# CALIFORNIA 6C ELECTRONIC TOLL COLLECTION STANDARD

VERSION 1.0

MAY 5, 2017

# Table of Contents

# 1 Introduction

## 1.1 Purpose

The purpose of this document is to create and maintain a standard based on the ISO/IEC 18000-6C (known as 6C) communication protocol for tolling applications that use automatic vehicle identification (AVI). The guidance is intended for tag and reader manufacturers, toll lane vendors, system integrators, back-office providers, and other members of the RFID industry. This standard meets the interoperability requirements developed by IBTTA's Roadside Interoperability Group.

## 1.2 Scope

This document addresses the following areas of interest:

- Memory Mapping
- Transponder Requirements
- Reader Requirements
- Security and Data Integrity Validation

## 1.3 Definitions, Acronyms, and Abbreviations

| | |
|---|---|
| *AFI* | Application Family Identifier |
| *CRC* | Cyclic Redundancy Check |
| *DSFID* | Data Storage Format Identifier |
| *EPC* | Electronic Product Code |
| *HOV* | High Occupancy Vehicle |
| *IEC* | International Electrotechnical Commission |
| *ISO* | International Organization for Standardization |
| *NAK* | Negative Acknowledgement |
| *PC* | Protocol Control |
| *RFID* | Radio Frequency Identification |
| *TID* | Transponder Identification Gen2 transponder memory bank 10 |
| *TSN* | Transponder Serial Number |
| *UM* | User Memory Gen2 transponder memory bank 11 |
| *UII* | Unique Item Identifier, ISO/IEC 18000-6C transponder memory bank 01 |
| *XPC* | Extended protocol control |

# 2 Memory Mapping

The ISO/IEC 18000-6C transponder memory is separated into four memory banks:

| | |
|---|---|
| Bank 00 | Reserved |
| Bank 10 | TID |
| Bank 01 | CRC, PC, UII |
| Bank 11 | User Memory |

## 2.1 Reserved Memory Specification

The Reserved memory shall be programmed by the tag provider and contents shared with the issuing agency.

## 2.2 TID Memory Specification

The Transponder Identification (TID) memory shall contain a minimum of 64 bits (8 byte) unalterable unique chip ID programmed by the chip manufacturer. This field will not be specified to be any particular value, but it is assumed to be unique for all -6C chips, per the ISO 18000-6C standard.

## 2.3 Memory Bank 01 Specification

There are three memory areas contained with Memory Bank 01.

Stored CRC – This 16-bit long area is stored at memory location 00h - 0Fh and is calculated by the transponder.

Stored PC - This area is 16 bits long and is stored at memory location 10h – 1Fh. The PC word contains the Application Family Identifier (AFI) – an 8-bit identifier (the value being 0xB0) assigned to the 6C Toll Operators Coalition. This number has been assigned for tolling by ISO, along with the Data Storage Format Identifier (DSFID, value of 0x3E) and explicitly describes a tag belonging to the 6C Toll Operators Coalition.

This number can be used to filter the responses of tags to ensure that only toll tags are being read.

The PC word is encoded during chip initialization and is dependent on the type of chip being encoded, not on an individual tag's data.

Unique Item Identifier (UII) – This area is at least 96 bits long and is stored beginning at memory location 20h. Any memory in excess of 96 bits is undefined and may be used by the issuing agency; however, the additional memory shall not interfere with any of the functionality contained in this document. The UII shall provide read-only access to users. The issuing agency may lock write access permanently or may allow write access by a password maintained by the issuing agency.

***Table 2-1 UII Memory Map***

| Area | # | Memory Address | Section | Description | Values |
|---|---|---|---|---|---|
| Stored CRC | 1-16 | 00h-0Fh (16 bits) | Calculated | Area is calculated based on other transponder memory values per ISO 18000-6C specification. | Varies |
| Stored PC | 1-5 | 10h-14h (5 bits) | Length | Number of 16-bit words in the UII | 00110 = 6 words (indicates 96-bit UII) – will vary based on UII length |
| Stored PC | 6 | 15h (1 bit) | User Memory | Indicates status of the User Memory | 0 = no user memory<br>1 = user memory available |
| Stored PC | 7 | 16h (1 bit) | XPC | Indicates status of extended tag features | 0 = no XPC<br>1 = XPC available |
| Stored PC | 8 | 17h (1 bit) | Numbering System Indicator | Indicates if the tag is coded as an EPC or ISO tag. | 0 = EPC<br>1 = ISO (correct value for 6C TOC applications) |
| Stored PC | 9-16 | 18h-1Fh (8 bits) | AFI | Application Family Identifier for 6C TOC – 0xB0 | 1011 0000 = 6C TOC AFI (B0) |
| UII | 1-8 | 20h-27h (8 bits) | DSFID | Data Storage Format Identifier for 6C TOC – 0x3E | 0011 1110 = 6C TOC DSFID (3E) |
| UII | 9 - 21 | 28h–34h (13 bits) | Agency Use | Individual agencies may add agency specific information here. | Assigned by agency |
| UII | 22-33 | 35h-40h | Classification | Classification is taken directly from E-ZPass Inter-Customer Service Center Interface File and Reporting Specifications, Appendix C and includes: | |
| UII | 22-33 | (1 bit) | Class | The first bit indicates if the tag has been assigned a classification value. If 0 is selected, the following 11 bits shall be ignored. | 0 = no class value assigned (default) 1 = class value assigned |

| Area | # | Memory Address | Section | Description | Values |
|---|---|---|---|---|---|
| UII | 22-33 | (5 bits) | Vehicle Type | This field indicates the type of vehicle. | 00000 = undefined (default) 00001 = automobile<br>00010 = motorcycle 00011 = pickup truck<br>00100 = van (seats 1-9) 00101 = minibus (seats 10-15)<br>00110 = bus (seats 16+) 00111 = recreational vehicle<br>01000 = truck 01001 = auto transporter (≤ 65')<br>01010 = auto transporter (>65') 01011 = tractor & trailer (≤48')<br>01100 = tractor & trailer (>48') 01101 = tractor & dual trailers each (≤28.5')<br>01110 = tractor & dual trailers each (>28.5')<br>01111 = tractor & dual trailers each (one ≤28.5' other >28.5') |
| UII | 22-33 | (5 bits) | Vehicle Type | This field indicates the type of vehicle. | 10000 = undefined<br>10001 = tractor/mobile home combination<br>10010-11111 = undefined |
| UII | 22-33 | (4 bits) | Vehicle Axles | This field indicates the number of axles. | 0000 = undefined (default) 1000 = 8 axles<br>0001 = undefined 1001 = 9 axles<br>0010 = 2 axles 1010 = 10 axles<br>0011 = 3 axles 1011 = 11 axles<br>0100 = 4 axles 1100 = 12 axles<br>0101 = 5 axles 1101 = 13 axles<br>0110 = 6 axles 1110 = 14 axles<br>0111 = 7 axles 1111 = 15 axles |
| UII | 22-33 | (1 bit) | Vehicle Weight | This field indicates the weight of vehicle. | 0 = ≤ 7,000 lbs (default)<br>1 = > 7,000 lbs |
| UII | 22-33 | (1 bit) | Vehicle Rear Tires | This field indicates the number of rear tires. | 0 = Single rear tires (default) 1 = Dual rear tires |
| UII | 34-36 | 41h-43h (3 bits) | HOV Declaration | These three bits indicate the declaration status of the tag. All single mode transponders shall be assigned the default value – 000 unless they are carpool specific tags. | 000 = single mode (default) 001 = SOV (non-carpool) 010 = HOV 2+<br>011 = HOV 3+<br>100 = Carpool (as defined by roadway) 101 = reserved for future use<br>110 = reserved for future use 111 = reserved for future use |
| UII | 37-40 | 44h-47h (4 bits) | Version | There are 16 possible values to indicate the version of 6C TOC programming standard used on the tag. | 0000 = unassigned<br>0001 = Ver. 1.0<br>0010 = Ver. 2.0<br>0011 = Ver. 3.0 |

| Area | # | Memory Address | Section | Description | Values |
|---|---|---|---|---|---|
| UII | 41-52 | 48h-53h (12 bits) | Agency | The Agency Code allows for up to 4,096 agencies. The known agencies are included in the values column. See Appendix A for details. | See Appendix A – Table of Agencies |
| UII | 53-80 | 54h-6Fh (28 bits) | Transponder Serial Number | This identifies the particular tag within the agency.<br>There are 268,435,456 values accommodated in this space. The values in this field will be assigned by each agency. | Assigned by agency |
| UII | 81-96 | 70h-7Fh (16 bits) | UII Validation (Hash Value) | This is calculated using the first 80 UII bits and 32-byte key. Example is provided in Section 5. | Assigned at the time of transponder manufacturer. Calculated as per Section 5. |

## 2.4 User Memory Specification

As of the publication date of this Version, none of the current 6C toll operators write to their tags, nor do any of them read the User memory. It is anticipated that this memory bank may be required to accommodate future group members or affiliates. The following general specifications shall apply.

The User memory shall have at least 512 bits (64 bytes).

The User memory bank shall be designated as a temporary data field, where facilities may read and write whatever information is necessary, recognizing that the data may be overwritten at any time. For example, an agency operating a closed ticket type of system may choose to use this bank and write trip start date, time, location, and price as the trip begins and read this information at the conclusion of the trip. This could be used to compute the correct toll.

Any agency-specific use of User memory outside the specifications in this document should be closely coordinated to reduce the risk of future conflicts.

DSFID – Data Storage Format Identifier

The DSFID declares the data format for the data in User Memory. The User Memory portion of the tag shall have the following format:

***Table 2-2 User Memory Mapping***

| # | Memory Address | Section | Description | Values |
|---|---|---|---|---|
| 1-8 | 00h-07h (8 bits) | DSFID | Data Storage Format Identifier | 0011 1110 = 6C TOC DSFID (3E) |
| 9-20 | 08h-23h (12 bits) | Agency | 12-bit Agency Code. As assigned in the previous section. | Section 2.3.1 |
| 21-27 | 24h-1Ah (7 bits) | Plaza ID | 7-bit Plaza ID. Each operator may choose. | To be defined by agencies using this field. |
| 28-32 | 1Bh-1Fh (5 bits) | Lane ID | 5-bit Lane ID. Each operator may choose. | To be defined by agencies using this field. |
| 33-57 | 20h-38h (25 bits) | Day/Time | 25-bit Day. Each operator may choose. (Seconds since Jan 01 00:00:00) | To be defined by agencies using this field. |
| 58—60 | 39h-3Bh (3 bits) | Occupancy Setting | 3-bit Occupancy. Each operator may choose. | To be defined by agencies using this field. |
| 61+ | 3Ch - | Undefined | The remaining bits may be defined as individual agency needs arise. | |

# 3 Transponder Requirements

## 3.1 Transponder Characteristics

All values are measured per the EPC Global Tag Performance Parameters and Test Methods Version 1.1.3 test protocol, limited to the 902 – 928 MHz frequency range and modified as follows to use a horizontally, linearly polarized test antenna with tags mounted on material applicable for the intended location on the vehicle; and as described in Section 3.1.3.

### 3.1.1 Minimum Activation Energy

Tags shall have a minimum activation energy (forward link range) resulting in a test read range between 7 m and 12 m.

### 3.1.2 Return Signal Strength (Backscatter Range)

Tags shall have a return signal strength (reverse link range) resulting in a test read at a minimum of 14 m.

### 3.1.3 Antenna Polarization and Pointing Loss

Tags shall be horizontally polarized.

When tilted +/- 15 degree horizontally (see Figure 1) from the installation reference angle defined by the transponder manufacturer, tags shall have a minimum activation energy (forward link range) resulting in a test read range between 5 m and 12 m. For example, when a tag is not installed horizontally level ("crooked").

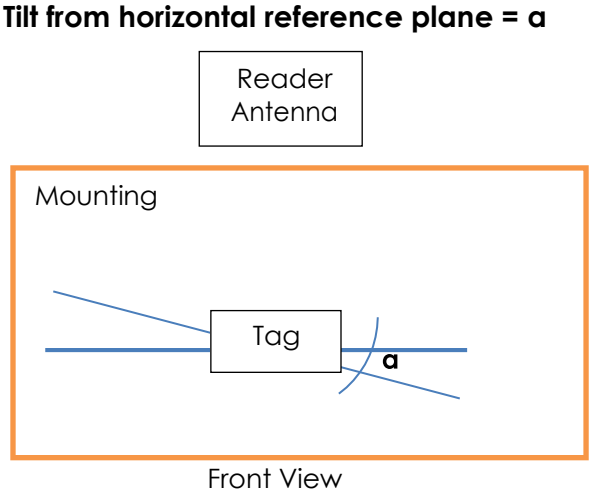


*Figure 3-1 Diagram schematically depicting tilt from horizontal angle between tag placement and reader antenna.*

When tilted +/- 45 degrees vertically (see Figure 2) from the installation reference angle defined by the transponder manufacturer, tags shall have a minimum activation energy (forward link range) resulting in a test read range between 5 m and 12 m. For example, this addresses windshield angles between steeply sloped windshields (sports car) and near vertical windshields (semi-tractor trailers).

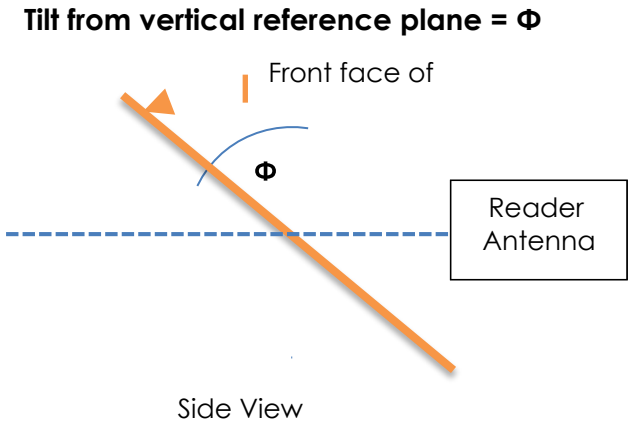


*Figure 3-2 Diagram schematically depicting tilt from vertical angle between tag placement and reader antenna.*

When rotated +/- 18 degrees from the horizontal plane (see Figure 3) from the installation reference angle defined by the transponder manufacturer, tags shall have a minimum activation energy (forward link range) resulting in a test read range between 5 m and 12 m. For example, this addresses transponder mounting locations on flat windshields versus curved windshields and headlights.

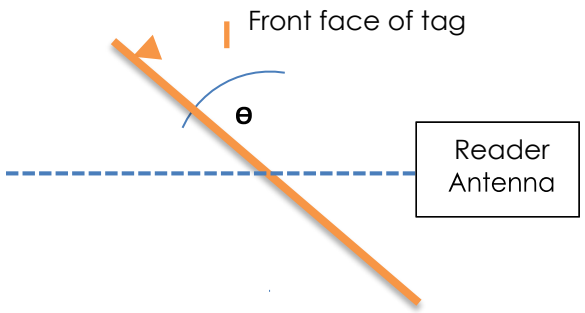


*Figure 3-3 Diagram schematically depicting rotation from horizontal plane angle between tag placement and reader antenna.*

## 3.2 Tag Environmental Conditions

Transponders shall be able to perform under the following environmental conditions:

1. All interior transponders shall be able to be subjected to and operated in 95% humidity, non-condensing environments.
2. All exterior transponders shall operate in 100% humidity, condensing environments.
3. Tags shall be able to operate at temperatures between - 40° F and +185° F.
4. Sunlight screening shall be built into both the internal and external transponders to ensure they perform as well under conditions of direct sunlight as in overcast conditions.

## 3.3 Barcode Format

The transponder barcode includes only the Agency Code and the Transponder Serial Number along with a check digit. The barcode shall be printed using EPC Code 128 and the code data digits shall be in decimal format AAAATTTTTTTTTL where AAAA is the Agency Code as a 4-digit number with leading zeros, TTTTTTTTT is the Transponder Serial Number (TSN) as a 10-digit number with leading zeros and L is the Luhn check digit computed using only the last 2 digits of the Agency Code and all 10 digits of the TSN.

Below the barcode the Agency Code, the TSN and the check digit shall be displayed in the following decimal format <AA>AA TTTTTTTTT L. The printed Agency Code shall NOT contain leading zeros and shall be separated from the TSN by a double space., where <AA>AA is the Agency code excluding leading zeros. The TSN shall include the leading zeros (to fill all 10 digits) and shall be separated from the check digit number L by a double space.

**<AA>AA TTTTTTTTT L**

Where:

**<AA>AA**= 4 digit Agency Code (leading zeroes not printed)

**TTTTTTTTT**= 10 digit Transponder Serial Number (leading zeroes printed)

**L** = Check digit Luhn (mod10) coded – calculated based upon **<AA>AA** (third and fourth digits only) and **TTTTTTTTT** (all ten digits)

For example, a transponder with serial number 12 for agency 77 would return 007700000000123 as the barcode content and the printed information below the barcode would be

**77 0000000012 3**.

Similarly for agency 449 a transponder with serial number 12 would return 044900000000122 as the barcode content and the printed information below the barcode would be

**449 0000000012 2**.

## 3.4 Transponder Ordering and Delivery (Manifest information)

To facilitate loading of data in back-office transponder inventory on transponder delivery, manufacturers should provide a file with comma separated UII memory and TID. Each transponder entry should be on a new line:

12_Byte_UII_Memory, TID (length varies)

**0101CE00010000000101CE8C, E2003412012EC0FFEE041392**[1]

[1] Note: Values shown are for illustrative purposes only and are not actual/valid EPC or TID values. A 12-byte TID is used for example purposes.

# 4 Reader Requirements

## 4.1 ISO Commands

The following ISO reader commands are optional:

1. NAK
2. Kill
3. Lock

# 5 Security and Data Integrity Validation

## 5.1 Overview

Transponder security is critical to the toll industry. It is anticipated that as more security features become available, they will be evaluated and deployed, as appropriate. The following security measures are currently employed.

## 5.2 Memory Bank Security

### 5.2.1 Reserved Memory Bank

1. The Access Password shall have a Lock Status of locked with an Access Password known to and secured by the transponder issuing agency.
2. The Kill Password and its Lock Status shall be configurable by the transponder issuing agency. It is recommended that the transponder issuing agency configure tags to permanently disable the ability to kill their tags.

### 5.2.2 TID Memory Bank

The transponder identification number shall be uniquely assigned by the manufacturer. It shall be readable without a password, cannot be altered and must be unique.

### 5.2.3 UII Memory Bank

1. The transponder issuing agency shall be the only entity authorized to change the encoded bits on the transponder. UII memory bank shall have a Lock Status of locked.
2. UII Authentication/Validation – The UII memory data should be authenticated with two hashed validation bytes. The UII Validation bytes can be used for transponder data verification and can also provide some level of transponder authentication. Further details are contained in Section 5.3.

### 5.2.4 User Memory Bank

1. Password – The User memory shall be writable without a password. The User memory bank shall have a Lock Status of unlock.
2. Authentication/Validation – Authentication and validation shall not be used.

### 5.2.5 ENCRYPTION

Under development.

## 5.3 UII Validation

Below is example of how the UII validation bytes shall be calculated using:

1. The first 10 bytes of the UII (starting with the "DSFID" field)
2. The 32-byte key (determined by the tag issuing agency)
3. The bytes of the transponder TID[2] (length varies - see footnote)

For ensuring interagency interoperability and consistency between transponders manufactured by different vendors the open standard SHA1 hashing algorithm shall be used. The hashing sequence shall be:

a. Concatenate the 10 UII memory bytes, the 32-byte key and the TID bytes to form a single byte sequence
b. Determine the SHA1 hash of this byte sequence above
c. For UII Validation the first 2 bytes from the 40-byte hash result shall be used.

UII Validation Reference Calculation is provided below:

UII 10 byte: 0x**FFFFFFFFFFFFFFFFFFFF**

Key 32 byte:
0x**ABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABAB**

TID (12-byte example):0x**000000000000000000000000**

Result 20-byte hash value: 0x**167F9C5B3933148B68AAD51EE3C4B5F858166451**

UII Validation bytes: 0x**167F**

The 12 UII bytes shall be encoded as: 0x**FFFFFFFFFFFFFFFFFFFF167F**

Tags which are not fully serialized (that is, have at least a 48-bit unique serial number) will not conform to this standards document and should not be used for interoperable 6C tolling deployments.

[2] The TID length can vary per the ISO 18000-6C specification. For fully serialized tags, the complete header and serialized portion of the TID (which can be anywhere from 96 - 192 bits, given the allowable serial number length of 48 - 144 bits) will be used for the indicated calculations. Per the standard, the length of a transponder's TID serial number is indicated on each transponder, in bits 20h - 22h of the TID.

# 6 APPENDICES

## 6.1 Appendix A – Table of Agencies

*Table 6-1 Agency IDs. Contact Caltrans for most recent list.*

| Agency | Acronym | State | Status | Decimal | Hex | Binary |
|---|---|---|---|---|---|---|
| Reserved | N/A | N/A | Reserved | 0 | 0 | 0000 0000 0000 |
| North Carolina Turnpike Authority | NCTA | NC | Assigned | 33 | 21 | 0000 0010 0001 |
| Washington State Department of Transportation | WSDOT | WA | Assigned | 77 | 4D | 0000 0100 1101 |
| Bay Area Toll Authority | BATA | CA | Assigned | 101 | 65 | 0000 0110 0101 |
| California Department of Transportation | CalTrans | CA | Assigned | 102 | 66 | 0000 0110 0110 |
| Transportation Corridor Agency | TCA | CA | Assigned | 103 | 67 | 0000 0110 0111 |
| | | | Unassigned | 104 | 68 | 0000 0110 1000 |
| Golden Gate Bridge, Highway and Tunnel District | GGBHTD | CA | Assigned | 105 | 69 | 0000 0110 1001 |
| Los Angeles County Metropolitan Transportation Authority | LACMTA | CA | Assigned | 106 | 6A | 0000 0110 1010 |
| Orange County Transportation Authority | OCTA | CA | Assigned | 107 | 6B | 0000 0110 1011 |
| Riverside County Transportation Commission | RCTC | CA | Assigned | 108 | 6C | 0000 0110 1100 |
| San Diego Association of Governments | SANDAG | CA | Assigned | 109 | 6D | 0000 0110 1101 |
| Santa Clara Valley Transportation Authority | VTA | CA | Assigned | 110 | 6E | 0000 0110 1110 |
| South Bay Expressway, LLC | SBX | CA | Assigned | 111 | 6F | 0000 0110 1111 |
| Sunol SMART Carpool Lanes Joint Powers Authority | Sunol JPA | CA | Assigned | 112 | 70 | 0000 0111 0000 |
| San Francisco County Transportation Authority | SFCTA | CA | Assigned | 113 | 71 | 0000 0111 0001 |
| San Bernardino Associated Governments | SANBAG | CA | Assigned | 114 | 72 | 0000 0111 0010 |
| Concession A25 sec | A25 | QC | Assigned | 115 | 73 | 0000 0111 0011 |
| Port of Hood River | POHR | OR | Assigned | 116 | 74 | 0000 0111 0100 |
| McAllen-Hidalgo & Anzalduas Bridges | MHAB | TX | Assigned | 118 | 76 | 0000 0111 0110 |
| E-470 | E-470 | CO | Assigned | 194 | C2 | 0000 1100 0010 |
| State Road & Toll Way Authority | SRTA | GA | Assigned | 321 | 141 | 0001 0100 0001 |
| Puerto Rico Highway & Transportation Authority | PRHTA | PR | Assigned | 448 | 1C0 | 0001 1100 0000 |
| Louisville-Southern Indiana Ohio River Bridges | LSIORB | KY | Assigned | 449 | 1C1 | 0001 1100 0001 |
| Louisiana Department of Transportation and Development | LADOTD | LA | Assigned | 450 | 1C2 | 0001 1100 0010 |
| Utah Department of Transportation | UDOT | UT | Reserved | 1409 | 581 | 0101 1000 0001 |

| Agency | Acronym | State | Status | Decimal | Hex | Binary |
|---|---|---|---|---|---|---|
| Washington State Department of Transportation | WSDOT | WA | Reserved | 1505 | 5E1 | 0101 1110 0001 |
| Transportation Investment Corporation | TI Corp | BC | Assigned | 2305 | 901 | 1001 0000 0001 |
| Blue Water Bridge Authority | BWBA | ON | Assigned | 2529 | 9E1 | 1001 1110 0001 |
| Reserved for Testing | TEST | N/A | Reserved | 4080 - 4095 | FF0-FFF | 1111 1111 0000-1111 1111 1111 |