it will be ignored as well
34         if(CommandIsImplemented(in->clearList.commandCodes[i]))
35             PhysicalPresenceCommandClear(in->clearList.commandCodes[i]);
36
37     // Save the change of PP list
38     NvWriteReserved(NV_PP_LIST, &gp.ppList);
39
40     return TPM_RC_SUCCESS;
41 }
```

28.3 TPM2_SetAlgorithmSet

28.3.1 General Description

This command allows the platform to change the set of algorithms that are used by the TPM. The *algorithmSet* setting is a vendor-dependent value.

If the changing of the algorithm set results in a change of the algorithms of PCR banks, then the TPM will need to be reset (`_TPM_Init` and `TPM2_Startup(TPM_SU_CLEAR)`) before the new PCR settings take effect. After this command executes successfully, if *startupType* in the next `TPM2_Startup()` is not `TPM_SU_CLEAR`, the TPM shall return `TPM_RC_VALUE` and enter Failure mode.

This command does not change the algorithms available to the platform.

NOTE The reference implementation does not have support for this command. In particular, it does not support use of this command to selectively disable algorithms. Proper support would require modification of the unmarshaling code so that each time an algorithm is unmarshaled, it would be verified as being enabled.

28.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "SetAlgorithmSet_fp.h"
3  TPM_RC
4  TPM2_SetAlgorithmSet(
5      SetAlgorithmSet_In    *in           // IN: input parameter list
6  )
7  {
8      TPM_RC    result;
9
10     // The command needs NV update. Check if NV is available.
11     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
12     // this point
13     result = NvIsAvailable();
14     if(result != TPM_RC_SUCCESS) return result;
15
16     // Internal Data Update
17     gp.algorithmSet = in->algorithmSet;
18
19     // Write the algorithm set changes to NV
20     NvWriteReserved(NV_ALGORITHM_SET, &gp.algorithmSet);
21
22     return TPM_RC_SUCCESS;
23 }
```

29 Field Upgrade

29.1 Introduction

This clause contains the commands for managing field upgrade of the firmware in the TPM. The field upgrade scheme may be used for replacement or augmentation of the firmware installed in the TPM.

EXAMPLE 1 If an algorithm is found to be flawed, a patch of that algorithm might be installed using the firmware upgrade process. The patch might be a replacement of a portion of the code or a complete replacement of the firmware.

EXAMPLE 2 If an additional set of ECC parameters is needed, the firmware process may be used to add the parameters to the TPM data set.

The field upgrade process uses two commands (TPM2_FieldUpgradeStart() and TPM2_FieldUpgradeData()). TPM2_FieldUpgradeStart() validates that a signature on the provided digest is from the TPM manufacturer and that proper authorization is provided using *platformPolicy*.

NOTE 1 The *platformPolicy* for field upgraded is defined by the PM and may include requirements that the upgrade be signed by the PM or the TPM owner and include any other constraints that are desired by the PM.

If the proper authorization is given, the TPM will retain the signed digest and enter the Field Upgrade mode (FUM). While in FUM, the TPM will accept TPM2_FieldUpgradeData() commands. It may accept other commands if it is able to complete them using the previously installed firmware. Otherwise, it will return TPM_RC_UPGRADE.

Each block of the field upgrade shall contain the digest of the next block of the field upgrade data. That digest shall be included in the digest of the previous block. The digest of the first block is signed by the TPM manufacturer. That signature and first block digest are the parameters for TPM2_FieldUpgradeStart(). The digest is saved in the TPM as the required digest for the next field upgrade data block and as the identifier of the field upgrade sequence.

For each field upgrade data block that is sent to the TPM by TPM2_FieldUpgradeData(), the TPM shall validate that the digest matches the required digest and if not, shall return TPM_RC_VALUE. The TPM shall extract the digest of the next expected block and return that value to the caller, along with the digest of the first data block of the update sequence.

The system may attempt to abandon the firmware upgrade by using a zero-length buffer in TPM2_FieldUpgradeData(). If the TPM is able to resume operation using the firmware present when the upgrade started, then the TPM will indicate that it has abandon the update by setting the digest of the next block to the Empty Buffer. If the TPM cannot abandon the update, it will return the expected next digest.

The system may also attempt to abandon the update because of a power interruption. If the TPM is able to resume normal operations, then it will respond normally to TPM2_Startup(). If the TPM is not able to resume normal operations, then it will respond to any command but TPM2_FieldUpgradeData() with TPM_RC_FIELDUPGRADE.

After a _TPM_Init, system software may not be able to resume the field upgrade that was in process when the power interruption occurred. In such case, the TPM firmware may be reset to one of two other values:

- the original firmware that was installed at the factory (“initial firmware”); or
- the firmware that was in the TPM when the field upgrade process started (“previous firmware”).

The TPM retains the digest of the first block for these firmware images and checks to see if the first block after _TPM_Init matches either of those digests. If so, the firmware update process restarts and the original firmware may be loaded.

NOTE 2 The TPM is required to accept the previous firmware as either a vendor-provided update or as recovered from the TPM using TPM2_FirmwareRead().

When the last block of the firmware upgrade is loaded into the TPM (indicated to the TPM by data in the data block in a TPM vendor-specific manner), the TPM will complete the upgrade process. If the TPM is able to resume normal operations without a reboot, it will set the hash algorithm of the next block to TPM_ALG_NULL and return TPM_RC_SUCCESS. If a reboot is required, the TPM shall return TPM_RC_REBOOT in response to the last TPM2_FieldUpgradeData() and all subsequent TPM commands until a _TPM_Init is received.

NOTE 3 Because no additional data is allowed when the response code is not TPM_RC_SUCCESS, the TPM returns TPM_RC_SUCCESS for all calls to TPM2_FieldUpgradeData() except the last. In this manner, the TPM is able to indicate the digest of the next block. If a _TPM_Init occurs while the TPM is in FUM, the next block may be the digest for the first block of the original firmware. If it is not, then the TPM will not accept the original firmware until the next _TPM_Init when the TPM is in FUM.

During the field upgrade process, the TPM shall preserve:

- Primary Seeds;
- Hierarchy *authValue*, *authPolicy*, and *proof* values;
- Lockout *authValue* and authorization failure count values;
- PCR *authValue* and *authPolicy* values;
- NV Index allocations and contents;
- Persistent object allocations and contents; and
- Clock.

29.2 TPM2_FieldUpgradeStart

29.2.1 General Description

This command uses *platformPolicy* and a TPM Vendor Authorization Key to authorize a Field Upgrade Manifest.

If the signature checks succeed, the authorization is valid and the TPM will accept TPM2_FieldUpgradeData().

This signature is checked against the loaded key referenced by *keyHandle*. This key will have a Name that is the same as a value that is part of the TPM firmware data. If the signature is not valid, the TPM shall return TPM_RC_SIGNATURE.

NOTE A loaded key is used rather than a hard-coded key to reduce the amount of memory needed for this key data in case more than one vendor key is needed.

29.2.2 Command and Response

Table 173 — TPM2_FieldUpgradeStart Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_FieldUpgradeStart
TPMI_RH_PLATFORM	@authorization	TPM_RH_PLATFORM+{PP} Auth Index:1 Auth Role: ADMIN
TPMI_DH_OBJECT	keyHandle	handle of a public area that contains the TPM Vendor Authorization Key that will be used to validate <i>manifestSignature</i> Auth Index: None
TPM2B_DIGEST	fuDigest	digest of the first block in the field upgrade sequence
TPMT_SIGNATURE	manifestSignature	signature over <i>fuDigest</i> using the key associated with <i>keyHandle</i> (not optional)

Table 174 — TPM2_FieldUpgradeStart Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

29.2.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "FieldUpgradeStart_fp.h"
3  #if CC_FieldUpgradeStart == YES
4  TPM_RC
5  TPM2_FieldUpgradeStart(
6      FieldUpgradeStart_In      *in          // IN: input parameter list
7  )
8  {
9      // Not implemented
10     UNUSED_PARAMETER(in);
11     return TPM_RC_SUCCESS;
12 }
13 #endif
```

29.3 TPM2_FieldUpgradeData

29.3.1 General Description

This command will take the actual field upgrade image to be installed on the TPM. The exact format of *fuData* is vendor-specific. This command is only possible following a successful TPM2_FieldUpgradeStart(). If the TPM has not received a properly authorized TPM2_FieldUpgradeStart(), then the TPM shall return TPM_RC_FIELDUPGRADE.

The TPM will validate that the digest of *fuData* matches an expected value. If so, the TPM may buffer or immediately apply the update. If the digest of *fuData* does not match an expected value, the TPM shall return TPM_RC_VALUE.

29.3.2 Command and Response

Table 175 — TPM2_FieldUpgradeData Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_FieldUpgradeData {NV}
TPM2B_MAX_BUFFER	fuData	field upgrade image data

Table 176 — TPM2_FieldUpgradeData Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMT_HA+	nextDigest	tagged digest of the next block TPM_ALG_NULL if field update is complete
TPMT_HA	firstDigest	tagged digest of the first block of the sequence

29.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "FieldUpgradeData_fp.h"
3  #if CC_FieldUpgradeData == YES
4  TPM_RC
5  TPM2_FieldUpgradeData(
6      FieldUpgradeData_In      *in,          // IN: input parameter list
7      FieldUpgradeData_Out     *out         // OUT: output parameter list
8  )
9  {
10     // Not implemented
11     UNUSED_PARAMETER(in);
12     UNUSED_PARAMETER(out);
13     return TPM_RC_SUCCESS;
14 }
15 #endif
```

29.4 TPM2_FirmwareRead

29.4.1 General Description

This command is used to read a copy of the current firmware installed in the TPM.

The presumption is that the data will be returned in reverse order so that the last block in the sequence would be the first block given to the TPM in case of a failure recovery. If the TPM2_FirmwareRead sequence completes successfully, then the data provided from the TPM will be sufficient to allow the TPM to recover from an abandoned upgrade of this firmware.

To start the sequence of retrieving the data, the caller sets *sequenceNumber* to zero. When the TPM has returned all the firmware data, the TPM will return the Empty Buffer as *fuData*.

The contents of *fuData* are opaque to the caller.

NOTE 1 The caller should retain the ordering of the update blocks so that the blocks sent to the TPM have the same size and inverse order as the blocks returned by a sequence of calls to this command.

NOTE 2 Support for this command is optional even if the TPM implements TPM2_FieldUpgradeStart() and TPM2_FieldUpgradeData().

29.4.2 Command and Response

Table 177 — TPM2_FirmwareRead Command

Type	Name	Description
TPML_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_FirmwareRead
UINT32	sequenceNumber	the number of previous calls to this command in this sequence set to 0 on the first call

Table 178 — TPM2_FirmwareRead Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_MAX_BUFFER	fuData	field upgrade image data

29.4.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "FirmwareRead_fp.h"
3  TPM_RC
4  TPM2_FirmwareRead(
5      FirmwareRead_In      *in,           // IN: input parameter list
6      FirmwareRead_Out     *out          // OUT: output parameter list
7  )
8  {
9      // Not implemented
10     UNUSED_PARAMETER(in);
11     UNUSED_PARAMETER(out);
12     return TPM_RC_SUCCESS;
13 }
```

30 Context Management

30.1 Introduction

Three of the commands in this clause (TPM2_ContextSave(), TPM2_ContextLoad(), and TPM2_FlushContext()) implement the resource management described in the "Context Management" clause in Part 1.

The fourth command in this clause (TPM2_EvictControl()) is used to control the persistence of a loadable objects in TPM memory. Background for this command may be found in the "Owner and Platform Evict Objects" clause in Part 1.

30.2 TPM2_ContextSave

30.2.1 General Description

This command saves a session context, object context, or sequence object context outside the TPM.

No authorization sessions of any type are allowed with this command and tag is required to be TPM_ST_NO_SESSIONS.

NOTE This preclusion avoids complex issues of dealing with the same session in *handle* and in the session area. While it might be possible to provide specificity, it would add unnecessary complexity to the TPM and, because this capability would provide no application benefit, use of authorization sessions for audit or encryption is prohibited.

The TPM shall encrypt and integrity protect the context as described in the "Context Protection" clause in Part 1.

See the "Context Data" clause in Part 2 for a description of the *context* structure in the response.

30.2.2 Command and Response

Table 179 — TPM2_ContextSave Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	TPM_ST_NO_SESSIONS
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ContextSave
TPMI_DH_CONTEXT	saveHandle	handle of the resource to save Auth Index: None

Table 180 — TPM2_ContextSave Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMS_CONTEXT	context	

30.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ContextSave_fp.h"
3  #include "Context_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_CONTEXT_GAP	a <i>contextID</i> could not be assigned for a session context save
TPM_RC_TOO_MANY_CONTEXTS	no more contexts can be saved as the counter has maxed out

```

4  TPM_RC
5  TPM2_ContextSave(
6      ContextSave_In    *in,        // IN: input parameter list
7      ContextSave_Out  *out        // OUT: output parameter list
8  )
9  {
10     TPM_RC            result;
11     UINT16           fingerprintSize; // The size of fingerprint in context
12     // blob.
13     UINT64           contextID = 0;   // session context ID
14     TPM2B_SYM_KEY    symKey;
15     TPM2B_IV         iv;
16
17     TPM2B_DIGEST     integrity;
18     UINT16           integritySize;
19     BYTE             *buffer;
20
21     // This command may cause the orderlyState to be cleared due to
22     // the update of state reset data. If this is the case, check if NV is
23     // available first
24     if(gp.orderlyState != SHUTDOWN_NONE)
25     {
26         // The command needs NV update. Check if NV is available.
27         // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
28         // this point
29         result = NvIsAvailable();
30         if(result != TPM_RC_SUCCESS) return result;
31     }
32
33     // Internal Data Update
34
35     // Initialize output handle. At the end of command action, the output
36     // handle of an object will be replaced, while the output handle
37     // for a session will be the same as input
38     out->context.savedHandle = in->saveHandle;
39
40     // Get the size of fingerprint in context blob. The sequence value in
41     // TPMS_CONTEXT structure is used as the fingerprint
42     fingerprintSize = sizeof(out->context.sequence);
43
44     // Compute the integrity size at the beginning of context blob
45     integritySize = sizeof(integrity.t.size)
46                   + CryptGetHashDigestSize(CONTEXT_INTEGRITY_HASH_ALG);
47
48
49     // Perform object or session specific context save
50     switch(HandleGetType(in->saveHandle))
51     {
52     case TPM_HT_TRANSIENT:
53     {

```

```

54     OBJECT      *object = ObjectGet(in->saveHandle);
55     OBJECT      *outObject =
56                 (OBJECT *) (out->context.contextBlob.t.buffer
57                             + integritySize + fingerprintSize);
58
59     // Set size of the context data. The contents of context blob is vendor
60     // defined. In this implementation, the size is size of integrity
61     // plus fingerprint plus the whole internal OBJECT structure
62     out->context.contextBlob.t.size = integritySize +
63                                     fingerprintSize + sizeof(*object);
64
65     // Copy the whole internal OBJECT structure to context blob, leave
66     // the size for fingerprint
67     *outObject = *object;
68
69     // Increment object context ID
70     gr.objectContextID++;
71     // If object context ID overflows, TPM should be put in failure mode
72     if(gr.objectContextID == 0)
73         FAIL(FATAL_ERROR_INTERNAL);
74
75     // Fill in other return values for an object.
76     out->context.sequence = gr.objectContextID;
77     // For regular object, savedHandle is 0x80000000. For sequence object,
78     // savedHandle is 0x80000001. For object with stClear, savedHandle
79     // is 0x80000002
80     if(ObjectIsSequence(object))
81     {
82         out->context.savedHandle = 0x80000001;
83         SequenceDataImportExport(object, outObject, EXPORT_STATE);
84     }
85     else if(object->attributes.stClear == SET)
86     {
87         out->context.savedHandle = 0x80000002;
88     }
89     else
90     {
91         out->context.savedHandle = 0x80000000;
92     }
93
94     // Get object hierarchy
95     out->context.hierarchy = ObjectDataGetHierarchy(object);
96
97     break;
98 }
99 case TPM_HT_HMAC_SESSION:
100 case TPM_HT_POLICY_SESSION:
101 {
102     SESSION      *session = SessionGet(in->saveHandle);
103
104     // Set size of the context data. The contents of context blob is vendor
105     // defined. In this implementation, the size of context blob is the
106     // size of a internal session structure plus the size of
107     // fingerprint plus the size of integrity
108     out->context.contextBlob.t.size = integritySize +
109                                     fingerprintSize + sizeof(*session);
110
111     // Copy the whole internal SESSION structure to context blob.
112     // Save space for fingerprint at the beginning of the buffer
113     // This is done before anything else so that the actual context
114     // can be reclaimed after this call
115     MemoryCopy(out->context.contextBlob.t.buffer
116               + integritySize + fingerprintSize,
117               session, sizeof(*session),

```

```

118         sizeof(out->context.contextBlob.t.buffer)
119             - integritySize - fingerprintSize);
120
121     // Fill in the other return parameters for a session
122     // Get a context ID and set the session tracking values appropriately
123     // TPM_RC_CONTEXT_GAP is a possible error.
124     // SessionContextSave() will flush the in-memory context
125     // so no additional errors may occur after this call.
126     result = SessionContextSave(out->context.savedHandle, &contextID);
127     if(result != TPM_RC_SUCCESS) return result;
128
129     // sequence number is the current session contextID
130     out->context.sequence = contextID;
131
132     // use TPM_RH_NULL as hierarchy for session context
133     out->context.hierarchy = TPM_RH_NULL;
134
135     break;
136 }
137 default:
138     // SaveContext may only take an object handle or a session handle.
139     // All the other handle type should be filtered out at unmarshal
140     pAssert(FALSE);
141     break;
142 }
143
144 // Save fingerprint at the beginning of encrypted area of context blob.
145 // Reserve the integrity space
146 MemoryCopy(out->context.contextBlob.t.buffer + integritySize,
147     &out->context.sequence, sizeof(out->context.sequence),
148     sizeof(out->context.contextBlob.t.buffer) - integritySize);
149
150 // Compute context encryption key
151 ComputeContextProtectionKey(&out->context, &symKey, &iv);
152
153 // Encrypt context blob
154 CryptSymmetricEncrypt(out->context.contextBlob.t.buffer + integritySize,
155     CONTEXT_ENCRYPT_ALG, CONTEXT_ENCRYPT_KEY_BITS,
156     TPM_ALG_CFB, symKey.t.buffer, &iv,
157     out->context.contextBlob.t.size - integritySize,
158     out->context.contextBlob.t.buffer + integritySize);
159
160 // Compute integrity hash for the object
161 // In this implementation, the same routine is used for both sessions
162 // and objects.
163 ComputeContextIntegrity(&out->context, &integrity);
164
165 // add integrity at the beginning of context blob
166 buffer = out->context.contextBlob.t.buffer;
167 TPM2B_DIGEST_Marshal(&integrity, &buffer, NULL);
168
169 // orderly state should be cleared because of the update of state reset and
170 // state clear data
171 g_clearOrderly = TRUE;
172
173 return TPM_RC_SUCCESS;
174 }

```

30.3 TPM2_ContextLoad

30.3.1 General Description

This command is used to reload a context that has been saved by TPM2_ContextSave().

No authorization sessions of any type are allowed with this command and tag is required to be TPM_ST_NO_SESSIONS (see note in 30.2.1).

The TPM will return TPM_RC_HIERARCHY if the context is associated with a hierarchy that is disabled.

NOTE Contexts for authorization sessions and for sequence objects belong to the NULL hierarchy which is never disabled.

See the "Context Data" clause in Part 2 for a description of the values in the *context* parameter.

If the integrity HMAC of the saved context is not valid, the TPM shall return TPM_RC_INTEGRITY.

The TPM shall perform a check on the decrypted context as described in the "Context Confidentiality Protections" clause of Part 1 and enter failure mode if the check fails.

30.3.2 Command and Response

Table 181 — TPM2_ContextLoad Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	TPM_ST_NO_SESSIONS
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ContextLoad
TPMS_CONTEXT	context	the context blob

Table 182 — TPM2_ContextLoad Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMI_DH_CONTEXT	loadedHandle	the handle assigned to the resource after it has been successfully loaded

30.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "ContextLoad_fp.h"
3  #include "Context_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_CONTEXT_GAP	there is only one available slot and this is not the oldest saved session context
TPM_RC_HANDLE	'context.savedHandle' does not reference a saved session
TPM_RC_HIERARCHY	'context.hierarchy' is disabled
TPM_RC_INTEGRITY	context integrity check fail
TPM_RC_OBJECT_MEMORY	no free slot for an object
TPM_RC_SESSION_MEMORY	no free session slots
TPM_RC_SIZE	incorrect context blob size

```

4  TPM_RC
5  TPM2_ContextLoad(
6      ContextLoad_In    *in,        // IN: input parameter list
7      ContextLoad_Out  *out        // OUT: output parameter list
8  )
9  {
10     // Local Variables
11     TPM_RC      result = TPM_RC_SUCCESS;
12
13     TPM2B_DIGEST    ingerityToCompare;
14     TPM2B_DIGEST    integrity;
15     UINT16          integritySize;
16     UINT64          fingerprint;
17     BYTE            *buffer;
18     INT32           size;
19
20     TPM_HT          handleType;
21     TPM2B_SYM_KEY   symKey;
22     TPM2B_IV        iv;
23
24     // Input Validation
25
26     // Check context blob size
27     handleType = HandleGetType(in->context.savedHandle);
28
29     // Check integrity
30     // In this implementation, the same routine is used for both sessions
31     // and objects.
32     integritySize = sizeof(integrity.t.size)
33                   + CryptGetHashDigestSize(CONTEXT_INTEGRITY_HASH_ALG);
34
35     // Get integrity from context blob
36     buffer = in->context.contextBlob.t.buffer;
37     size = (INT32) in->context.contextBlob.t.size;
38     result = TPM2B_DIGEST_Unmarshal(&integrity, &buffer, &size);
39     if(result != TPM_RC_SUCCESS)
40         return result;
41
42     // Compute context integrity
43     ComputeContextIntegrity(&in->context, &ingerityToCompare);

```

```

44
45 // Compare integrity
46 if(!Memory2BEqual(&integrity.b, &ingerityToCompare.b))
47     return TPM_RC_INTEGRITY + RC_ContextLoad_context;
48
49 // Compute context encryption key
50 ComputeContextProtectionKey(&in->context, &symKey, &iv);
51
52 // Decrypt context data in place
53 CryptSymmetricDecrypt(in->context.contextBlob.t.buffer + integritySize,
54                       CONTEXT_ENCRYPT_ALG, CONTEXT_ENCRYPT_KEY_BITS,
55                       TPM_ALG_CFB, symKey.t.buffer, &iv,
56                       in->context.contextBlob.t.size - integritySize,
57                       in->context.contextBlob.t.buffer + integritySize);
58
59 // Read the fingerprint value, skip the leading integrity size
60 MemoryCopy(&fingerprint, in->context.contextBlob.t.buffer + integritySize,
61           sizeof(fingerprint), sizeof(fingerprint));
62 // Check fingerprint. If the check fails, TPM should be put to failure mode
63 if(fingerprint != in->context.sequence)
64     FAIL(FATAL_ERROR_INTERNAL);
65
66 // Perform object or session specific input check
67 switch(handleType)
68 {
69 case TPM_HT_TRANSIENT:
70 {
71     // Get a pointer to the object in the context blob
72     OBJECT *outObject = (OBJECT *) (in->context.contextBlob.t.buffer
73                                     + integritySize + sizeof(fingerprint));
74
75     // Discard any changes to the handle that the TRM might have made
76     in->context.savedHandle = TRANSIENT_FIRST;
77
78     // If hierarchy is disabled, no object context can be loaded in this
79     // hierarchy
80     if(!HierarchyIsEnabled(in->context.hierarchy))
81         return TPM_RC_HIERARCHY + RC_ContextLoad_context;
82
83     // Restore object. A TPM_RC_OBJECT_MEMORY error may be returned at
84     // this point
85     result = ObjectContextLoad(outObject, &out->loadedHandle);
86     if(result != TPM_RC_SUCCESS)
87         return result;
88
89     // If this is a sequence object, the crypto library may need to
90     // reformat the data into an internal format
91     if(ObjectIsSequence(outObject))
92         SequenceDataImportExport(ObjectGet(out->loadedHandle),
93                                 outObject, IMPORT_STATE);
94
95     break;
96 }
97 }
98 case TPM_HT_POLICY_SESSION:
99 case TPM_HT_HMAC_SESSION:
100 {
101
102     SESSION *session = (SESSION *) (in->context.contextBlob.t.buffer
103                                     + integritySize + sizeof(fingerprint));
104
105     // This command may cause the orderlyState to be cleared due to
106     // the update of state reset data. If this is the case, check if NV is
107     // available first

```



```
108     if(gp.orderlyState != SHUTDOWN_NONE)
109     {
110         // The command needs NV update. Check if NV is available.
111         // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned
112         // at this point
113         result = NvIsAvailable();
114         if(result != TPM_RC_SUCCESS)
115             return result;
116     }
117
118     // Check if input handle points to a valid saved session
119     if(!SessionIsSaved(in->context.savedHandle))
120         return TPM_RC_HANDLE + RC_ContextLoad_context;
121
122     // Restore session. A TPM_RC_SESSION_MEMORY, TPM_RC_CONTEXT_GAP error
123     // may be returned at this point
124     result = SessionContextLoad(session, &in->context.savedHandle);
125     if(result != TPM_RC_SUCCESS)
126         return result;
127
128     out->loadedHandle = in->context.savedHandle;
129
130     // orderly state should be cleared because of the update of state
131     // reset and state clear data
132     g_clearOrderly = TRUE;
133
134     break;
135 }
136 default:
137     // Context blob may only have an object handle or a session handle.
138     // All the other handle type should be filtered out at unmarshal
139     pAssert(FALSE);
140     break;
141 }
142
143 return TPM_RC_SUCCESS;
144 }
```

30.4 TPM2_FlushContext

30.4.1 General Description

This command causes all context associated with a loaded object or session to be removed from TPM memory.

This command may not be used to remove a persistent object from the TPM.

A session does not have to be loaded in TPM memory to have its context flushed. The saved session context associated with the indicated handle is invalidated.

No sessions of any type are allowed with this command and tag is required to be TPM_ST_NO_SESSIONS (see note in 30.2.1).

If the handle is for a transient object and the handle is not associated with a loaded object, then the TPM shall return TPM_RC_HANDLE.

If the handle is for an authorization session and the handle does not reference a loaded or active session, then the TPM shall return TPM_RC_HANDLE.

NOTE *flushHandle* is a parameter and not a handle. If it were in the handle area, the TPM would validate that the context for the referenced entity is in the TPM. When a TPM2_FlushContext references a saved session context, it is not necessary for the context to be in the TPM.

30.4.2 Command and Response**Table 183 — TPM2_FlushContext Command**

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	TPM_ST_NO_SESSIONS
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_FlushContext
TPMI_DH_CONTEXT	flushHandle	the handle of the item to flush NOTE This is a use of a handle as a parameter.

Table 184 — TPM2_FlushContext Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

30.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "FlushContext_fp.h"

```

Error Returns	Meaning
TPM_RC_HANDLE	<i>flushHandle</i> does not reference a loaded object or session

```

3  TPM_RC
4  TPM2_FlushContext(
5      FlushContext_In      *in          // IN: input parameter list
6  )
7  {
8  // Internal Data Update
9
10     // Call object or session specific routine to flush
11     switch(HandleGetType(in->flushHandle))
12     {
13     case TPM_HT_TRANSIENT:
14         if(!ObjectIsPresent(in->flushHandle))
15             return TPM_RC_HANDLE;
16         // Flush object
17         ObjectFlush(in->flushHandle);
18         break;
19     case TPM_HT_HMAC_SESSION:
20     case TPM_HT_POLICY_SESSION:
21         if(!SessionIsLoaded(in->flushHandle)
22             && !SessionIsSaved(in->flushHandle))
23             return TPM_RC_HANDLE;
24
25         // If the session to be flushed is the exclusive audit session, then
26         // indicate that there is no exclusive audit session any longer.
27         if(in->flushHandle == g_exclusiveAuditSession)
28             g_exclusiveAuditSession = TPM_RH_UNASSIGNED;
29
30         // Flush session
31         SessionFlush(in->flushHandle);
32         break;
33     default:
34         // This command only take object or session handle. Other handles
35         // should be filtered out at handle unmarshal
36         pAssert(FALSE);
37         break;
38     }
39 }
40
41 return TPM_RC_SUCCESS;
42 }

```

30.5 TPM2_EvictControl

30.5.1 General Description

This command allows a transient object to be made persistent or a persistent object to be evicted.

NOTE 1 A transient object is one that may be removed from TPM memory using either TPM2_FlushContext or TPM2_Startup(). A persistent object is not removed from TPM memory by TPM2_FlushContext() or TPM2_Startup().

If *objectHandle* is a transient object, then the call is to make the object persistent and assign *persistentHandle* to the persistent version of the object. If *objectHandle* is a persistent object, then the call is to evict the persistent object.

Before execution of TPM2_EvictControl code below, the TPM verifies that *objectHandle* references an object that is resident on the TPM and that *persistentHandle* is a valid handle for a persistent object.

NOTE 2 This requirement simplifies the unmarshaling code so that it only need check that *persistentHandle* is always a persistent object.

If *objectHandle* references a transient object:

- a) The TPM shall return TPM_RC_ATTRIBUTES if
 - 1) it is in the hierarchy of TPM_RH_NULL,
 - 2) only the public portion of the object is loaded, or
 - 3) the *stClear* is SET in the object or in an ancestor key.
- b) The TPM shall return TPM_RC_HIERARCHY if the object is not in the proper hierarchy as determined by *auth*.
 - 1) If *auth* is TPM_RH_PLATFORM, the proper hierarchy is the Platform hierarchy.
 - 2) If *auth* is TPM_RH_OWNER, the proper hierarchy is either the Storage or the Endorsement hierarchy.
- c) The TPM shall return TPM_RC_RANGE if *persistentHandle* is not in the proper range as determined by *auth*.
 - 1) If *auth* is TPM_RH_OWNER, then *persistentHandle* shall be in the inclusive range of 81 00 00 00₁₆ to 81 7F FF FF₁₆.
 - 2) If *auth* is TPM_RH_PLATFORM, then *persistentHandle* shall be in the inclusive range of 81 80 00 00₁₆ to 81 FF FF FF₁₆.
- d) The TPM shall return TPM_RC_NV_DEFINED if a persistent object exists with the same handle as *persistentHandle*.
- e) The TPM shall return TPM_RC_NV_SPACE if insufficient space is available to make the object persistent.
- f) The TPM shall return TPM_RC_NV_SPACE if execution of this command will prevent the TPM from being able to hold two transient objects of any kind.

NOTE 3 This requirement anticipates that a TPM may be implemented such that all TPM memory is non-volatile and not subject to endurance issues. In such case, there is no movement of an object between memory of different types and it is necessary that the TPM ensure that it is always possible for the management software to move objects to/from TPM memory in order to ensure that the objects required for command execution can be context restored.

- g) If the TPM returns TPM_RC_SUCCESS, the object referenced by *objectHandle* will not be flushed and both *objectHandle* and *persistentHandle* may be used to access the object.

If *objectHandle* references a persistent object:

- h) The TPM shall return TPM_RC_RANGE if *objectHandle* is not in the proper range as determined by *auth*. If *auth* is TPM_RC_OWNER, *objectHandle* shall be in the inclusive range of 81 00 00 00₁₆ to 81 7F FF FF₁₆. If *auth* is TPM_RC_PLATFORM, *objectHandle* may be any valid persistent object handle.
- i) If the TPM returns TPM_RC_SUCCESS, *objectHandle* will be removed from persistent memory and no longer be accessible.

NOTE 4 The persistent object is not converted to a transient object, as this would prevent the immediate revocation of an object by removing it from persistent memory.

30.5.2 Command and Response

Table 185 — TPM2_EvictControl Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_PROVISION	commandCode @auth	TPM_CC_EvictControl {NV} TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Handle: 1 Auth Role: USER
TPMI_DH_OBJECT	objectHandle	the handle of a loaded object Auth Index: None
TPMI_DH_PERSISTENT	persistentHandle	if <i>objectHandle</i> is a transient object handle, then this is the persistent handle for the object if <i>objectHandle</i> is a persistent object handle, then this shall be the same value as <i>persistentHandle</i>

Table 186 — TPM2_EvictControl Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

30.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "EvictControl_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	an object with <i>temporary</i> , <i>stClear</i> or <i>publicOnly</i> attribute SET cannot be made persistent
TPM_RC_HIERARCHY	<i>auth</i> cannot authorize the operation in the hierarchy of <i>evictObject</i>
TPM_RC_HANDLE	<i>evictHandle</i> of the persistent object to be evicted is not the same as the <i>persistentHandle</i> argument
TPM_RC_NV_HANDLE	<i>persistentHandle</i> is unavailable
TPM_RC_NV_SPACE	no space in NV to make <i>evictHandle</i> persistent
TPM_RC_RANGE	<i>persistentHandle</i> is not in the range corresponding to the hierarchy of <i>evictObject</i>

```

3  TPM_RC
4  TPM2_EvictControl(
5      EvictControl_In      *in          // IN: input parameter list
6  )
7  {
8      TPM_RC      result;
9      OBJECT      *evictObject;
10
11     // The command needs NV update. Check if NV is available.
12     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
13     // this point
14     result = NvIsAvailable();
15     if(result != TPM_RC_SUCCESS) return result;
16
17     // Input Validation
18
19     // Get internal object pointer
20     evictObject = ObjectGet(in->objectHandle);
21
22     // Temporary, stClear or public only objects can not be made persistent
23     if( evictObject->attributes.temporary == SET
24         || evictObject->attributes.stClear == SET
25         || evictObject->attributes.publicOnly == SET
26     )
27         return TPM_RC_ATTRIBUTES + RC_EvictControl_objectHandle;
28
29     // If objectHandle refers to a persistent object, it should be the same as
30     // input persistentHandle
31     if( evictObject->attributes.evict == SET
32         && evictObject->evictHandle != in->persistentHandle
33     )
34         return TPM_RC_HANDLE + RC_EvictControl_objectHandle;
35
36     // Additional auth validation
37     if(in->auth == TPM_RH_PLATFORM)
38     {
39         // To make persistent
40         if(evictObject->attributes.evict == CLEAR)
41         {
42             // Platform auth can not set evict object in storage or endorsement
43             // hierarchy

```



```
44     if(evictObject->attributes.ppsHierarchy == CLEAR)
45         return TPM_RC_HIERARCHY + RC_EvictControl_objectHandle;
46
47     // Platform cannot use a handle outside of platform persistent range.
48     if(!NvIsPlatformPersistentHandle(in->persistentHandle))
49         return TPM_RC_RANGE + RC_EvictControl_persistentHandle;
50     }
51     // Platform auth can delete any persistent object
52 }
53 else if(in->auth == TPM_RH_OWNER)
54 {
55     // Owner auth can not set or clear evict object in platform hierarchy
56     if(evictObject->attributes.ppsHierarchy == SET)
57         return TPM_RC_HIERARCHY + RC_EvictControl_objectHandle;
58
59     // Owner cannot use a handle outside of owner persistent range.
60     if( evictObject->attributes.evict == CLEAR
61        && !NvIsOwnerPersistentHandle(in->persistentHandle)
62        )
63         return TPM_RC_RANGE + RC_EvictControl_persistentHandle;
64     }
65     else
66     {
67         // Other auth is not allowed in this command and should be filtered out
68         // at unmarshal process
69         pAssert(FALSE);
70     }
71
72 // Internal Data Update
73
74 // Change evict state
75 if(evictObject->attributes.evict == CLEAR)
76 {
77     // Make object persistent
78     // A TPM_RC_NV_HANDLE or TPM_RC_NV_SPACE error may be returned at this
79     // point
80     result = NvAddEvictObject(in->persistentHandle, evictObject);
81     if(result != TPM_RC_SUCCESS) return result;
82 }
83 else
84 {
85     // Delete the persistent object in NV
86     NvDeleteEntity(evictObject->evictHandle);
87 }
88
89 return TPM_RC_SUCCESS;
90
91 }
```

31 Clocks and Timers

31.1 TPM2_ReadClock

31.1.1 General Description

This command reads the current TPMS_TIME_INFO structure that contains the current setting of *Time*, *Clock*, *resetCount*, and *restartCount*.

No authorization sessions of any type are allowed with this command and tag is required to be TPM_ST_NO_SESSIONS.

NOTE This command is intended to allow the TCB to have access to values that have the potential to be privacy sensitive. The values may be read without authorization because the TCB will not disclose these values. Since they are not signed and cannot be accessed in a command that uses an authorization session, it is not possible for any entity, other than the TCB, to be assured that the values are accurate.

31.1.2 Command and Response

Table 187 — TPM2_ReadClock Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	TPM_ST_NO_SESSIONS
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ReadClock

Table 188 — TPM2_ReadClock Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	returnCode	
TPMS_TIME_INFO	currentTime	

31.1.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "ReadClock_fp.h"
3  TPM_RC
4  TPM2_ReadClock(
5      ReadClock_Out *out          // OUT: output parameter list
6  )
7  {
8  // Command Output
9
10     out->currentTime.time = g_time;
11     TimeFillInfo(&out->currentTime.clockInfo);
12
13     return TPM_RC_SUCCESS;
14 }
```

31.2 TPM2_ClockSet

31.2.1 General Description

This command is used to advance the value of the TPM's *Clock*. The command will fail if *newTime* is less than the current value of *Clock* or if the new time is greater than FF FF 00 00 00 00 00 00₁₆. If both of these checks succeed, *Clock* is set to *newTime*. If either of these checks fails, the TPM shall return TPM_RC_VALUE and make no change to *Clock*.

NOTE This maximum setting would prevent *Clock* from rolling over to zero for approximately 8,000 years if the *Clock* update rate was set so that TPM time was passing 33 percent faster than real time. This would still be more than 6,000 years before *Clock* would roll over to zero. Because *Clock* will not roll over in the lifetime of the TPM, there is no need for external software to deal with the possibility that *Clock* may wrap around.

If the value of *Clock* after the update makes the volatile and non-volatile versions of TPMS_CLOCK_INFO.*clock* differ by more than the reported update interval, then the TPM shall update the non-volatile version of TPMS_CLOCK_INFO.*clock* before returning.

This command requires *platformAuth* or *ownerAuth*.

31.2.2 Command and Response

Table 189 — TPM2_ClockSet Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ClockSet {NV}
TPMI_RH_PROVISION	@auth	TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Handle: 1 Auth Role: USER
UINT64	newTime	new <i>Clock</i> setting in milliseconds

Table 190 — TPM2_ClockSet Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	returnCode	

31.2.3 Detailed Actions

```
1 #include "InternalRoutines.h"
2 #include "ClockSet_fp.h"
```

Read the current TPMS_TIMER_INFO structure settings

Error Returns	Meaning
TPM_RC_VALUE	invalid new clock

```
3 TPM_RC
4 TPM2_ClockSet(
5     ClockSet_In *in                // IN: input parameter list
6 )
7 {
8     #define CLOCK_UPDATE_MASK ((1ULL << NV_CLOCK_UPDATE_INTERVAL) - 1)
9     UINT64     clockNow;
10
11     // Input Validation
12
13     // new time can not be bigger than 0xFFFF000000000000 or smaller than
14     // current clock
15     if(in->newTime > 0xFFFF000000000000ULL
16         || in->newTime < go.clock)
17         return TPM_RC_VALUE + RC_ClockSet_newTime;
18
19     // Internal Data Update
20
21     // Internal Data Update
22     clockNow = go.clock; // grab the old value
23     go.clock = in->newTime; // set the new value
24     // Check to see if the update has caused a need for an nvClock update
25     if((in->newTime & CLOCK_UPDATE_MASK) > (clockNow & CLOCK_UPDATE_MASK))
26     {
27         CryptDrbgGetPutState(GET_STATE);
28         NvWriteReserved(NV_ORDERLY_DATA, &go);
29
30         // Now the time state is safe
31         go.clockSafe = YES;
32     }
33
34     return TPM_RC_SUCCESS;
35 }
```

31.3 TPM2_ClockRateAdjust

31.3.1 General Description

This command adjusts the rate of advance of *Clock* and *Time* to provide a better approximation to real time.

The *rateAdjust* value is relative to the current rate and not the nominal rate of advance.

EXAMPLE 1 If this command had been called three times with *rateAdjust* = TPM_CLOCK_COARSE_SLOWER and once with *rateAdjust* = TPM_CLOCK_COARSE_FASTER, the net effect will be as if the command had been called twice with *rateAdjust* = TPM_CLOCK_COARSE_SLOWER.

The range of adjustment shall be sufficient to allow *Clock* and *Time* to advance at real time but no more. If the requested adjustment would make the rate advance faster or slower than the nominal accuracy of the input frequency, the TPM shall return TPM_RC_VALUE.

EXAMPLE 2 If the frequency tolerance of the TPM's input clock is +/-10 percent, then the TPM will return TPM_RC_VALUE if the adjustment would make *Clock* run more than 10 percent faster or slower than nominal. That is, if the input oscillator were nominally 100 megahertz (MHz), then 1 millisecond (ms) would normally take 100,000 counts. The update *Clock* should be adjustable so that 1 ms is between 90,000 and 110,000 counts.

The interpretation of "fine" and "coarse" adjustments is implementation-specific.

The nominal rate of advance for *Clock* and *Time* shall be accurate to within 15 percent. That is, with no adjustment applied, *Clock* and *Time* shall be advanced at a rate within 15 percent of actual time.

NOTE If the adjustments are incorrect, it will be possible to make the difference between advance of *Clock/Time* and real time to be as much as 1.15^2 or ~ 1.33 .

Changes to the current *Clock* update rate adjustment need not be persisted across TPM power cycles.

31.3.2 Command and Response

Table 191 — TPM2_ClockRateAdjust Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_ClockRateAdjust
TPMI_RH_PROVISION	@auth	TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Handle: 1 Auth Role: USER
TPM_CLOCK_ADJUST	rateAdjust	Adjustment to current <i>Clock</i> update rate

Table 192 — TPM2_ClockRateAdjust Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	returnCode	

31.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "ClockRateAdjust_fp.h"
3  TPM_RC
4  TPM2_ClockRateAdjust(
5      ClockRateAdjust_In      *in           // IN: input parameter list
6  )
7  {
8  // Internal Data Update
9      TimeSetAdjustRate(in->rateAdjust);
10
11     return TPM_RC_SUCCESS;
12 }
```

32 Capability Commands

32.1 Introduction

The TPM has numerous values that indicate the state, capabilities, and properties of the TPM. These values are needed for proper management of the TPM. The TPM2_GetCapability() command is used to access these values.

TPM2_GetCapability() allows reporting of multiple values in a single call. The values are grouped according to type.

NOTE TPM2_TestParms() is used to determine if a TPM supports a particular combination of algorithm parameters

32.2 TPM2_GetCapability

32.2.1 General Description

This command returns various information regarding the TPM and its current state.

The *capability* parameter determines the category of data returned. The *property* parameter selects the first value of the selected category to be returned. If there is no property that corresponds to the value of *property*, the next higher value is returned, if it exists.

EXAMPLE 1 The list of handles of transient objects currently loaded in the TPM may be read one at a time. On the first read, set the property to TRANSIENT_FIRST and *propertyCount* to one. If a transient object is present, the lowest numbered handle is returned and *moreData* will be YES if transient objects with higher handles are loaded. On the subsequent call, use returned handle value plus 1 in order to access the next higher handle.

The *propertyCount* parameter indicates the number of capabilities in the indicated group that are requested. The TPM will return the number of requested values (*propertyCount*) or until the last property of the requested type has been returned.

NOTE 1 The type of the capability is determined by a combination of *capability* and *property*.

When all of the properties of the requested type have been returned, the *moreData* parameter in the response will be set to NO. Otherwise, it will be set to YES.

NOTE 2 The *moreData* parameter will be YES if there are more properties even if the requested number of capabilities has been returned.

The TPM is not required to return more than one value at a time. It is not required to provide the same number of values in response to subsequent requests.

EXAMPLE 2 A TPM may return 4 properties in response to a TPM2_GetCapability(*capability* = TPM_CAP_TPM_PROPERTY, *property* = TPM_PT_MANUFACTURER, *propertyCount* = 8) and for a latter request with the same parameters, the TPM may return as few as one and as many as 8 values.

When the TPM is in Failure mode, a TPM is required to allow use of this command for access of the following capabilities:

- TPM_PT_MANUFACTURER
- TPM_PT_VENDOR_STRING_1
- TPM_PT_VENDOR_STRING_2⁽³⁾
- TPM_PT_VENDOR_STRING_3⁽³⁾
- TPM_PT_VENDOR_STRING_4⁽³⁾
- TPM_PT_VENDOR_TPM_TYPE
- TPM_PT_FIRMWARE_VERSION_1
- TPM_PT_FIRMWARE_VERSION_2

NOTE 3 If the vendor string does not require one of these values, the property type does not need to exist.

A vendor may optionally allow the TPM to return other values.

If in Failure mode and a capability is requested that is not available in Failure mode, the TPM shall return no value.

EXAMPLE 3 Assume the TPM is in Failure mode and the TPM only supports reporting of the minimum required set of properties (the limited set to TPML_TAGGED_PCR_PROPERTY values). If a TPM2_GetCapability is received requesting a capability that has a property type value greater than TPM_PT_FIRMWARE_VERSION_2, the TPM will return a zero length list with the moreData parameter set to NO. If the property type is less than TPM_PT_MANUFACTURER, the TPM will return TPM_PT_MANUFACTURER.

In Failure mode, *tag* is required to be TPM_ST_NO_SESSIONS or the TPM shall return TPM_RC_FAILURE.

The capability categories and the types of the return values are:

capability	property	Return Type
TPM_CAP_ALGS	TPM_ALG_ID ⁽¹⁾	TPML_ALG_PROPERTY
TPM_CAP_HANDLES	TPM_HANDLE	TPML_HANDLE
TPM_CAP_COMMANDS	TPM_CC	TPML_CCA
TPM_CAP_PP_COMMANDS	TPM_CC	TPML_CC
TPM_CAP_AUDIT_COMMANDS	TPM_CC	TPML_CC
TPM_CAP_PCERS	Reserved	TPML_PCR_SELECTION
TPM_CAP_TPM_PROPERTIES	TPM_PT	TPML_TAGGED_TPM_PROPERTY
TPM_CAP_PCR_PROPERTIES	TPM_PT_PCR	TPML_TAGGED_PCR_PROPERTY
TPM_CAP_ECC_CURVE	TPM_ECC_CURVE ⁽¹⁾	TPML_ECC_CURVE
TPM_CAP_VENDOR_PROPERTY	manufacturer specific	manufacturer-specific values
NOTES: (1) The TPM_ALG_ID or TPM_ECC_CURVE is cast to a UINT32		

- **TPM_CAP_ALGS** – Returns a list of TPMS_ALG_PROPERTIES. Each entry is an algorithm ID and a set of properties of the algorithm.
- **TPM_CAP_HANDLES** – Returns a list of all of the handles within the handle range of the *property* parameter. The range of the returned handles is determined by the handle type (the most-significant octet (MSO) of the *property*). Any of the defined handle types is allowed

EXAMPLE 4 If the MSO of *property* is TPM_HT_NV_INDEX, then the TPM will return a list of NV Index values.

EXAMPLE 5 If the MSO of *property* is TPM_HT_PCR, then the TPM will return a list of PCR.

- For this capability, use of TPM_HT_LOADED_SESSION and TPM_HT_SAVED_SESSION is allowed. Requesting handles with a handle type of TPM_HT_LOADED_SESSION will return handles for loaded sessions. The returned handle values will have a handle type of either TPM_HT_HMAC_SESSION or TPM_HT_POLICY_SESSION. If saved sessions are requested, all returned values will have the TPM_HT_HMAC_SESSION handle type because the TPM does not track the session type of saved sessions.

NOTE 2 TPM_HT_LOADED_SESSION and TPM_HT_HMAC_SESSION have the same value, as do TPM_HT_SAVED_SESSION and TPM_HT_POLICY_SESSION. It is not possible to request that the TPM return a list of loaded HMAC sessions without including the policy sessions.

- **TPM_CAP_COMMANDS** – Returns a list of the command attributes for all of the commands implemented in the TPM, starting with the TPM_CC indicated by the *property* parameter. If vendor specific commands are implemented, the vendor-specific command attribute with the lowest *commandIndex*, is returned after the non-vendor-specific (base) command.

NOTE 4 The type of the property parameter is a TPM_CC while the type of the returned list is TPML_CCA.

- **TPM_CAP_PP_COMMANDS** – Returns a list of all of the commands currently requiring Physical Presence for confirmation of platform authorization. The list will start with the TPM_CC indicated by *property*.
- **TPM_CAP_AUDIT_COMMANDS** – Returns a list of all of the commands currently set for command audit.
- **TPM_CAP_PCRS** – Returns the current allocation of PCR in a TPML_PCR_SELECTION. The *property* parameter shall be zero. The TPM will always respond to this command with the full PCR allocation and *moreData* will be NO.
- **TPM_CAP_TPM_PROPERTIES** – Returns a list of tagged properties. The tag is a TPM_PT and the property is a 32-bit value. The properties are returned in groups. Each property group is on a 256-value boundary (that is, the boundary occurs when the TPM_PT is evenly divisible by 256). The TPM will only return values in the same group as the *property* parameter in the command.
- **TPM_CAP_PCR_PROPERTIES** – Returns a list of tagged PCR properties. The tag is a TPM_PT_PCR and the property is a TPMS_PCR_SELECT.

The input command property is a TPM_PT_PCR (see Part 2 for PCR properties to be requested) that specifies the first property to be returned. If *propertyCount* is greater than 1, the list of properties begins with that property and proceeds in TPM_PT_PCR sequence.

NOTE 5 If the propertyCount selects an unimplemented property, the next higher implemented property is returned.

Each item in the list is a TPMS_PCR_SELECT structure that contains a bitmap of all PCR.

NOTE 6 A PCR index in all banks (all hash algorithms) has the same properties, so the hash algorithm is not specified here.

- `TPM_CAP_TPM_ECC_CURVES` – Returns a list of ECC curve identifiers currently available for use in the TPM.

The *moreData* parameter will have a value of YES if there are more values of the requested type that were not returned.

If no next capability exists, the TPM will return a zero-length list and *moreData* will have a value of NO.

32.2.2 Command and Response**Table 193 — TPM2_GetCapability Command**

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_GetCapability
TPM_CAP	capability	group selection; determines the format of the response
UINT32	property	further definition of information
UINT32	propertyCount	number of properties of the indicated type to return

Table 194 — TPM2_GetCapability Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPMI_YES_NO	moreData	flag to indicate if there are more values of this type
TPMS_CAPABILITY_DATA	capabilityData	the capability data

32.2.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "GetCapability_fp.h"

```

Error Returns	Meaning
TPM_RC_HANDLE	value of <i>property</i> is in an unsupported handle range for the TPM_CAP_HANDLES <i>capability</i> value
TPM_RC_VALUE	invalid <i>capability</i> ; or <i>property</i> is not 0 for the TPM_CAP_PCERS <i>capability</i> value

```

3  TPM_RC
4  TPM2_GetCapability(
5      GetCapability_In    *in,           // IN: input parameter list
6      GetCapability_Out  *out          // OUT: output parameter list
7  )
8  {
9      // Command Output
10
11     // Set output capability type the same as input type
12     out->capabilityData.capability = in->capability;
13
14     switch(in->capability)
15     {
16     case TPM_CAP_ALGS:
17         out->moreData = AlgorithmCapGetImplemented((TPM_ALG_ID) in->property,
18             in->propertyCount, &out->capabilityData.data.algorithms);
19         break;
20     case TPM_CAP_HANDLES:
21         switch(HandleGetType((TPM_HANDLE) in->property))
22         {
23         case TPM_HT_TRANSIENT:
24             // Get list of handles of loaded transient objects
25             out->moreData = ObjectCapGetLoaded((TPM_HANDLE) in->property,
26                 in->propertyCount,
27                 &out->capabilityData.data.handles);
28             break;
29         case TPM_HT_PERSISTENT:
30             // Get list of handles of persistent objects
31             out->moreData = NvCapGetPersistent((TPM_HANDLE) in->property,
32                 in->propertyCount,
33                 &out->capabilityData.data.handles);
34             break;
35         case TPM_HT_NV_INDEX:
36             // Get list of defined NV index
37             out->moreData = NvCapGetIndex((TPM_HANDLE) in->property,
38                 in->propertyCount,
39                 &out->capabilityData.data.handles);
40             break;
41         case TPM_HT_LOADED_SESSION:
42             // Get list of handles of loaded sessions
43             out->moreData = SessionCapGetLoaded((TPM_HANDLE) in->property,
44                 in->propertyCount,
45                 &out->capabilityData.data.handles);
46             break;
47         case TPM_HT_ACTIVE_SESSION:
48             // Get list of handles of
49             out->moreData = SessionCapGetSaved((TPM_HANDLE) in->property,
50                 in->propertyCount,
51                 &out->capabilityData.data.handles);

```



```

52     break;
53 case TPM_HT_PCR:
54     // Get list of handles of PCR
55     out->moreData = PCRCapGetHandles((TPM_HANDLE) in->property,
56                                     in->propertyCount,
57                                     &out->capabilityData.data.handles);
58     break;
59 case TPM_HT_PERMANENT:
60     // Get list of permanent handles
61     out->moreData = PermanentCapGetHandles(
62         (TPM_HANDLE) in->property,
63         in->propertyCount,
64         &out->capabilityData.data.handles);
65     break;
66 default:
67     // Unsupported input handle type
68     return TPM_RC_HANDLE + RC_GetCapability_property;
69     break;
70 }
71 break;
72 case TPM_CAP_COMMANDS:
73     out->moreData = CommandCapGetCCList((TPM_CC) in->property,
74                                         in->propertyCount,
75                                         &out->capabilityData.data.command);
76     break;
77 case TPM_CAP_PP_COMMANDS:
78     out->moreData = PhysicalPresenceCapGetCCList((TPM_CC) in->property,
79                                                 in->propertyCount, &out->capabilityData.data.ppCommands);
80     break;
81 case TPM_CAP_AUDIT_COMMANDS:
82     out->moreData = CommandAuditCapGetCCList((TPM_CC) in->property,
83                                             in->propertyCount,
84                                             &out->capabilityData.data.auditCommands);
85     break;
86 case TPM_CAP_PCERS:
87     // Input property must be 0
88     if(in->property != 0)
89         return TPM_RC_VALUE + RC_GetCapability_property;
90     out->moreData = PCRCapGetAllocation(in->propertyCount,
91                                       &out->capabilityData.data.assignedPCR);
92     break;
93 case TPM_CAP_PCR_PROPERTIES:
94     out->moreData = PCRCapGetProperties((TPM_PT_PCR) in->property,
95                                       in->propertyCount,
96                                       &out->capabilityData.data.pcrProperties);
97     break;
98 case TPM_CAP_TPM_PROPERTIES:
99     out->moreData = TPMCapGetProperties((TPM_PT) in->property,
100                                     in->propertyCount,
101                                     &out->capabilityData.data.tpmProperties);
102     break;
103 #ifdef TPM_ALG_ECC
104 case TPM_CAP_ECC_CURVES:
105     out->moreData = CryptCapGetECCCurve((TPM_ECC_CURVE ) in->property,
106                                       in->propertyCount,
107                                       &out->capabilityData.data.eccCurves);
108     break;
109 #endif // TPM_ALG_ECC
110 case TPM_CAP_VENDOR_PROPERTY:
111     // vendor property is not implemented
112 default:
113     // Unexpected TPM_CAP value
114     return TPM_RC_VALUE;
115     break;

```

```
116     }  
117  
118     return TPM_RC_SUCCESS;  
119 }
```

32.3 TPM2_TestParms

32.3.1 General Description

This command is used to check to see if specific combinations of algorithm parameters are supported.

The TPM will unmarshal the provided TPMT_PUBLIC_PARMS. If the parameters unmarshal correctly, then the TPM will return TPM_RC_SUCCESS, indicating that the parameters are valid for the TPM. The TPM will return the appropriate unmarshaling error if a parameter is not valid.

32.3.2 Command and Response**Table 195 — TPM2_TestParms Command**

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_TestParms
TPMT_PUBLIC_PARMS	parameters	algorithm parameters to be validated

Table 196 — TPM2_TestParms Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	TPM_RC

32.3.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "TestParms_fp.h"
3  TPM_RC
4  TPM2_TestParms(
5      TestParms_In      *in          // IN: input parameter list
6  )
7  {
8      // Input parameter is not reference in command action
9      in = NULL;
10
11     // The parameters are tested at unmarshal process. We do nothing in command
12     // action
13     return TPM_RC_SUCCESS;
14 }
```

33 Non-volatile Storage

33.1 Introduction

The NV commands are used to create, update, read, and delete allocations of space in NV memory. Before an Index may be used, it must be defined (TPM2_NV_DefineSpace()).

An Index may be modified if the proper write authorization is provided or read if the proper read authorization is provided. Different controls are available for reading and writing.

An Index may have an Index-specific *authValue* and *authPolicy*. The *authValue* may be used to authorize reading if TPMA_NV_AUTHREAD is SET and writing if TPMA_NV_AUTHWRITE is SET. The *authPolicy* may be used to authorize reading if TPMA_NV_POLICYREAD is SET and writing if TPMA_NV_POLICYWRITE is SET.

TPMA_NV_PPREAD and TPMA_NV_PPWRITE indicate if reading or writing of the NV Index may be authorized by *platformAuth* or *platformPolicy*.

TPMA_NV_OWNERREAD and TPMA_NV_OWNERWRITE indicate if reading or writing of the NV Index may be authorized by *ownerAuth* or *ownerPolicy*.

If an operation on an NV index requires authorization, and the *authHandle* parameter is the handle of an NV Index, then the *nvIndex* parameter must have the same value or the TPM will return TPM_RC_NV_AUTHORIZATION.

NOTE 1 This check ensures that the authorization that was provided is associated with the NV Index being authorized.

For creating an Index, *ownerAuth* may not be used if *shEnable* is CLEAR and *platformAuth* may not be used if *phEnableNV* is CLEAR.

If an Index was defined using *platformAuth*, then that Index is not accessible when *phEnableNV* is CLEAR. If an Index was defined using *ownerAuth*, then that Index is not accessible when *shEnable* is CLEAR.

For read access control, any combination of TPMA_NV_PPREAD, TPMA_NV_OWNERREAD, TPMA_NV_AUTHREAD, or TPMA_NV_POLICYREAD is allowed as long as at least one is SET.

For write access control, any combination of TPMA_NV_PPWRITE, TPMA_NV_OWNERWRITE, TPMA_NV_AUTHWRITE, or TPMA_NV_POLICYWRITE is allowed as long as at least one is SET.

If an Index has been defined and not written, then any operation on the NV Index that requires read authorization will fail (TPM_RC_NV_INITIALIZED). This check may be made before or after other authorization checks but shall be performed before checking the NV Index *authValue*. An authorization failure due to the NV Index not having been written shall not be logged by the dictionary attack logic.

If TPMA_NV_CLEAR_STCLEAR is SET, then the TPMA_NV_WRITTEN will be CLEAR on each TPM2_Startup(TPM_SU_CLEAR). TPMA_NV_CLEAR_STCLEAR shall not be SET if TPMA_NV_COUNTER is SET.

The code in the “Detailed Actions” clause of each command is written to interface with an implementation-dependent library that allows access to NV memory. The actions assume no specific layout of the structure of the NV data.

Only one NV Index may be directly referenced in a command.

NOTE 2 This means that, if *authHandle* references an NV Index, then *nvIndex* will have the same value. However, this does not limit the number of changes that may occur as side effects. For example, any number of NV Indexes might be relocated as a result of deleting or adding a NV Index.

33.2 NV Counters

When an Index has the TPMA_NV_COUNTER attribute set, it behaves as a monotonic counter and may only be updated using TPM2_NV_Increment().

When an NV counter is created, the TPM shall initialize the 8-octet counter value with a number that is greater than any count value for any NV counter on the TPM since the time of TPM manufacture.

An NV counter may be defined with the TPMA_NV_ORDERLY attribute to indicate that the NV Index is expected to be modified at a high frequency and that the data is only required to persist when the TPM goes through an orderly shutdown process. The TPM may update the counter value in RAM and occasionally update the non-volatile version of the counter. An orderly shutdown is one occasion to update the non-volatile count. If the difference between the volatile and non-volatile version of the counter becomes as large as MAX_ORDERLY_COUNT, this shall be another occasion for updating the non-volatile count.

Before an NV counter can be used, the TPM shall validate that the count is not less than a previously reported value. If the TPMA_NV_ORDERLY attribute is not SET, or if the TPM experienced an orderly shutdown, then the count is assumed to be correct. If the TPMA_NV_ORDERLY attribute is SET, and the TPM shutdown was not orderly, then the TPM shall OR MAX_ORDERLY_COUNT to the contents of the non-volatile counter and set that as the current count.

NOTE 1 Because the TPM would have updated the NV Index if the difference between the count values was equal to MAX_ORDERLY_COUNT + 1, the highest value that could have been in the NV Index is MAX_ORDERLY_COUNT so it is safe to restore that value.

NOTE 2 The TPM may implement the RAM portion of the counter such that the effective value of the NV counter is the sum of both the volatile and non-volatile parts. If so, then the TPM may initialize the RAM version of the counter to MAX_ORDERLY_COUNT and no update of NV is necessary.

NOTE 3 When a new NV counter is created, the TPM may search all the counters to determine which has the highest value. In this search, the TPM would use the sum of the non-volatile and RAM portions of the counter. The RAM portion of the counter shall be properly initialized to reflect shutdown process (orderly or not) of the TPM.

33.3 TPM2_NV_DefineSpace

33.3.1 General Description

This command defines the attributes of an NV Index and causes the TPM to reserve space to hold the data associated with the NV Index. If a definition already exists at the NV Index, the TPM will return TPM_RC_NV_DEFINED.

The TPM will return TPM_RC_ATTRIBUTES if more than one of TPMA_NV_COUNTER, TPMA_NV_BITS, or TPMA_NV_EXTEND is SET in *publicInfo*.

NOTE It is not required that any of these three attributes be set.

The TPM shall return TPM_RC_ATTRIBUTES if TPMA_NV_WRITTEN, TPM_NV_READLOCKED, or TPMA_NV_WRITELOCKED is SET.

If TPMA_NV_COUNTER or TPMA_NV_BITS is SET, then *publicInfo*→*dataSize* shall be set to eight (8) or the TPM shall return TPM_RC_SIZE.

If TPMA_NV_EXTEND is SET, then *publicInfo*→*dataSize* shall match the digest size of the *publicInfo.nameAlg* or the TPM shall return TPM_RC_SIZE.

If the NV Index is an ordinary Index and *publicInfo*→*dataSize* is larger than supported by the TPM implementation then the TPM shall return TPM_RC_SIZE.

NOTE The limit for the data size may vary according to the type of the index. For example, if the index is has TPMA_NV_ORDERLY SET, then the maximum size of an ordinary NV Index may be less than the size of an ordinary NV Index that has TPMA_NV_ORDERLY CLEAR.

At least one of TPMA_NV_PPREAD, TPMA_NV_OWNERREAD, TPMA_NV_AUTHREAD, or TPMA_NV_POLICYREAD shall be SET or the TPM shall return TPM_RC_ATTRIBUTES.

At least one of TPMA_NV_PPWRITE, TPMA_NV_OWNERWRITE, TPMA_NV_AUTHWRITE, or TPMA_NV_POLICYWRITE shall be SET or the TPM shall return TPM_RC_ATTRIBUTES.

If TPMA_NV_CLEAR_STCLEAR is SET, then TPMA_NV_COUNTER shall be CLEAR or the TPM shall return TPM_RC_ATTRIBUTES.

If *platformAuth/platformPolicy* is used for authorization, then TPMA_NV_PLATFORMCREATE shall be SET in *publicInfo*. If *ownerAuth/ownerPolicy* is used for authorization, TPMA_NV_PLATFORMCREATE shall be CLEAR in *publicInfo*. If TPMA_NV_PLATFORMCREATE is not set correctly for the authorization, the TPM shall return TPM_RC_ATTRIBUTES.

If TPMA_NV_POLICY_DELETE is SET, then the authorization shall be with *platformAuth* or the TPM shall return TPM_RC_ATTRIBUTES.

If the implementation does not support TPM2_NV_Increment(), the TPM shall return TPM_RC_ATTRIBUTES if TPMA_NV_COUNTER is SET.

If the implementation does not support TPM2_NV_SetBits(), the TPM shall return TPM_RC_ATTRIBUTES if TPMA_NV_BITS is SET.

If the implementation does not support TPM2_NV_Extend(), the TPM shall return TPM_RC_ATTRIBUTES if TPMA_NV_EXTEND is SET.

If the implementation does not support TPM2_NV_UndefineSpaceSpecial(), the TPM shall return TPM_RC_ATTRIBUTES if TPMA_NV_POLICY_DELETE is SET.

After the successful completion of this command, the NV Index exists but TPMA_NV_WRITTEN will be CLEAR. Any access of the NV data will return TPM_RC_NV_UNINITIALIZED.

In some implementations, an NV Index with the `TPMA_NV_COUNTER` attribute may require special TPM resources that provide higher endurance than regular NV. For those implementations, if this command fails because of lack of resources, the TPM will return `TPM_RC_NV_SPACE`.

The value of *auth* is saved in the created structure. The size of *auth* is limited to be no larger than the size of the digest produced by the NV Index's *nameAlg* (`TPM_RC_SIZE`).

33.3.2 Command and Response

Table 197 — TPM2_NV_DefineSpace Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_DefineSpace {NV}
TPMI_RH_PROVISION	@authHandle	TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPM2B_AUTH	auth	the authorization value
TPM2B_NV_PUBLIC	publicInfo	the public parameters of the NV area

Table 198 — TPM2_NV_DefineSpace Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.3.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_DefineSpace_fp.h"

```

Error Returns	Meaning
TPM_RC_NV_ATTRIBUTES	attributes of the index are not consistent
TPM_RC_NV_DEFINED	index already exists
TPM_RC_HIERARCHY	for authorizations using TPM_RH_PLATFORM <i>phEnable_NV</i> is clear.
TPM_RC_NV_SPACE	Insufficient space for the index
TPM_RC_SIZE	'auth->size' or ' <i>publicInfo->authPolicy.size</i> ' is larger than the digest size of ' <i>publicInfo->nameAlg</i> ', or ' <i>publicInfo->dataSize</i> ' is not consistent with ' <i>publicInfo->attributes</i> '.

```

3  TPM_RC
4  TPM2_NV_DefineSpace(
5      NV_DefineSpace_In          *in          // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9      TPMA_NV         attributes;
10     UINT16          nameSize;
11
12     nameSize = CryptGetHashDigestSize(in->publicInfo.t.nvPublic.nameAlg);
13
14     // Check if NV is available. NvIsAvailable may return TPM_RC_NV_UNAVAILABLE
15     // TPM_RC_NV_RATE or TPM_RC_SUCCESS.
16     result = NvIsAvailable();
17     if(result != TPM_RC_SUCCESS)
18         return result;
19
20     // Input Validation
21     // If an index is being created by the owner and shEnable is
22     // clear, then we would not reach this point because ownerAuth
23     // can't be given when shEnable is CLEAR. However, if phEnable
24     // is SET but phEnableNV is CLEAR, we have to check here
25     if(in->authHandle == TPM_RH_PLATFORM && gc.phEnableNV == CLEAR)
26         return TPM_RC_HIERARCHY + RC_NV_DefineSpace_authHandle;
27
28     attributes = in->publicInfo.t.nvPublic.attributes;
29
30     //TPMS_NV_PUBLIC validation.
31     // Counters and bit fields must have a size of 8
32     if ( (attributes.TPMA_NV_COUNTER == SET || attributes.TPMA_NV_BITS == SET)
33         && (in->publicInfo.t.nvPublic.dataSize != 8))
34         return TPM_RC_SIZE + RC_NV_DefineSpace_publicInfo;
35
36     // check that the authPolicy consistent with hash algorithm
37     if( in->publicInfo.t.nvPublic.authPolicy.t.size != 0
38         && in->publicInfo.t.nvPublic.authPolicy.t.size != nameSize)
39         return TPM_RC_SIZE + RC_NV_DefineSpace_publicInfo;
40
41     // make sure that the authValue is not too large
42     MemoryRemoveTrailingZeros(&in->auth);
43     if(in->auth.t.size > nameSize)
44         return TPM_RC_SIZE + RC_NV_DefineSpace_auth;

```

```

45
46
47 //TPMA_NV validation.
48 // Locks may not be SET and written cannot be SET
49 if( attributes.TPMA_NV_WRITTEN == SET
50 || attributes.TPMA_NV_WRITELOCKED == SET
51 || attributes.TPMA_NV_READLOCKED == SET)
52     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
53
54 // There must be a way to read the index
55 if( attributes.TPMA_NV_OWNERREAD == CLEAR
56 && attributes.TPMA_NV_PPREAD == CLEAR
57 && attributes.TPMA_NV_AUTHREAD == CLEAR
58 && attributes.TPMA_NV_POLICYREAD == CLEAR)
59     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
60
61 // There must be a way to write the index
62 if( attributes.TPMA_NV_OWNERWRITE == CLEAR
63 && attributes.TPMA_NV_PPWRITE == CLEAR
64 && attributes.TPMA_NV_AUTHWRITE == CLEAR
65 && attributes.TPMA_NV_POLICYWRITE == CLEAR)
66     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
67
68 // Make sure that no attribute is used that is not supported by the proper
69 // command
70 #if CC_NV_Increment == NO
71     if( attributes.TPMA_NV_COUNTER == SET)
72         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
73 #endif
74 #if CC_NV_SetBits == NO
75     if( attributes.TPMA_NV_BITS == SET)
76         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
77 #endif
78 #if CC_NV_Extend == NO
79     if( attributes.TPMA_NV_EXTEND == SET)
80         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
81 #endif
82 #if CC_NV_UndefineSpaceSpecial == NO
83     if( attributes.TPMA_NV_POLICY_DELETE == SET)
84         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
85 #endif
86
87 // Can be COUNTER or BITS or EXTEND but not more than one
88 if( attributes.TPMA_NV_COUNTER == SET
89 && attributes.TPMA_NV_BITS == SET)
90     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
91 if( attributes.TPMA_NV_COUNTER == SET
92 && attributes.TPMA_NV_EXTEND == SET)
93     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
94 if( attributes.TPMA_NV_BITS == SET
95 && attributes.TPMA_NV_EXTEND == SET)
96     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
97
98 // An index with TPMA_NV_CLEAR_STCLEAR can't be a counter
99 if( attributes.TPMA_NV_CLEAR_STCLEAR == SET
100 && attributes.TPMA_NV_COUNTER == SET)
101     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
102
103 // The index is allowed to have one of GLOBALLOCK or WRITEDEFINE SET
104 if( attributes.TPMA_NV_GLOBALLOCK == SET
105 && attributes.TPMA_NV_WRITEDEFINE == SET)
106     return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
107
108 // Make sure that the creator of the index can delete the index

```

```
109     if( ( in->publicInfo.t.nvPublic.attributes.TPMA_NV_PLATFORMCREATE == SET
110           && in->authHandle == TPM_RH_OWNER
111         )
112       || ( in->publicInfo.t.nvPublic.attributes.TPMA_NV_PLATFORMCREATE == CLEAR
113           && in->authHandle == TPM_RH_PLATFORM
114         )
115     )
116         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_authHandle;
117
118     // If TPMA_NV_POLICY_DELETE is SET, then the index must be defined by
119     // the platform
120     if( in->publicInfo.t.nvPublic.attributes.TPMA_NV_POLICY_DELETE == SET
121       && TPM_RH_PLATFORM != in->authHandle
122     )
123         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
124
125     // If the NV index is used as a PCR, the data size must match the digest
126     // size
127     if( in->publicInfo.t.nvPublic.attributes.TPMA_NV_EXTEND == SET
128       && in->publicInfo.t.nvPublic.dataSize != nameSize
129     )
130         return TPM_RC_ATTRIBUTES + RC_NV_DefineSpace_publicInfo;
131
132     // See if the index is already defined.
133     if(NvIsUndefinedIndex(in->publicInfo.t.nvPublic.nvIndex))
134         return TPM_RC_NV_DEFINED;
135
136     // Internal Data Update
137     // define the space. A TPM_RC_NV_SPACE error may be returned at this point
138     result = NvDefineIndex(&in->publicInfo.t.nvPublic, &in->auth);
139     if(result != TPM_RC_SUCCESS)
140         return result;
141
142     return TPM_RC_SUCCESS;
143 }
144 }
```

33.4 TPM2_NV_UndefineSpace

33.4.1 General Description

This command removes an Index from the TPM.

If *nvIndex* is not defined, the TPM shall return TPM_RC_HANDLE.

If *nvIndex* references an Index that has its TPMA_NV_PLATFORMCREATE attribute SET, the TPM shall return TPM_RC_NV_AUTHORITY unless *platformAuth* is provided.

NOTE An Index with TPMA_NV_PLATFORMCREATE CLEAR may be deleted with *platformAuth* as long as shEnable is SET. If shEnable is CLEAR, indexes created using ownerAuth are not accessible even for deletion by the platform.

33.4.2 Command and Response

Table 199 — TPM2_NV_UndefineSpace Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_UndefineSpace {NV}
TPMI_RH_PROVISION	@authHandle	TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index to remove from NV space Auth Index: None

Table 200 — TPM2_NV_UndefineSpace Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.4.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_UndefineSpace_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	TPMA_NV_POLICY_DELETE is SET in the Index referenced by <i>nvIndex</i> so this command may not be used to delete this Index (see TPM2_NV_UndefineSpaceSpecial())
TPM_RC_NV_AUTHORIZATION	attempt to use <i>ownerAuth</i> to delete an index created by the platform

```

3  TPM_RC
4  TPM2_NV_UndefineSpace(
5      NV_UndefineSpace_In *in          // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9      NV_INDEX        nvIndex;
10
11     // The command needs NV update. Check if NV is available.
12     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
13     // this point
14     result = NvIsAvailable();
15     if(result != TPM_RC_SUCCESS) return result;
16
17     // Input Validation
18
19     // Get NV index info
20     NvGetIndexInfo(in->nvIndex, &nvIndex);
21
22     // This command can't be used to delete an index with TPMA_NV_POLICY_DELETE SET
23     if(SET == nvIndex.publicArea.attributes.TPMA_NV_POLICY_DELETE)
24         return TPM_RC_ATTRIBUTES + RC_NV_UndefineSpace_nvIndex;
25
26     // The owner may only delete an index that was defined with ownerAuth. The
27     // platform may delete an index that was created with either auth.
28     if( in->authHandle == TPM_RH_OWNER
29         && nvIndex.publicArea.attributes.TPMA_NV_PLATFORMCREATE == SET)
30         return TPM_RC_NV_AUTHORIZATION;
31
32     // Internal Data Update
33
34     // Call implementation dependent internal routine to delete NV index
35     NvDeleteEntity(in->nvIndex);
36
37     return TPM_RC_SUCCESS;
38 }

```


33.5 TPM2_NV_UndefineSpaceSpecial

33.5.1 General Description

This command allows removal of a platform-created NV Index that has TPMA_NV_POLICY_DELETE SET.

This command requires that the policy of the NV Index be satisfied before the NV Index may be deleted. Because administrative role is required, the policy must contain a command that sets the policy command code to TPM_CC_NV_UndefineSpaceSpecial. This indicates that the policy that is being used is a policy that is for this command, and not a policy that would approve another use. That is, authority to use an object does not grant authority to undefine the object.

If *nvIndex* is not defined, the TPM shall return TPM_RC_HANDLE.

If *nvIndex* references an Index that has its TPMA_NV_PLATFORMCREATE or TPMA_NV_POLICY_DELETE attribute CLEAR, the TPM shall return TPM_RC_NV_ATTRIBUTES.

NOTE An Index with TPMA_NV_PLATFORMCREATE CLEAR may be deleted with TPM2_UndefineSpace() as long as shEnable is SET. If shEnable is CLEAR, indexes created using ownerAuth are not accessible even for deletion by the platform.

33.5.2 Command and Response

Table 201 — TPM2_NV_UndefineSpaceSpecial Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_UndefineSpaceSpecial {NV}
TPMI_RH_NV_INDEX	@nvIndex	Index to be deleted Auth Index: 1 Auth Role: ADMIN
TPMI_RH_PLATFORM	@platform	TPM_RH_PLATFORM + {PP} Auth Index: 2 Auth Role: USER

Table 202 — TPM2_NV_UndefineSpaceSpecial Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.5.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_UndefineSpaceSpecial_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	TPMA_NV_POLICY_DELETE is not SET in the Index referenced by <i>nvIndex</i>

```

3  TPM_RC
4  TPM2_NV_UndefineSpaceSpecial(
5      NV_UndefineSpaceSpecial_In *in          // IN: input parameter list
6  )
7  {
8      TPM_RC      result;
9      NV_INDEX    nvIndex;
10
11     // The command needs NV update. Check if NV is available.
12     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
13     // this point
14     result = NvIsAvailable();
15     if(result != TPM_RC_SUCCESS)
16         return result;
17
18     // Input Validation
19
20     // Get NV index info
21     NvGetIndexInfo(in->nvIndex, &nvIndex);
22
23     // This operation only applies when the TPMA_NV_POLICY_DELETE attribute is SET
24     if(CLEAR == nvIndex.publicArea.attributes.TPMA_NV_POLICY_DELETE)
25         return TPM_RC_ATTRIBUTES + RC_NV_UndefineSpaceSpecial_nvIndex;
26
27     // Internal Data Update
28
29     // Call implementation dependent internal routine to delete NV index
30     NvDeleteEntity(in->nvIndex);
31
32     return TPM_RC_SUCCESS;
33 }

```

33.6 TPM2_NV_ReadPublic

33.6.1 General Description

This command is used to read the public area and Name of an NV Index. The public area of an Index is not privacy-sensitive and no authorization is required to read this data.

33.6.2 Command and Response

Table 203 — TPM2_NV_ReadPublic Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_ReadPublic
TPMI_RH_NV_INDEX	nvIndex	the NV Index Auth Index: None

Table 204 — TPM2_NV_ReadPublic Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_NV_PUBLIC	nvPublic	the public area of the NV Index
TPM2B_NAME	nvName	the Name of the <i>nvIndex</i>

33.6.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "NV_ReadPublic_fp.h"
3  TPM_RC
4  TPM2_NV_ReadPublic(
5      NV_ReadPublic_In      *in,           // IN: input parameter list
6      NV_ReadPublic_Out     *out          // OUT: output parameter list
7  )
8  {
9      NV_INDEX      nvIndex;
10
11  // Command Output
12
13  // Get NV index info
14  NvGetIndexInfo(in->nvIndex, &nvIndex);
15
16  // Copy data to output
17  out->nvPublic.t.nvPublic = nvIndex.publicArea;
18
19  // Compute NV name
20  out->nvName.t.size = NvGetName(in->nvIndex, &out->nvName.t.name);
21
22  return TPM_RC_SUCCESS;
23 }
```

33.7 TPM2_NV_Write

33.7.1 General Description

This command writes a value to an area in NV memory that was previously defined by TPM2_NV_DefineSpace().

Proper authorizations are required for this command as determined by TPMA_NV_PPWRITE; TPMA_NV_OWNERWRITE; TPMA_NV_AUTHWRITE; and, if TPMA_NV_POLICY_WRITE is SET, the *authPolicy* of the NV Index.

If the TPMA_NV_WRITELOCKED attribute of the NV Index is SET, then the TPM shall return TPM_RC_NV_LOCKED.

NOTE 1 If authorization sessions are present, they are checked before checks to see if writes to the NV Index are locked.

If TPMA_NV_COUNTER, TPMA_NV_BITS or TPMA_NV_EXTEND of the NV Index is SET, then the TPM shall return TPM_RC_NV_ATTRIBUTE.

If the size of the *data* parameter plus the *offset* parameter adds to a value that is greater than the size of the NV Index *data*, the TPM shall return TPM_RC_NV_RANGE and not write any data to the NV Index.

If the TPMA_NV_WRITEALL attribute of the NV Index is SET, then the TPM shall return TPM_RC_NV_RANGE if the size of the *data* parameter of the command is not the same as the *data* field of the NV Index.

If all checks succeed, the TPM will merge the *data.size* octets of *data.buffer* value into the *nvIndex→data* starting at *nvIndex→data[offset]*. If the NV memory is implemented with a technology that has endurance limitations, the TPM shall check that the merged data is different from the current contents of the NV Index and only perform a write to NV memory if they differ.

After successful completion of this command, TPMA_NV_WRITTEN for the NV Index will be SET.

NOTE 2 Once SET, TPMA_NV_WRITTEN remains SET until the NV Index is undefined or the NV Index is cleared.

33.7.2 Command and Response

Table 205 — TPM2_NV_Write Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_Write {NV}
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index of the area to write Auth Index: None
TPM2B_MAX_NV_BUFFER	data	the data to write
UINT16	offset	the offset into the NV Area

Table 206 — TPM2_NV_Write Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.7.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_Write_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	Index referenced by <i>nvIndex</i> has either TPMA_NV_BITS, TPMA_NV_COUNTER, or TPMA_NV_EVENT attribute SET
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to write to the Index referenced by <i>nvIndex</i>
TPM_RC_NV_LOCKED	Index referenced by <i>nvIndex</i> is write locked
TPM_RC_NV_RANGE	if TPMA_NV_WRITEALL is SET then the write is not the size of the Index referenced by <i>nvIndex</i> ; otherwise, the write extends beyond the limits of the Index

```

4  TPM_RC
5  TPM2_NV_Write(
6      NV_Write_In          *in          // IN: input parameter list
7  )
8  {
9      NV_INDEX          nvIndex;
10     TPM_RC            result;
11
12     // Input Validation
13
14     // Get NV index info
15     NvGetIndexInfo(in->nvIndex, &nvIndex);
16
17     // common access checks. NvWriteAccessChecks() may return
18     // TPM_RC_NV_AUTHORIZATION or TPM_RC_NV_LOCKED
19     result = NvWriteAccessChecks(in->authHandle, in->nvIndex);
20     if(result != TPM_RC_SUCCESS)
21         return result;
22
23     // Bits index, extend index or counter index may not be updated by
24     // TPM2_NV_Write
25     if( nvIndex.publicArea.attributes.TPMA_NV_COUNTER == SET
26        || nvIndex.publicArea.attributes.TPMA_NV_BITS == SET
27        || nvIndex.publicArea.attributes.TPMA_NV_EXTEND == SET)
28         return TPM_RC_ATTRIBUTES;
29
30     // Too much data
31     if((in->data.t.size + in->offset) > nvIndex.publicArea.dataSize)
32         return TPM_RC_NV_RANGE;
33
34     // If this index requires a full sized write, make sure that input range is
35     // full sized
36     if( nvIndex.publicArea.attributes.TPMA_NV_WRITEALL == SET
37        && in->data.t.size < nvIndex.publicArea.dataSize)
38         return TPM_RC_NV_RANGE;
39
40     // Internal Data Update
41
42     // Perform the write. This called routine will SET the TPMA_NV_WRITTEN
43     // attribute if it has not already been SET. If NV isn't available, an error
44     // will be returned.
45     return NvWriteIndexData(in->nvIndex, &nvIndex, in->offset,

```

```
46         in->data.t.size, in->data.t.buffer);  
47  
48     }
```

33.8 TPM2_NV_Increment

33.8.1 General Description

This command is used to increment the value in an NV Index that has TPMA_NV_COUNTER SET. The data value of the NV Index is incremented by one.

NOTE 1 The NV Index counter is an unsigned value.

If TPMA_NV_COUNTER is not SET in the indicated NV Index, the TPM shall return TPM_RC_ATTRIBUTES.

If TPMA_NV_WRITELOCKED is SET, the TPM shall return TPM_RC_NV_LOCKED.

If TPMA_NV_WRITTEN is CLEAR, it will be SET.

If TPMA_NV_ORDERLY is SET, and the difference between the volatile and non-volatile versions of this field is greater than MAX_ORDERLY_COUNT, then the non-volatile version of the counter is updated.

NOTE 2 If a TPM implements TPMA_NV_ORDERLY and an Index is defined with TPMA_NV_ORDERLY and TPMA_NV_COUNTER both SET, then in the Event of a non-orderly shutdown, the non-volatile value for the counter Index will be advanced by MAX_ORDERLY_COUNT at the next TPM2_Startup().

NOTE 3 An allowed implementation would keep a counter value in NV and a resettable counter in RAM. The reported value of the NV Index would be the sum of the two values. When the RAM count increments past the maximum allowed value (MAX_ORDERLY_COUNT), the non-volatile version of the count is updated with the sum of the values and the RAM count is reset to zero.

33.8.2 Command and Response

Table 207 — TPM2_NV_Increment Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_Increment {NV}
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index to increment Auth Index: None

Table 208 — TPM2_NV_Increment Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.8.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_Increment_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	NV index is not a counter
TPM_RC_NV_AUTHORIZATION	authorization failure
TPM_RC_NV_LOCKED	Index is write locked

```

4  TPM_RC
5  TPM2_NV_Increment(
6      NV_Increment_In      *in          // IN: input parameter list
7  )
8  {
9      TPM_RC      result;
10     NV_INDEX     nvIndex;
11     UINT64      countValue;
12
13
14     // Input Validation
15
16     // Common access checks, a TPM_RC_NV_AUTHORIZATION or TPM_RC_NV_LOCKED
17     // error may be returned at this point
18     result = NvWriteAccessChecks(in->authHandle, in->nvIndex);
19     if(result != TPM_RC_SUCCESS)
20         return result;
21
22     // Get NV index info
23     NvGetIndexInfo(in->nvIndex, &nvIndex);
24
25     // Make sure that this is a counter
26     if(nvIndex.publicArea.attributes.TPMA_NV_COUNTER != SET)
27         return TPM_RC_ATTRIBUTES + RC_NV_Increment_nvIndex;
28
29     // Internal Data Update
30
31     // If counter index is not been written, initialize it
32     if(nvIndex.publicArea.attributes.TPMA_NV_WRITTEN == CLEAR)
33         countValue = NvInitialCounter();
34     else
35         // Read NV data in native format for TPM CPU.
36         NvGetIntIndexData(in->nvIndex, &nvIndex, &countValue);
37
38     // Do the increment
39     countValue++;
40
41     // If this is an orderly counter that just rolled over, need to be able to
42     // write to NV to proceed. This check is done here, because NvWriteIndexData()
43     // does not see if the update is for counter rollover.
44     if(
45         nvIndex.publicArea.attributes.TPMA_NV_ORDERLY == SET
46         && (countValue & MAX_ORDERLY_COUNT) == 0)
47     {
48         result = NvIsAvailable();
49         if(result != TPM_RC_SUCCESS)
50             return result;
51
52         // Need to force an NV update

```

```
52     g_updateNV = TRUE;
53 }
54
55 // Write NV data back. A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may
56 // be returned at this point. If necessary, this function will set the
57 // TPMA_NV_WRITTEN attribute
58 return NvWriteIndexData(in->nvIndex, &nvIndex, 0, 8, &countValue);
59
60 }
```

33.9 TPM2_NV_Extend

33.9.1 General Description

This command extends a value to an area in NV memory that was previously defined by TPM2_NV_DefineSpace.

If TPMA_NV_EXTEND is not SET, then the TPM shall return TPM_RC_ATTRIBUTES.

Proper write authorizations are required for this command as determined by TPMA_NV_PPWRITE, TPMA_NV_OWNERWRITE, TPMA_NV_AUTHWRITE, and the *authPolicy* of the NV Index.

After successful completion of this command, TPMA_NV_WRITTEN for the NV Index will be SET.

NOTE 1 Once SET, TPMA_NV_WRITTEN remains SET until the NV Index is undefined or the NV Index is cleared.

If the TPMA_NV_WRITELOCKED attribute of the NV Index is SET, then the TPM shall return TPM_RC_NV_LOCKED.

NOTE 2 If authorization sessions are present, they are checked before checks to see if writes to the NV Index are locked.

The *data.buffer* parameter may be larger than the defined size of the NV Index.

The Index will be updated by:

$$nvIndex \rightarrow data_{new} := H_{nameAlg}(nvIndex \rightarrow data_{old} || data.buffer) \quad (39)$$

where

$H_{nameAlg}()$	the hash algorithm indicated in <i>nvIndex</i> → <i>nameAlg</i>
<i>nvIndex</i> → <i>data</i>	the value of the data field in the NV Index
<i>data.buffer</i>	the data buffer of the command parameter

NOTE 3 If TPMA_NV_WRITTEN is CLEAR, then *nvIndex* → *data* is a Zero Digest.

33.9.2 Command and Response

Table 209 — TPM2_NV_Extend Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_Extend {NV}
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index to extend Auth Index: None
TPM2B_MAX_NV_BUFFER	data	the data to extend

Table 210 — TPM2_NV_Extend Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.9.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_Extend_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	the TPMA_NV_EXTEND attribute is not SET in the Index referenced by <i>nvIndex</i>
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to write to the Index referenced by <i>nvIndex</i>
TPM_RC_NV_LOCKED	the Index referenced by <i>nvIndex</i> is locked for writing

```

4  TPM_RC
5  TPM2_NV_Extend(
6      NV_Extend_In          *in          // IN: input parameter list
7  )
8  {
9      TPM_RC          result;
10     NV_INDEX        nvIndex;
11
12     TPM2B_DIGEST    oldDigest;
13     TPM2B_DIGEST    newDigest;
14     HASH_STATE      hashState;
15
16     // Input Validation
17
18     // Common access checks, NvWriteAccessCheck() may return TPM_RC_NV_AUTHORIZATION
19     // or TPM_RC_NV_LOCKED
20     result = NvWriteAccessChecks(in->authHandle, in->nvIndex);
21     if(result != TPM_RC_SUCCESS)
22         return result;
23
24     // Get NV index info
25     NvGetIndexInfo(in->nvIndex, &nvIndex);
26
27     // Make sure that this is an extend index
28     if(nvIndex.publicArea.attributes.TPMA_NV_EXTEND != SET)
29         return TPM_RC_ATTRIBUTES + RC_NV_Extend_nvIndex;
30
31     // If the Index is not-orderly, or if this is the first write, NV will
32     // need to be updated.
33     if( nvIndex.publicArea.attributes.TPMA_NV_ORDERLY == CLEAR
34        || nvIndex.publicArea.attributes.TPMA_NV_WRITTEN == CLEAR)
35     {
36         // Check if NV is available. NvIsAvailable may return TPM_RC_NV_UNAVAILABLE
37         // TPM_RC_NV_RATE or TPM_RC_SUCCESS.
38         result = NvIsAvailable();
39         if(result != TPM_RC_SUCCESS)
40             return result;
41     }
42
43     // Internal Data Update
44
45     // Perform the write.
46     oldDigest.t.size = CryptGetHashDigestSize(nvIndex.publicArea.nameAlg);
47     if(nvIndex.publicArea.attributes.TPMA_NV_WRITTEN == SET)
48     {
49         NvGetIndexData(in->nvIndex, &nvIndex, 0,

```

```
50         oldDigest.t.size, oldDigest.t.buffer);
51     }
52     else
53     {
54         MemorySet(oldDigest.t.buffer, 0, oldDigest.t.size);
55     }
56     // Start hash
57     newDigest.t.size = CryptStartHash(nvIndex.publicArea.nameAlg, &hashState);
58
59     // Adding old digest
60     CryptUpdateDigest2B(&hashState, &oldDigest.b);
61
62     // Adding new data
63     CryptUpdateDigest2B(&hashState, &in->data.b);
64
65     // Complete hash
66     CryptCompleteHash2B(&hashState, &newDigest.b);
67
68     // Write extended hash back.
69     // Note, this routine will SET the TPMA_NV_WRITTEN attribute if necessary
70     return NvWriteIndexData(in->nvIndex, &nvIndex, 0,
71         newDigest.t.size, newDigest.t.buffer);
72 }
```

33.10 TPM2_NV_SetBits

33.10.1 General Description

This command is used to SET bits in an NV Index that was created as a bit field. Any number of bits from 0 to 64 may be SET. The contents of *data* are ORed with the current contents of the NV Index starting at *offset*. The checks on *data* and *offset* are the same as for TPM2_NV_Write.

If TPMA_NV_WRITTEN is not SET, then, for the purposes of this command, the NV Index is considered to contain all zero bits and *data* is OR with that value.

If TPMA_NV_BITS is not SET, then the TPM shall return TPM_RC_ATTRIBUTES.

After successful completion of this command, TPMA_NV_WRITTEN for the NV Index will be SET.

NOTE TPMA_NV_WRITTEN will be SET even if no bits were SET.

33.10.2 Command and Response

Table 211 — TPM2_NV_SetBits Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_SetBits {NV}
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	NV Index of the area in which the bit is to be set Auth Index: None
UINT64	bits	the data to OR with the current contents

Table 212 — TPM2_NV_SetBits Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.10.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_SetBits_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	the TPMA_NV_BITS attribute is not SET in the Index referenced by <i>nvIndex</i>
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to write to the Index referenced by <i>nvIndex</i>
TPM_RC_NV_LOCKED	the Index referenced by <i>nvIndex</i> is locked for writing

```

4  TPM_RC
5  TPM2_NV_SetBits(
6      NV_SetBits_In          *in          // IN: input parameter list
7  )
8  {
9      TPM_RC          result;
10     NV_INDEX         nvIndex;
11     UINT64          bitValue;
12
13
14
15     // Input Validation
16
17     // Common access checks, NvWriteAccessCheck() may return TPM_RC_NV_AUTHORIZATION
18     // or TPM_RC_NV_LOCKED
19     // error may be returned at this point
20     result = NvWriteAccessChecks(in->authHandle, in->nvIndex);
21     if(result != TPM_RC_SUCCESS)
22         return result;
23
24     // Get NV index info
25     NvGetIndexInfo(in->nvIndex, &nvIndex);
26
27     // Make sure that this is a bit field
28     if(nvIndex.publicArea.attributes.TPMA_NV_BITS != SET)
29         return TPM_RC_ATTRIBUTES + RC_NV_SetBits_nvIndex;
30
31     // If the Index is not-orderly, or if this is the first write, NV will
32     // need to be updated.
33     if(    nvIndex.publicArea.attributes.TPMA_NV_ORDERLY == CLEAR
34         || nvIndex.publicArea.attributes.TPMA_NV_WRITTEN == CLEAR)
35     {
36         // Check if NV is available. NvIsAvailable may return TPM_RC_NV_UNAVAILABLE
37         // TPM_RC_NV_RATE or TPM_RC_SUCCESS.
38         result = NvIsAvailable();
39         if(result != TPM_RC_SUCCESS)
40             return result;
41     }
42
43     // Internal Data Update
44
45     // If index is not been written, initialize it
46     if(nvIndex.publicArea.attributes.TPMA_NV_WRITTEN == CLEAR)
47         bitValue = 0;
48     else
49         // Read index data

```

```
50     NvGetIntIndexData(in->nvIndex, &nvIndex, &bitValue);
51
52     // OR in the new bit setting
53     bitValue |= in->bits;
54
55     // Write index data back. If necessary, this function will SET
56     // TPMA_NV_WRITTEN.
57     return NvWriteIndexData(in->nvIndex, &nvIndex, 0, 8, &bitValue);
58
59 }
```

33.11 TPM2_NV_WriteLock

33.11.1 General Description

If the TPMA_NV_WRITEDEFINE or TPMA_NV_WRITE_STCLEAR attributes of an NV location are SET, then this command may be used to inhibit further writes of the NV Index.

Proper write authorization is required for this command as determined by TPMA_NV_PPWRITE, TPMA_NV_OWNERWRITE, TPMA_NV_AUTHWRITE, and the *authPolicy* of the NV Index.

It is not an error if TPMA_NV_WRITELOCKED for the NV Index is already SET.

If neither TPMA_NV_WRITEDEFINE nor TPMA_NV_WRITE_STCLEAR of the NV Index is SET, then the TPM shall return TPM_RC_ATTRIBUTES.

If the command is properly authorized and TPMA_NV_WRITE_STCLEAR or TPMA_NV_WRITEDEFINE is SET, then the TPM shall SET TPMA_NV_WRITELOCKED for the NV Index. TPMA_NV_WRITELOCKED will be clear on the next TPM2_Startup(TPM_SU_CLEAR) unless TPMA_NV_WRITEDEFINE is SET.

33.11.2 Command and Response

Table 213 — TPM2_NV_WriteLock Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_WriteLock {NV}
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index of the area to lock Auth Index: None

Table 214 — TPM2_NV_WriteLock Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.11.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_WriteLock_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	neither TPMA_NV_WRITEDEFINE nor TPMA_NV_WRITE_STCLEAR is SET in Index referenced by <i>nvIndex</i>
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to write to the Index referenced by <i>nvIndex</i>

```

4  TPM_RC
5  TPM2_NV_WriteLock(
6      NV_WriteLock_In *in           // IN: input parameter list
7  )
8  {
9      TPM_RC      result;
10     NV_INDEX    nvIndex;
11
12     // The command needs NV update. Check if NV is available.
13     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
14     // this point
15     result = NvIsAvailable();
16     if(result != TPM_RC_SUCCESS)
17         return result;
18
19     // Input Validation:
20
21     // Common write access checks, a TPM_RC_NV_AUTHORIZATION or TPM_RC_NV_LOCKED
22     // error may be returned at this point
23     result = NvWriteAccessChecks(in->authHandle, in->nvIndex);
24     if(result != TPM_RC_SUCCESS)
25     {
26         if(result == TPM_RC_NV_AUTHORIZATION)
27             return TPM_RC_NV_AUTHORIZATION;
28         // If write access failed because the index is already locked, then it is
29         // no error.
30         return TPM_RC_SUCCESS;
31     }
32
33
34     // Get NV index info
35     NvGetIndexInfo(in->nvIndex, &nvIndex);
36
37     // if non of TPMA_NV_WRITEDEFINE or TPMA_NV_WRITE_STCLEAR is set, the index
38     // can not be write-locked
39     if( nvIndex.publicArea.attributes.TPMA_NV_WRITEDEFINE == CLEAR
40        && nvIndex.publicArea.attributes.TPMA_NV_WRITE_STCLEAR == CLEAR)
41         return TPM_RC_ATTRIBUTES + RC_NV_WriteLock_nvIndex;
42
43     // Internal Data Update
44
45     // Set the WRITELOCK attribute
46     nvIndex.publicArea.attributes.TPMA_NV_WRITELOCKED = SET;
47
48     // Write index info back
49     NvWriteIndexInfo(in->nvIndex, &nvIndex);
50

```

```
51     return TPM_RC_SUCCESS;  
52 }
```

33.12 TPM2_NV_GlobalWriteLock

33.12.1 General Description

The command will SET TPMA_NV_WRITELOCKED for all indexes that have their TPMA_NV_GLOBALLOCK attribute SET.

If an Index has both TPMA_NV_WRITELOCKED and TPMA_NV_WRITEDEFINE SET, then this command will permanently lock the NV Index for writing.

NOTE If an Index is defined with TPMA_NV_GLOBALLOCK SET, then the global lock does not apply until the next time this command is executed.

This command requires either platformAuth/platformPolicy or ownerAuth/ownerPolicy.

33.12.2 Command and Response

Table 215 — TPM2_NV_GlobalWriteLock Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_GlobalWriteLock
TPMI_RH_PROVISION	@authHandle	TPM_RH_OWNER or TPM_RH_PLATFORM+{PP} Auth Index: 1 Auth Role: USER

Table 216 — TPM2_NV_GlobalWriteLock Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.12.3 Detailed Actions

```
1  #include "InternalRoutines.h"
2  #include "NV_GlobalWriteLock_fp.h"
3  TPM_RC
4  TPM2_NV_GlobalWriteLock(
5      NV_GlobalWriteLock_In *in          // IN: input parameter list
6  )
7  {
8      TPM_RC          result;
9
10     // Input parameter is not reference in command action
11     in = NULL; // to silence compiler warnings.
12
13     // The command needs NV update. Check if NV is available.
14     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
15     // this point
16     result = NvIsAvailable();
17     if(result != TPM_RC_SUCCESS)
18         return result;
19
20     // Internal Data Update
21
22     // Implementation dependent method of setting the global lock
23     NvSetGlobalLock();
24
25     return TPM_RC_SUCCESS;
26 }
```

33.13 TPM2_NV_Read

33.13.1 General Description

This command reads a value from an area in NV memory previously defined by TPM2_NV_DefineSpace().

Proper authorizations are required for this command as determined by TPMA_NV_PPREAD, TPMA_NV_OWNERREAD, TPMA_NV_AUTHREAD, and the *authPolicy* of the NV Index.

If TPMA_NV_READLOCKED of the NV Index is SET, then the TPM shall return TPM_RC_NV_LOCKED.

NOTE If authorization sessions are present, they are checked before the read-lock status of the NV Index is checked.

If the *size* parameter plus the *offset* parameter adds to a value that is greater than the size of the NV Index *data* area, the TPM shall return TPM_RC_NV_RANGE and not read any data from the NV Index.

If the NV Index has been defined but the TPMA_NV_WRITTEN attribute is CLEAR, then this command shall return TPM_RC_NV_UNINITIALIZED even if *size* is zero.

The *data* parameter in the response may be encrypted using parameter encryption.

33.13.2 Command and Response

Table 217 — TPM2_NV_Read Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC TPMI_RH_NV_AUTH	commandCode @authHandle	TPM_CC_NV_Read the handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index to be read Auth Index: None
UINT16	size	number of octets to read
UINT16	offset	octet offset into the area This value shall be less than or equal to the size of the <i>nvIndex</i> data.

Table 218 — TPM2_NV_Read Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	
TPM2B_MAX_NV_BUFFER	data	the data read

33.13.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_Read_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to read from the Index referenced by <i>nvIndex</i>
TPM_RC_NV_LOCKED	the Index referenced by <i>nvIndex</i> is read locked
TPM_RC_NV_RANGE	read range defined by <i>size</i> and <i>offset</i> is outside the range of the Index referenced by <i>nvIndex</i>
TPM_RC_NV_UNINITIALIZED	the Index referenced by <i>nvIndex</i> has not been initialized (written)

```

4  TPM_RC
5  TPM2_NV_Read(
6      NV_Read_In      *in,          // IN: input parameter list
7      NV_Read_Out     *out         // OUT: output parameter list
8  )
9  {
10     NV_INDEX         nvIndex;
11     TPM_RC           result;
12
13     // Input Validation
14
15     // Get NV index info
16     NvGetIndexInfo(in->nvIndex, &nvIndex);
17
18     // Common read access checks. NvReadAccessChecks() returns
19     // TPM_RC_NV_AUTHORIZATION, TPM_RC_NV_LOCKED, or TPM_RC_NV_UNINITIALIZED
20     // error may be returned at this point
21     result = NvReadAccessChecks(in->authHandle, in->nvIndex);
22     if(result != TPM_RC_SUCCESS)
23         return result;
24
25     // Too much data
26     if((in->size + in->offset) > nvIndex.publicArea.dataSize)
27         return TPM_RC_NV_RANGE;
28
29     // Command Output
30
31     // Set the return size
32     out->data.t.size = in->size;
33     // Perform the read
34     NvGetIndexData(in->nvIndex, &nvIndex, in->offset, in->size, out->data.t.buffer);
35
36     return TPM_RC_SUCCESS;
37 }

```


33.14 TPM2_NV_ReadLock

33.14.1 General Description

If TPMA_NV_READ_STCLEAR is SET in an Index, then this command may be used to prevent further reads of the NV Index until the next TPM2_Startup (TPM_SU_CLEAR).

Proper authorizations are required for this command as determined by TPMA_NV_PPREAD, TPMA_NV_OWNERREAD, TPMA_NV_AUTHREAD, and the *authPolicy* of the NV Index.

NOTE Only an entity that may read an Index is allowed to lock the NV Index for read.

If the command is properly authorized and TPMA_NV_READ_STCLEAR of the NV Index is SET, then the TPM shall SET TPMA_NV_READLOCKED for the NV Index. If TPMA_NV_READ_STCLEAR of the NV Index is CLEAR, then the TPM shall return TPM_RC_NV_ATTRIBUTE. TPMA_NV_READLOCKED will be CLEAR by the next TPM2_Startup(TPM_SU_CLEAR).

It is not an error to use this command for an Index that is already locked for reading.

An Index that had not been written may be locked for reading.

33.14.2 Command and Response

Table 219 — TPM2_NV_ReadLock Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_ReadLock
TPMI_RH_NV_AUTH	@authHandle	the handle indicating the source of the authorization value Auth Index: 1 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	the NV Index to be locked Auth Index: None

Table 220 — TPM2_NV_ReadLock Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.14.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_ReadLock_fp.h"
3  #include "NV_spt_fp.h"

```

Error Returns	Meaning
TPM_RC_ATTRIBUTES	TPMA_NV_READ_STCLEAR is not SET so Index referenced by <i>nvIndex</i> may not be write locked
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to read from the Index referenced by <i>nvIndex</i>

```

4  TPM_RC
5  TPM2_NV_ReadLock(
6      NV_ReadLock_In *in          // IN: input parameter list
7  )
8  {
9      TPM_RC      result;
10     NV_INDEX     nvIndex;
11
12     // The command needs NV update. Check if NV is available.
13     // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
14     // this point
15     result = NvIsAvailable();
16     if(result != TPM_RC_SUCCESS) return result;
17
18     // Input Validation
19
20     // Common read access checks. NvReadAccessChecks() returns
21     // TPM_RC_NV_AUTHORIZATION, TPM_RC_NV_LOCKED, or TPM_RC_NV_UNINITIALIZED
22     // error may be returned at this point
23     result = NvReadAccessChecks(in->authHandle, in->nvIndex);
24     if(result != TPM_RC_SUCCESS)
25     {
26         if(result == TPM_RC_NV_AUTHORIZATION)
27             return TPM_RC_NV_AUTHORIZATION;
28         // Index is already locked for write
29         else if(result == TPM_RC_NV_LOCKED)
30             return TPM_RC_SUCCESS;
31
32         // If NvReadAccessChecks return TPM_RC_NV_UNINITIALIZED, then continue.
33         // It is not an error to read lock an uninitialized Index.
34     }
35
36     // Get NV index info
37     NvGetIndexInfo(in->nvIndex, &nvIndex);
38
39     // if TPMA_NV_READ_STCLEAR is not set, the index can not be read-locked
40     if(nvIndex.publicArea.attributes.TPMA_NV_READ_STCLEAR == CLEAR)
41         return TPM_RC_ATTRIBUTES + RC_NV_ReadLock_nvIndex;
42
43     // Internal Data Update
44
45     // Set the READLOCK attribute
46     nvIndex.publicArea.attributes.TPMA_NV_READLOCKED = SET;
47     // Write NV info back
48     NvWriteIndexInfo(in->nvIndex, &nvIndex);
49
50     return TPM_RC_SUCCESS;
51 }

```

33.15 TPM2_NV_ChangeAuth

33.15.1 General Description

This command allows the authorization secret for an NV Index to be changed.

If successful, the authorization secret (*authValue*) of the NV Index associated with *nvIndex* is changed.

This command requires that a policy session be used for authorization of *nvIndex* so that the ADMIN role may be asserted and that *commandCode* in the policy session context shall be TPM_CC_NV_ChangeAuth. That is, the policy must contain a specific authorization for changing the authorization value of the referenced object.

NOTE The reason for this restriction is to ensure that the administrative actions on *nvIndex* require explicit approval while other commands may use policy that is not command-dependent.

The size of the *newAuth* value may be no larger than the size of authorization indicated when the NV Index was defined.

Since the NV Index authorization is changed before the response HMAC is calculated, the *newAuth* value is used when generating the response HMAC key if required. See Part 4 ComputeResponseHMAC().

33.15.2 Command and Response

Table 221 — TPM2_NV_ChangeAuth Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_ChangeAuth {NV}
TPMI_RH_NV_INDEX	@nvIndex	handle of the object Auth Index: 1 Auth Role: ADMIN
TPM2B_AUTH	newAuth	new authorization value

Table 222 — TPM2_NV_ChangeAuth Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	

33.15.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "NV_ChangeAuth_fp.h"

```

Error Returns	Meaning
TPM_RC_SIZE	<i>newAuth</i> size is larger than the digest size of the Name algorithm for the Index referenced by <i>nvIndex</i>

```

3  TPM_RC
4  TPM2_NV_ChangeAuth(
5      NV_ChangeAuth_In      *in          // IN: input parameter list
6  )
7  {
8      TPM_RC      result;
9      NV_INDEX    nvIndex;
10
11     // Input Validation
12     // Check if NV is available. NvIsAvailable may return TPM_RC_NV_UNAVAILABLE
13     // TPM_RC_NV_RATE or TPM_RC_SUCCESS.
14     result = NvIsAvailable();
15     if(result != TPM_RC_SUCCESS) return result;
16
17     // Read index info from NV
18     NvGetIndexInfo(in->nvIndex, &nvIndex);
19
20     // Remove any trailing zeros that might have been added by the caller
21     // to obfuscate the size.
22     MemoryRemoveTrailingZeros(&(in->newAuth));
23
24     // Make sure that the authValue is no larger than the nameAlg of the Index
25     if(in->newAuth.t.size > CryptGetHashDigestSize(nvIndex.publicArea.nameAlg))
26         return TPM_RC_SIZE + RC_NV_ChangeAuth_newAuth;
27
28     // Internal Data Update
29     // Change auth
30     nvIndex.authValue = in->newAuth;
31     // Write index info back to NV
32     NvWriteIndexInfo(in->nvIndex, &nvIndex);
33
34     return TPM_RC_SUCCESS;
35 }

```

33.16 TPM2_NV_Certify

33.16.1 General Description

The purpose of this command is to certify the contents of an NV Index or portion of an NV Index.

If proper authorization for reading the NV Index is provided, the portion of the NV Index selected by *size* and *offset* are included in an attestation block and signed using the key indicated by *signHandle*. The attestation also includes *size* and *offset* so that the range of the data can be determined.

NOTE See 20.1 for description of how the signing scheme is selected.

33.16.2 Command and Response

Table 223 — TPM2_NV_Certify Command

Type	Name	Description
TPMI_ST_COMMAND_TAG	tag	
UINT32	commandSize	
TPM_CC	commandCode	TPM_CC_NV_Certify
TPMI_DH_OBJECT+	@signHandle	handle of the key used to sign the attestation structure Auth Index: 1 Auth Role: USER
TPMI_RH_NV_AUTH	@authHandle	handle indicating the source of the authorization value for the NV Index Auth Index: 2 Auth Role: USER
TPMI_RH_NV_INDEX	nvIndex	Index for the area to be certified Auth Index: None
TPM2B_DATA	qualifyingData	user-provided qualifying data
TPMT_SIG_SCHEME+	inScheme	signing scheme to use if the <i>scheme</i> for <i>signHandle</i> is TPM_ALG_NULL
UINT16	size	number of octets to certify
UINT16	offset	octet offset into the area This value shall be less than or equal to the size of the <i>nvIndex</i> data.

Table 224 — TPM2_NV_Certify Response

Type	Name	Description
TPM_ST	tag	see clause 8
UINT32	responseSize	
TPM_RC	responseCode	.
TPM2B_ATTEST	certifyInfo	the structure that was signed
TPMT_SIGNATURE	signature	the asymmetric signature over <i>certifyInfo</i> using the key referenced by <i>signHandle</i>

33.16.3 Detailed Actions

```

1  #include "InternalRoutines.h"
2  #include "Attest_spt_fp.h"
3  #include "NV_spt_fp.h"
4  #include "NV_Certify_fp.h"

```

Error Returns	Meaning
TPM_RC_NV_AUTHORIZATION	the authorization was valid but the authorizing entity (<i>authHandle</i>) is not allowed to read from the Index referenced by <i>nvIndex</i>
TPM_RC_KEY	<i>signHandle</i> does not reference a signing key
TPM_RC_NV_LOCKED	Index referenced by <i>nvIndex</i> is locked for reading
TPM_RC_NV_RANGE	<i>offset</i> plus <i>size</i> extends outside of the data range of the Index referenced by <i>nvIndex</i>
TPM_RC_NV_UNINITIALIZED	Index referenced by <i>nvIndex</i> has not been written
TPM_RC_SCHEME	<i>inScheme</i> is not an allowed value for the key definition

```

5  TPM_RC
6  TPM2_NV_Certify(
7      NV_Certify_In      *in,          // IN: input parameter list
8      NV_Certify_Out     *out         // OUT: output parameter list
9  )
10 {
11     TPM_RC              result;
12     NV_INDEX            nvIndex;
13     TPMS_ATTEST        certifyInfo;
14
15     // Attestation command may cause the orderlyState to be cleared due to
16     // the reporting of clock info. If this is the case, check if NV is
17     // available first
18     if(gp.orderlyState != SHUTDOWN_NONE)
19     {
20         // The command needs NV update. Check if NV is available.
21         // A TPM_RC_NV_UNAVAILABLE or TPM_RC_NV_RATE error may be returned at
22         // this point
23         result = NvIsAvailable();
24         if(result != TPM_RC_SUCCESS)
25             return result;
26     }
27
28     // Input Validation
29
30     // Get NV index info
31     NvGetIndexInfo(in->nvIndex, &nvIndex);
32
33     // Common access checks. A TPM_RC_NV_AUTHORIZATION or TPM_RC_NV_LOCKED
34     // error may be returned at this point
35     result = NvReadAccessChecks(in->authHandle, in->nvIndex);
36     if(result != TPM_RC_SUCCESS)
37         return result;
38
39     // See if the range to be certified is out of the bounds of the defined
40     // Index
41     if((in->size + in->offset) > nvIndex.publicArea.dataSize)
42         return TPM_RC_NV_RANGE;
43
44     // Command Output

```

```

45
46 // Filling in attest information
47 // Common fields
48 // FillInAttestInfo can return TPM_RC_SCHEME or TPM_RC_KEY
49 result = FillInAttestInfo(in->signHandle,
50                          &in->inScheme,
51                          &in->qualifyingData,
52                          &certifyInfo);
53 if(result != TPM_RC_SUCCESS)
54 {
55     if(result == TPM_RC_KEY)
56         return TPM_RC_KEY + RC_NV_Certify_signHandle;
57     else
58         return RcSafeAddToResult(result, RC_NV_Certify_inScheme);
59 }
60 // NV certify specific fields
61 // Attestation type
62 certifyInfo.type = TPM_ST_ATTEST_NV;
63
64 // Get the name of the index
65 certifyInfo.attested.nv.indexName.t.size =
66     NvGetName(in->nvIndex, &certifyInfo.attested.nv.indexName.t.name);
67
68 // Set the return size
69 certifyInfo.attested.nv.nvContents.t.size = in->size;
70
71 // Set the offset
72 certifyInfo.attested.nv.offset = in->offset;
73
74 // Perform the read
75 NvGetIndexData(in->nvIndex, &nvIndex,
76               in->offset, in->size,
77               certifyInfo.attested.nv.nvContents.t.buffer);
78
79 // Sign attestation structure. A NULL signature will be returned if
80 // signHandle is TPM_RH_NULL. SignAttestInfo() may return TPM_RC_VALUE,
81 // TPM_RC_SCHEME or TPM_RC_ATTRIBUTES.
82 // Note: SignAttestInfo may return TPM_RC_ATTRIBUTES if the key is not a
83 // signing key but that was checked above. TPM_RC_VALUE would mean that the
84 // data to sign is too large but the data to sign is a digest
85 result = SignAttestInfo(in->signHandle,
86                        &in->inScheme,
87                        &certifyInfo,
88                        &in->qualifyingData,
89                        &out->certifyInfo,
90                        &out->signature);
91 if(result != TPM_RC_SUCCESS)
92     return result;
93
94 // orderly state should be cleared because of the reporting of clock info
95 // if signing happens
96 if(in->signHandle != TPM_RH_NULL)
97     g_clearOrderly = TRUE;
98
99 return TPM_RC_SUCCESS;
100 }

```