AVI STANDARD

REQUIREMENTS AND GUIDANCE DOCUMENT

Version 4.0

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	V 0.5 – Move Technical Requirements Section
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1/28/16	V 3.0 Revision 2 – Added logo to cover page; clarified barcode format; corrected sample calculation of UII Validation hashing value.
3/15/16	V 3.0 Revision 3 – Added DSFID (0x3E) to be programmed as initial 2 bytes of UII.

7/22/16	V 3.0 Revision 4 – Added additional Agency codes to Appendix A. Corrected first bullet of 4.2 to reference new DSFID field in UII.
2/9/17	V 3.1 – Document title changed. Revised language in Section 1.1 to address backward compatibility. Deleted reference to backward compatibility in Section 1.2. Inserted Section 1.3 to clarify certification. Created a new Section 3 “Transponder Requirements” by combining previous barcode format and transponder manifest and adding transponder characteristics and environmental requirements. Previous Section 4 “Data Security” has been renumbered as Section 5 and has been edited to clarify Lock Status and Passwords. New Section 4 “Reader Requirements” has been created to clarify optional ISO Reader commands. Section 6 regarding backward compatibility and programming versions used by toll operators has been removed. Appendix A, code for TCA consolidated.
5/11/17	V 3.1 Revision 1 – Edited 3.1 to indicate method for calculating read distances of transponder parameters. Added clarification language to 3.1.1 and 3.1.2. Changed values and units for polarization and pointing loss in 3.1.3. Updated Agency ID list in Appendix A. Edits list of optional reader commands in 4.1
12/13/19	V 3.2 – Incorporated requirements from the 6C Coalition Interoperability Requirements and Certification Framework document (Document A) to a revamped Section 3. Removed requirement for 512bit minimum size of User Data. Formatting updates. Removed Agency ID listing (Appendix A) as it will now be a standalone document. Added new Appendix A (Legacy Toll Transponder Information) and Appendix B (Transponder Filtering).
9/22/2020	V 3.2a – Corrected binary DSFID value found in Appendix A Figure 7.
10/10/2023	V 4.0 – Added CRC to UII Memory Bank 01 mapping and marked certain fields in Memory Bank 01 as optional. Updated User Memory to be optional at agency discretion. Updated filtering information in Appendix A. Updated legacy tag quantities in Appendix B.

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1 INTRODUCTION

1.1 Purpose

The purpose of this document is to create and maintain a standard based on the 2010 and subsequent version of the ISO/IEC 18000-63 (known as 6C) communication protocol for tolling applications that use automatic vehicle identification (AVI). The guidance is intended for transponder and reader manufacturers, toll lane vendors, system integrators, back-office providers, and other members of the RFID industry. The current programming requirements standards are backward compatible to all previous versions of the standard deployed. A few toll operators have deployed 6C transponders prior to the adoption of Version 1.0 and continue to use their legacy systems. More information on legacy 6C memory maps used by toll operators can be found on the 6C Coalition website and in Appendix A of this document.

1.2 Scope

This document addresses the following areas of interest:

- Transponder Memory Mapping
- Interoperability Requirements
- Barcode Format
- Transponder Manifest Details
- Security and Data Integrity Validation

1.3 Interoperability

This AVI Standard provides a reference that enables device manufacturers to produce interoperable transponders and readers. It also provides a standard that integrators and agencies can use to verify conformance that ensures interoperability. Certification is the primary method of verifying conformance with the 6C Coalition AVI Standard.

1.4 Definitions, Acronyms, and Abbreviations

6C	Refers to the Type C portion of the ISO/IEC 18000-6 Type C UHF standard, including later updates to Type C of the ISO/IEC 18000-63 standard
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
UII	Unique Item Identifier, ISO/IEC 18000-63 (formerly '6C'), transponder memory bank 01
XPC	Extended protocol control

2 TRANSPONDER MEMORY MAPPING

The 6C transponder memory is separated into four memory as shown in Table 1 below.

Table 1: Transponder Memory Map

Bank #	Purpose
Bank 00	Reserved
Bank 01	CRC, PC, UII
Bank 10	TID
Bank 11	User Memory (Optional)

2.1 Reserved Memory Bank 00 Specification

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

2.2 CRC, PC, UII Memory Bank 01 Specification

Memory Bank 01 contains three addressed areas:

1. Stored CRC – This 16-bit long area is stored at memory location **`0x00 – 0x0F`** and calculated by the transponder.
2. Stored PC – This area is 16 bits long stored at memory location **`0x10 – 0x1F`**. The PC word contains the Application Family Identifier (AFI) – an 8-bit identifier (value **`0xB0`**) assigned to the 6C Coalition. This number can be used to filter the responses of V3.0 and later transponders to ensure that only toll transponders are being read. The ISO assigned this protocol control number for tolling, along with the Data Storage Format Identifier (DSFID, value **`0x3E`** which is programmed into the first byte of the UII memory area) and explicitly describes a transponder belonging to the 6C Coalition.

The Stored PC is encoded during chip initialization and is dependent on the type of chip being encoded, not on data within an individual transponder.

3. Unique Item Identifier (UII) – This area contains at least 96 bits of information beginning at memory location `0x20`. Any memory in excess of 96 bits remains undefined for this standard but usable 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.

2.2.1 Memory Bank 01 Mapping

The following tables describe the memory mapping for Bank 01. The tables and values within the tables appear in Memory Address (hex value) order ascending. All fields are mandatory unless indicated otherwise.

Table 2: Stored CRC Memory Bank 01 Mapping

#	Memory Address	Section	Description	Values
1-16	00h-0Fh (16 bits)	Calculated	Calculated value based on other transponder memory values per ISO 18000-63 specification	Varies

Table 3: Stored PC Memory Bank 01 Mapping

#	Memory Address	Section	Description	Values
1-5	10h-14h (5 bits)	Length	Number of 16-bit words in the UII	00110 = 6 words (indicates 96-bit UII) Varies based on UII length
6	15h (1 bit)	User Memory	Indicates status of the User Memory	0 = No user memory 1 = User memory available
7	16h (1 bit)	XPC	Indicates status of extended transponder features	0 = No XPC 1 = XPC available
8	17h (1 bit)	Numbering System Indicator	Indicates whether transponder coded as EPC or ISO	0 = EPC 1 = ISO (correct value for 6C Coalition applications)
9-16	18h-1Fh (8 bits)	AFI	Application Family Identifier for 6C Coalition – B0h	1011 0000 = 6C Coalition AFI (B0h)

Table 4: UII Memory Bank 01 Mapping

#	Memory Address	Section	Description	Values
1-8	20h-27h (8 bits)	DSFID	Data Storage Format Identifier for 6C Coalition – 3Eh	0011 1110 = 6C Coalition DSFID (3Eh)

#	Memory Address	Section	Description	Values
9-16	28h–2Fh (8 bits)	UII Validation (CRC)	Cyclic Redundancy Check calculated value using UII bits 17 – 80 (Agency Use thru Transponder Serial Number fields). Example appears in Section 6.	Assigned at the time of transponder manufacture. Calculated as per Section 6. This field is mandatory for version 4.0 and higher tags, optional for earlier versions.
17-21	30h–34h (5 bits)	Agency Use	Individual agencies may add agency specific information here.	Assigned by agency (Optional)
22-33	35h-40h	Classification	Classification is taken directly from EZPass Inter-Customer Service Center Interface File and Reporting Specifications, Appendix C and includes:	Population of the first bit indicating class value assignment is mandatory. Remaining classification fields are optional if assignment bit is "0".
	(1 bit)	Class	The first bit indicates if the transponder 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
	(5 bits)	Vehicle Type	This field indicates the type of vehicle.	00000 = Undefined (default) 00001 = Automobile 00010 = Motorcycle 00011 = Pickup truck 00100 = Van (seats 1-9) 00101 = Minibus (seats 10-15) 00110 = Bus (seats 16+) 00111 = Recreational vehicle 01000 = Truck 01001 = Auto transporter (≤ 65') 01010 = Auto transporter (>65') 01011 = Tractor & trailer (≤48') 01100 = Tractor & trailer (>48') 01101 = Tractor & dual trailers each (≤28.5') 01110 = Tractor & dual trailers each (>28.5') 01111 = Tractor & dual trailers each (one ≤28.5' other >28.5') 10000 = Undefined 10001 = Tractor/mobile home combination 10010-11111 = Undefined
	(4 bits)	Vehicle Axles	This field indicates the number of axles.	0000 = Undefined (default) 0001 = Undefined 0010 = 2 axles 0011 = 3 axles 0100 = 4 axles 0101 = 5 axles

#	Memory Address	Section	Description	Values
				0110 = 6 axles 0111 = 7 axles 1000 = 8 axles 1001 = 9 axles 1010 = 10 axles 1011 = 11 axles 1100 = 12 axles 1101 = 13 axles 1110 = 14 axles 1111 = 15 axles
	(1bit)	Vehicle Weight	This field indicates the weight of vehicle.	0 = ≤ 7,000 lbs. (default) 1 = > 7,000 lbs.
	(1 bit)	Vehicle Rear Tires	This field indicates the number of rear tires.	0 = Single rear tires (default) 1 = Dual rear tires
34-36	41h-43h (3 bits)	HOV Declaration	These three bits indicate the declaration status of the transponder. All single mode transponders shall be assigned the default value – 000, unless they are carpool specific transponders.	000 = Single mode (default) 001 = SOV (non-carpool) 010 = HOV 2+ 011 = HOV 3+ 100 = Carpool (as defined by roadway) 101 = Reserved for future use 110 = Reserved for future use 111 = Reserved for future use
37-40	44h-47h (4 bits)	Version	Allows for 16 possible values to indicate the version of the programming standard used on the transponder.	0000 = Unassigned 0001 = Ver. 1.0 0010 = Ver. 2.0 0011 = Ver. 3.0 0100 = Ver. 4.0 (current)
41-52	48h-53h (12 bits)	Agency	Allows for up to 4,096 agencies.	See 6C Coalition Table of Agencies (separate document)
53-80	54h-6Fh (28 bits)	Transponder Serial Number	Identifies the transponder within the agency. This space accommodates 268,435,456 values.	Assigned by agency
81-96	70h-7Fh (16 bits)	UII Authentication (Hash Value)	Calculated value using the first 80 UII bits and 32-byte key. Example appears in Section 6.	Assigned at the time of transponder manufacture. Calculated as per Section 6. Calculation/programming of this field is optional and it should be zero-filled if not calculated.

2.3 TID Memory Bank 10 Specification

The Transponder Identification (TID) memory has no specific value but is assumed to be unique and constant for all 6C transponders, per the 6C standard. The TID length can vary per the 6C specification and the length of a transponder's TID serial number is indicated on each transponder, in bits 0x20 – 0x22 of the TID. For fully serialized tags, the complete header and serialized portion of the TID can be anywhere from 96 - 192 bits, given the allowable serial number length of 48 - 144 bits. Transponders which are not fully serialized (that is, have at least a 48-bit unique serial number) should not be used for interoperable 6C tolling deployments.

2.4 User Memory Bank 11 Specification

This memory bank may be required to accommodate the future needs of group members or affiliates. Its provision and use are left optional at the discretion of individual members. It is important to note that given the absence of a universal requirement for User Memory, members should assume some portion of the tags programmed per this document may not contain a User Memory Bank 11.

Previous versions of this document required the User Memory bank be present on all tags and it be a minimum size of 64 bits. This memory was programmed per the following table. To maintain backwards compatibility with tags programmed under previous versions of this document, the below memory map must be used for tags that meet both conditions:

1. A User Memory bank is present on the tag
2. The 6C Coalition's DSFID value is programmed into the first byte of User Memory (per table 5 below)

Table 5: User Memory Bank 11 Mapping

#	Memory Address	Section	Description	Values
1-8	00h-07h (8 bits)	DSFID	Data Storage Format Identifier	0011 1110 = 6C TOC DSFID (3Eh)
9-20	08h-23h (12 bits)	Agency	Agency Code of agency writing to this memory bank.	See 6C Coalition Table of Agencies (separate document)
21-27	24h-1Ah (7 bits)	Plaza ID	7-bit Plaza ID. Each operator may choose.	Defined by agencies using this field.
28-32	1Bh-1Fh (5 bits)	Lane ID	5-bit Lane ID. Each operator may choose.	Defined by agencies using this field.
33-57	20h-38h (25 bits)	Day/Time	25-bit Day/Time. Each operator may choose. (seconds since Jan 01 00:00:00)	Defined by agencies using this field.
58—60	39h-3Bh (3 bits)	Occupancy Setting	3-bit Occupancy. Each operator may choose.	Defined by agencies using this field.
61+	3Ch -	Undefined	The remaining bits defined as individual agency needs arise.	

Tags that either do not have a User Memory bank, or do not have the 6C Coalition's DSFID programmed as the first byte of User Memory, are not subject to any requirements regarding User Memory.

3 Interoperability Requirements

3.1 Overview

The purpose of these requirements is to have all compliant transponders and readers operate as seamlessly as possible from one installation to the next. They create a basis for the development and refinement of testing methods used in a certification process. The 6C Coalition uses a third party to administer and conduct the certification program.

Interoperability testing demonstrates in lab and field conditions (replicating a reference toll environment) that transponders and readers operate predictably together. Agencies and integrators purchasing these products should be assured of basic equipment interoperability, but it does not substitute for performance testing in specific tolling installations. Due to the unique nature of each tolling installation, site-specific conditions, vehicle types, environmental conditions, etc., it is incumbent upon purchasers of equipment to test and tune for desired interoperability performance levels.

All transponders that conform to this 6C Coalition standard should be operable in any AVI system using a reader that conforms to this standard, as well as supporting other aspects relevant to the procurement and management of transponders. This necessitates that:

- All transponders conform to the same 6C air interface protocol physical layer.
- All transponders must support the full mandatory set of communications from the referenced 6C air interface protocol and must operate at all mandatory data rates supported by the protocol.
- Transponder performance must be reliable, and the communication zone should be within bounded limits for common or reference systems, which includes but is not limited to RF requirements such as operating on vehicles at the same field strength and under similar RF geometries defined by the 6C Coalition.

All readers that conform to this 6C Coalition standard should be operable with all types of transponders that conform to this standard. This necessitates that:

- All the protocol communications used by the reader must conform to the referenced 6C air interface protocol. However, this does not require that all the functions or commands that are mandatory for generic interrogators in the air interface protocol be supported by toll readers.
- The reader commands NAK, Kill, and Lock are optional for readers.
- Readers can report and be limited to reporting transponders coded as 6C toll transponders, using coding as defined in this document in the presence of other 6C transponders. See Appendix B for additional information regarding filtering of legacy 6C tolling transponders.

3.2 Conformance Testing

Conformance testing shall prove devices operate in accordance with the 6C PHY (Physical) and MAC (Medium Access Control) layers. All transponders and readers shall meet the conformance requirements defined in Table 6 below.

Table 7: Conformance Testing Requirements

#	Category	Requirement
1.1	Regulatory Approvals	Meet all applicable FCC compliance requirements for Part 15 and 90
1.2	Protocol Compliance	Conform to the 6C PHY (Physical) and MAC (Medium Access Control) layers, in accordance with ISO 18047-6 or EPCglobal Conformance test methods. For transponders - include mandatory modulation rates supported by the transponder (i.e., as per ISO 18047-6) and verification of QUERY and ACK as per ISO 18047-6 or equivalent. For readers –limited to only modulation rates that the reader manufacturer specifies (i.e., as per ISO 18047-6).
1.3	Frequency Range	Operate in the 902-928 MHz frequency range.
1.4	Regulatory Verification	Meet necessary regulatory and safety certifications specified by the FCC, vendor, or 6C Coalition as required/applicable.

3.3 Baseline Testing

Baseline Testing verifies that a device meets the minimum required performance for basic functionality, RF performance, and environmental performance in a lab environment.

3.3.1 Functional Baseline Tests

Functional Baseline Tests shall verify that the transponders comply with the 6C Coalition specifications. Transponders are tested to ensure that the various memory banks are properly programmed and can be written to as specified. Readers are tested to ensure transponders are properly read and transmitted to a higher-level system (e.g., lane controller).

Functional Baseline Tests are conducted in a laboratory environment to ensure that a transponder and a reader communicate via RFID commands. Testing of transponders for commands (executed with standardized parameters and transponder user data) may be embedded in automated test scripts run on the reference reader. There shall be enough tests to ensure that all commands and parameters function correctly, and that transponder data is read/written correctly and secured. For reader testing, the vendor shall state the set of commands used for toll operation. This testing shall verify through these commands the reader's capability to select, filter, and properly read 6C Coalition transponders.

Commands and Parameters – Transponders and readers shall be tested to make sure they can transition between all internal states while executing commands. A transponder must also demonstrate additional capabilities such as Lock, Kill, EPC re-programmability via secure access, and the ability to accept write directives. A reader must demonstrate the ability to filter only 6C Coalition transponders in the read zone.

Test Parameters – Antenna height, transponder height, and distance between transponder and antenna shall be held constant.

Test Approach - A reader submitted for testing shall be tested against reference transponders. A transponder submitted for testing shall be tested against reference readers.

3.3.2 Environmental Performance

Environmental baseline testing shall verify performance of transponder under various environmental conditions.

3.3.3 RF Performance

RF Performance Baseline Tests will verify RF performance of transponders in controlled free space to ensure interoperability between devices based on the transponder characteristics specified by the 6C Coalition's requirements. Transponder testing will determine transponder minimum activation energy, backscatter range, antenna polarization, and pointing loss. The tests are conducted in a simulated operational environment, which is not meant to substitute for toll operators conducting performance accuracy testing in a real-world toll application. The EPCglobal test document titled, *Tag Performance Parameters and Test Methods Version 1.1.3*, shall serve as the basis for testing:

1. Read range (EPCglobal test document Section 8.1)
2. Orientation tolerance (EPCglobal test document Section 8.2)
3. Frequency tolerance (EPCglobal test document Section 8.3)
4. Backscatter range (EPCglobal test document Section 8.5)

All values are measured per the EPCglobal *Tag Performance Parameters and Test Methods Version 1.1.3* test protocol, limited to the 902 – 928 MHz frequency range and modified as follows:

1. Use a horizontally, linearly polarized test antenna
2. Transponders mounted on material applicable for the intended location on the vehicle

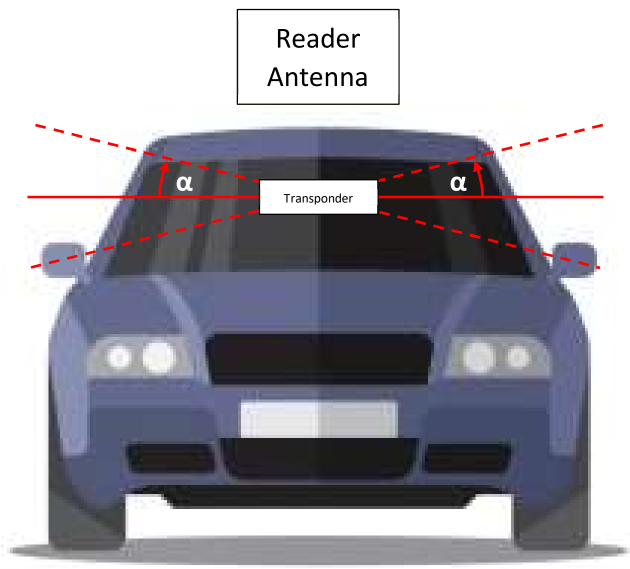
3.3.4 Transponder Requirements

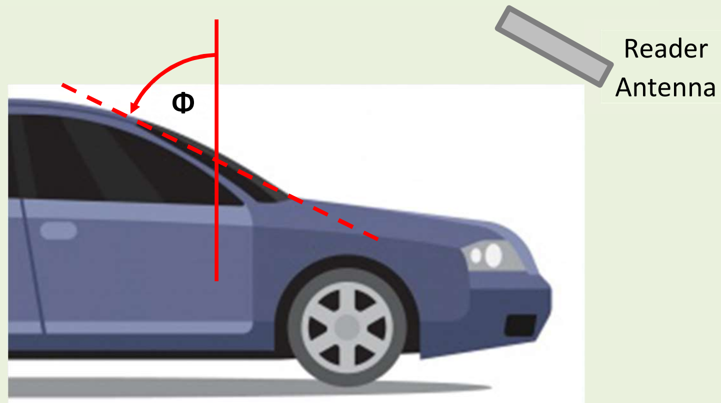
Transponders shall meet the baseline testing requirements shown in 8 below.

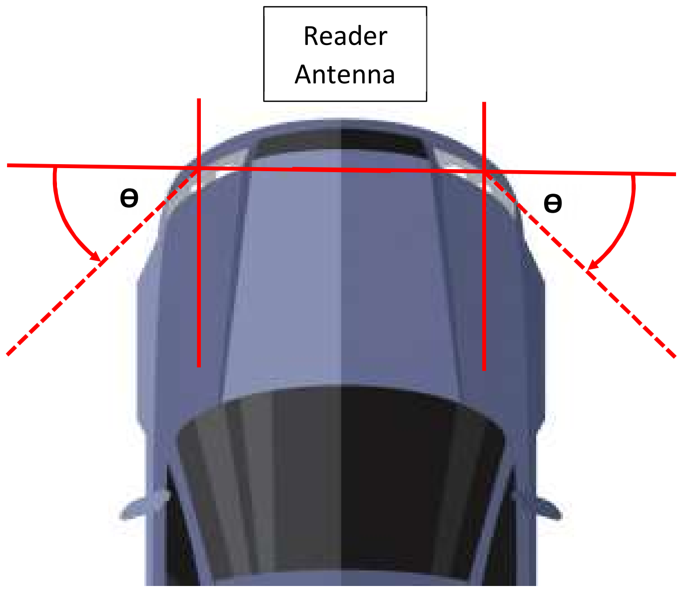
Table 9: Transponder Baseline Testing Requirements

#	Category	Requirement
2.1	Functional - Memory Bank 10	Contain a minimum of 64 bits (8 byte) unique chip ID programmed by the chip manufacturer (TID)
2.2	Functional – Memory Bank 01	Programmed per section 2.2.1 of this document
2.3		Optional and length variable

#	Category	Requirement
2.4	Functional - Memory Bank 11	Previous versions of this standard required this area be programmed with the DSFID (00h-07h) set to 3Eh, 0011 1110 = 6C Coalition DSFID (3Eh). If this area of memory is present and programmed with the DSFID (as stated in previous sentence), the size of the User Memory Bank 11 shall be at least 64 bits.
2.5		Programmed unused and undefined bits with zeros
2.6	Functional - Memory Bank 00	See section 2.1 of this document
2.7	Environmental	All interior transponders – able to be subjected to and operated in 95% humidity, non-condensing environments
2.8		All exterior transponders – able operate in 100% humidity, condensing environments.
2.9		All interior transponders – able to operate at temperatures between – 40° F and +185° F.
2.10		All exterior transponders – able to operate at temperatures between – 40° F and +140° F.
2.11		All transponders – perform consistently under Ultraviolet (UV)/direct sunlight as well as in overcast conditions.
2.12	RF Performance - Minimum Activation Energy	All transponders - have a Minimum Activation Energy (forward link range) resulting in a baseline test read range between 7 m and 12 m.
2.13	RF Performance - Return Signal Strength (Backscatter Range)	All transponders - have a return signal strength/backscatter range (reverse link range) resulting in a baseline test read at a minimum of 14 m.

#	Category	Requirement
2.14	RF Performance - Antenna Polarization and Pointing Loss	All transponders - have a minimum activation energy (forward link range) for "Tilt from Horizontal" resulting in a baseline test read range, between 5 m and 12 m, when tilted +/- 15 degree horizontally (see Figure 1) from the installation reference angle defined by the transponder manufacturer. Facing the reader antenna, "Tilt from Horizontal" is the angle α from the horizontal mounting of a transponder. This represents transponders that are not installed horizontally level ("crooked"). **Tilt from horizontal reference plane (roll angle) = α**  *Figure 1: Diagram depicting roll angle between transponder and reader antenna*

#	Category	Requirement
2.15	RF Performance - Antenna Polarization and Pointing Loss	All transponders - have a minimum activation energy (forward link range) for "Tilt from Vertical" resulting in a baseline test read range between 5 m and 12 m, when tilted up to 45 degrees from vertical. Looking from the side, "Tilt from Vertical" is the angle Φ showing the difference of the mounted transponder from perfectly vertical as shown in Figure 2. This represents windshield angles between steeply sloped windshields (sports car) and near vertical windshields (semi-tractor trailers). **Tilt from vertical reference plane (pitch angle) = Φ**  *Figure 2: Diagram depicting pitch angle between transponder and reader antenna*

#	Category	Requirement
2.16	RF Performance - Antenna Polarization and Pointing Loss	All transponders - have a minimum activation energy (forward link range) for "Rotation from Horizontal" resulting in a baseline test read range between 5 m and 12 m, when rotated +/- 18 degrees from the horizontal plane (see Figure 3) from horizontal. Looking top down, Rotation from Horizontal is the rotation angle Ɵ from the horizontal plane of the transponder face away from the reader antenna. This represents transponder mounting locations on flat windshields versus curved windshields and headlights. **Rotation from horizontal reference plane (yaw angle) = Ɵ**  *Figure 3: Diagram depicting yaw angle between transponder and reader antenna*

3.3.5 Reader Requirements

Readers shall meet the baseline testing requirements shown in Table 10 below.

Table 10: Reader Baseline Testing Requirements

#	Category	Requirement
3.1	Power Level	Have a maximum power/field strength allowed by local regulatory authority.
3.2	Interference	Provide interference mitigation for use with other readers at a toll plaza in single protocol reader and multiple protocol reader modes.
3.3	Transponder Filtering	Able to filter and report 6C Coalition coded transponders and information.
3.4	Transponder Filtering	Able to filter out non-6C Coalition transponders.
3.5	Reporting Transponder Data	Verify that reader can correctly read transponder data and supply it to a higher-level system (e.g. lane controller).

3.4 Field Testing

Field Testing shall use a simulated field environment to evaluate device performance at different ranges, speeds (up to 85 mph), windshield angles, and lane placement. For both transponder and reader testing, reader frequency may be any frequency within the 902 – 928 MHz range and reader power or field strength can be up to the maximum allowed by local regulatory authorities.

3.4.1 Transponders

Tests occur in various toll operating environments (varied ranges, speeds and transponder densities). Transponders are tested using reader reference test systems set up per vendor instructions. Vehicle passages will cover both the mainline path and lane edges.

Transponder performance shall meet the field-testing requirements described in Table 11 below.

Table 12: Transponder Performance Requirements

#	Category	Requirement
4.1	Transponder Height	Above ground for car windshield mountings: 36”-48” (0.91m-1.2m) Above ground for medium truck windshield mountings: 48”-65” (1.2m-1.6m) Above ground for Large truck (Straight and Tractor) windshield mountings: 72”-108” (1.8m-2.7m)
4.2	Transponder orientation (3-D)	Tilt horizontal α = +/- 15 degrees (roll angle) Tilt vertical Φ = 0 to - 45 degrees (pitch angle) Rotation horizontal θ = +/- 18 degrees (yaw angle)
4.3	Transponder Speed	Speed of 0, 15, 85 MPH
4.4	Transponder Mounting	Windshield (Ford F150 4’x6’ portion) Headlight (Ford F150 full headlight assembly) Bumper (metal or plastic according to vendor instructions) Other mounting type per vendor instructions
4.5	Interrogator antenna orientation	Fixed reference system with horizontal linear polarization and antenna 15 degrees from horizontal facing oncoming traffic pattern
4.6	Antenna Height	Fixed reference system with lowest portion of antenna assembly 19’ above center point of travel lane

3.4.2 Readers

Reader systems are configured as single lane or multiple lane ORT per the vendor recommended toll configuration setup.

Readers shall meet the field-testing requirements described in Table 13 below.

Table 14: Reader Field-testing Requirements

#	Category	Requirement
5.1	Transponder Population	Filter one 6C Coalition transponder (programming consistent with version 3.1 of this standard or higher) from nine non-6C Coalition transponders. Filtering information can be found in Appendix A Table 11 of this document (AFI, DSFID and Version values available to be filtered upon).
5.2	Transponder Lane Placements	Pass multiple reference transponders through the read zone on vehicles using in-line positions and cross-over (lane change) locations, and will include multiple simultaneous vehicles in the ORT configuration
5.3	Transponder Height	Above ground for car windshield mountings: 36”-48” (0.91m-1.2m) Above ground for medium truck windshield mountings: 48”-65” (1.2m-1.6m) Above ground for Large truck (Straight and Tractor) windshield mountings: 72”-108” (1.8m-2.7m)
5.4	Transponder orientation (3-D)	Tilt horizontal α = +/- 15 degrees (roll angle) Tilt vertical Φ = 0 to - 45 degrees (pitch angle) Rotation horizontal θ = +/- 18 degrees (yaw angle)
5.5	Transponder Speed	Speed of 0, 15, 85 MPH
5.6	Transponder Mounting	Windshield (Ford F150 4’x6’ portion) Headlight (Ford F150 full headlight assembly) Bumper (metal or plastic according to vendor instructions) Other mounting type per vendor instructions
5.7	Interrogator antenna orientation	Per vendor recommendation and using vendor antenna
5.8	Antenna Height	Per vendor recommendation and using vendor antenna

3.5 Multiprotocol Environments

The 6C protocol will be used in conjunction with other protocols, therefore:

1. Multiprotocol transponders – Transponders with multiple protocols that incorporate the 6C protocol are required to meet the minimum 6C protocol performance prescribed in this document.
2. Multiprotocol readers – Readers with multiple protocol functionality that read the 6C protocol are required to meet the minimum 6C protocol performance described in this document.

4 Barcode Format

The transponder barcode includes the Agency Code, the Transponder Serial Number, and a check digit. The barcode shall be printed using EPC Code 128 and the code data digits shall be in decimal format **AAAATTTTTTTTTTL** where **AAAA** is the Agency Code as a 4-digit number with leading zeros, **TTTTTTTTTT** 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 TTTTTTTTTT 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. The check digit **L** is Luhn (mod10) coded – calculated based upon **<AA>AA** (third and fourth digits only) and **TTTTTTTTTT** (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 contain:

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 contain:

449 0000000012 2

5 Transponder Manifest Details

Accompanying an order of transponders, it is suggested that tag manufacturers provide a file including an entry for each transponder delivered to facilitate loading of data into back office systems. This should include both the UII programmed value and TID programmed value. Each transponder entry should appear on a new line as shown in the example below:

12_Byte_UII_Memory,TID (length varies)

0101CE00010000000101CE8C,E2003412012EC0FFEE041392

6 Security and Data Integrity Validation

6.1 Overview

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

6.2 Memory Bank Security

6.2.1 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 transponders to permanently disable the ability to kill their transponders.

6.2.2 UII Memory Bank

1. The transponder issuing agency shall be the only entity authorized to change the encoded bits on the transponder. The UII memory bank shall have a Lock Status of locked.
2. UII Validation - The UII content can be validated by comparing a CRC computed on the received UII data against the UII validation byte contained within the UII. Further details are contained in section 6.4.
3. UII Authentication – The UII memory data should be authenticated with two hashed authentication bytes. The UII Authentication bytes can be used for transponder data authentication. Further details are contained in Section 6.5.

6.2.3 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.

6.2.4 User Memory Bank

1. Password – If a User Memory bank is included on the tag, it shall be writable without a password.
2. Lock Status - If a User Memory bank is included on the tag, it shall have a Lock Status of unlock.
3. Authentication/Validation – Authentication and validation shall not be used.

6.3 Encryption

Under development.

6.4 UII Validation (CRC Calculation)

The CRC is included in tag memory to easily validate the integrity of UII bits 17 – 80 (Agency Use through Transponder Serial Number fields). Should any portion of this area of tag memory become erroneous/faulty, validation of the CRC field provides a means to detect this. The CRC is calculated using an 8-bit CRC applied to UII bits 17 – 80. Note the *UII Authentication (Hash Value)* portion of tag memory is intentionally not included in this calculation. This allows the CRC to be calculated both prior to and independently of the calculation of the *UII Authentication*. The *UII Authentication* value can then be calculated once the CRC value is determined.

The CRC to be used is an 8-bit CRC (CRC-8/ITU), with a polynomial of $x^8 + x^2 + x + 1$, with a preset value of 0x00 and an output XOR mask of 0x55 (see 0x83 [implicit+1 notation] in Best CRC Polynomials[1]). As stated above, the data feed for the CRC calculation is UII bits 17 – 80.

Below is an example of how the CRC byte shall be calculated using:

1. An example UII bits 17 – 80 (64 bits or 8 bytes) value of **0xFFFFFFFFFFFFFFFF**
2. Polynomial (implicit+1 notation) **0x83**
3. Initial CRC value **0x00**
4. Output XOR **0x55**
5. CRC remainder **0xD7**
6. The resulting CRC output is **0x82**. CRC implementations can be verified using the CRC-8/ITU calculation in https://crccalc.com

6.5 UII Authentication (Hash Value)

Below is an example of how the UII Authentication 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 transponder issuing agency)
3. The bytes of the transponder TID (length varies - see footnote)

[1] Implicit+1 notation in https://users.ece.cmu.edu/~koopman/crc/index.html by Phillip Koopman, Carnegie Mellon University, aka CRC-8-CCITT in https://en.wikipedia.org/wiki/Cyclic_redundancy_check#table

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:

1. Concatenate the 10 UII memory bytes, the 32-byte key and the TID bytes to form a single byte sequence
2. Determine the SHA1 hash of this byte sequence above
3. 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: **0xFFFFFFFFFFFFFFFFFFFF**

Key 32 byte:

0xABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABAB

TID (12-byte example): **0x000000000000000000000000**

Result 20-byte hash value: **0x167F9C5B3933148B68AAD51EE3C4B5F858166451**

UII Validation bytes: **0x167F**

The 12 UII bytes shall be encoded as: **0xFFFFFFFFFFFFFFFFFFFF167F**

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.

7 APPENDICES

Appendix A Legacy 6C Toll Transponder Information

The programming standard described in this document intends to enable consistent tag programming among the member agencies. However, developing the standard required several iterations before achieving a steady state in Version 3.1. Thus, slight differences exist between the current version and previous versions. This appendix explains how to determine the programming standard used and the forward compatibility of the Agency Codes.

A.1 Assumptions

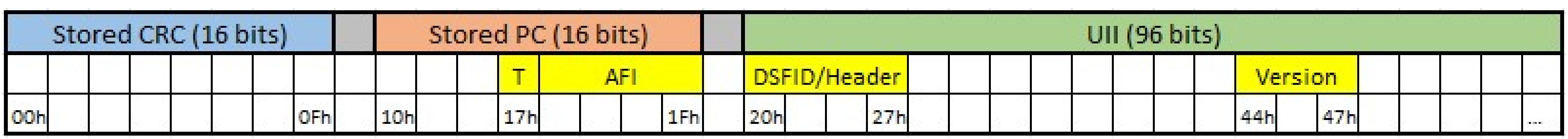
1. All values discussed appear in hexadecimal, except where noted.
2. This appendix only discusses Memory Bank 01 (CRC, PC, and the UII) described in section 2.2

A.2 Determining the Tag Programming Standard

Use the AFI, Header/DSFID, and Version values to validate the tag and determine the Programming Standard used. Figure 4 illustrates the location of the bits.

- AFI - Memory Address **18h - 1Fh**
- Header/DSFID - Memory Address **20h – 27h**
- Version - Memory Address **44h – 47h**

Figure 4: Snip of Memory Map - Highlights the location of key identification bits



For a tag to comply as an interoperable 6C Coalition tag, one of the following statements must apply:

1. [AFI] contains no value, [Header] contains **35**, and [Version] contains **0**, the tag uses Programming Standard Version 0.9.

2. [AFI] contains no value, [Header] is **35**, and [Version] is **1**, the tag uses Programming Standard Version 1.0. – no longer used
3. [AFI] contains no value, [Header] contains **B0**, and [Version] contains **2**, the tag uses Programming Standard Version 2.0.
4. [T] contains 1, [AFI] contains **B0**, [Header] contains no value, and [Version] contains **3**, the tag uses Programming Standard Version 3.0.
5. [T] contains 1, [AFI] contains **B0**, [DSFID] contains **3E**, and [Version] contains **3**, the tag uses Programming Standard Version 3.1.
6. [T] contains 1, [AFI] contains **B0**, [DSFID] contains **3E**, and [Version] contains **4**, the tag uses Programming Standard Version 4.0.

The following table provides a summary of the values discussed above:

Table 15: Programing Standard Identification

	T bit and AFI (9 Bits) **Memory Address:** 17h – 1Fh Bits 8-16 of the Stored PC		**DSFID / Header (8 Bits)** **Memory Address:** 20h – 27h Bits 1-8 of the UII		**Version (4 Bits)** **Memory Address:** 44h – 47h Bits 37-40 of the UII	
Version	**Binary**	**Hex**	**Binary**	**Hex**	**Binary**	**Hex**
4	1 1011 0000	1 B0	0011 1110	3E	0100	4
3.1	1 1011 0000	1 B0	0011 1110	3E	0011	3
3	1 1011 0000	1 B0	N/A	N/A	0011	3
2	N/A	N/A	1011 0000	B0	0010	2
1	N/A	N/A	0011 0101	35	0001	1
0.9	N/A	N/A	0011 0101	35	0000	0

A.3 Identifying Agencies

For Versions 0.9 and 1.0, a combination of the State Code (7 bits) and the Agency Code (5 bits) identified an agency. This concept allowed a single state or region to have multiple agencies (Figure 5).

Figure 5: Version 0.9 and 1.0 State and Agency Code

State (7)							Agency (5)				
0	0	0	0	1	1	0	0	0	0	1	0

Version 2.0 replaced the separate State Code and Agency Code with a single Agency Code (12 bits), using the same Memory Address (Figure 6). This code design allows forward compatibility. For example, in Version 0.9/1.0, the Colorado E-470 Public Highway Authority had a State Code of 6 for Colorado and an Agency Code of 2 for E-470. As depicted in Figure 5, the binary code `0000110` equals decimal value 6 and the binary code `00010` equals decimal value 2.

In Version 2.0 and above, the Agency Code uses the entire 12 bits and all Agency Code values have 12-bit values. Using the example from above, E-470 has a decimal value of 194 as shown in the figure below.

Figure 6: Version 2.0, 3.0, and 3.1 Agency Code – Currently used

Agency (12)											
0	0	0	0	1	1	0	0	0	0	1	0

Figure 7 provides a reference chart comparing the different programming standards by version.

Figure 7: Memory Bank 01 Programming Summary by Version

Version	1.0				2.0				3.0 Rev 2				3.1				4.0			
Area	**#**	**Memory Address**	**Bits**	**Section**	**#**	**Memory Address**	**Bits**	**Section**	**#**	**Memory Address**	**Bits**	**Section**	**#**	**Memory Address**	**Bits**	**Section**	**#**	**Memory Address**	**Bits**	**Section**
Stored CRC	1-16	00h - 0Fh	16	N/A	1-16	00h - 0Fh	16	N/A	1-16	00h - 0Fh	16	Calculated	1-16	00h - 0Fh	16	Calculated	1-16	00h - 0Fh	16	Calculated
Stored PC	1-5	10h - 14h	5	N/A	1-5	10h - 14h	5	N/A	1-5	10h - 14h	5	Length	1-5	10h - 14h	5	Length	1-5	10h - 14h	5	Length
	6	15h	1	N/A	6	15h	1	N/A	6	15h	1	User Memory	6	15h	1	User Memory	6	15h	1	User Memory
	7	16h	1	N/A	7	16h	1	N/A	7	16h	1	XPC	7	16h	1	XPC	7	16h	1	XPC
	8	17h	1	N/A	8	17h	1	N/A	8	17h	1	Numbering System Indicator	8	17h	1	Numbering System Indicator	8	17h	1	Numbering System Indicator
	9-16	18h - 1Fh	8	N/A	9-16	18h - 1Fh	8	N/A	9-16	18h - 1Fh	8	AFI (B0 = 1011 0000)	9-16	18h - 1Fh	8	AFI (B0 = 1011 0000)	9-16	18h - 1Fh	8	AFI (B0 = 1011 0000)
UII	1-8	20h-27h	8	Header (0011 0101)	1-16	20h-2Fh	16	Header (B0 = 1011 0000 xxxx xxxx)	1-21	20h-34h	21	Agency Use	1-8	20h-27h	8	DSFID (3E = 0011 1110)	1-8	20h-27h	8	DSFID (3E = 0011 1110)
	9-36	28h-43h	28	General Manager Number									9-21	28h-34h	13	Agency Use	9-16	28h-2Fh	8	CRC
					17-21	30h-34h	5	Reserved Space									17-21	30h-34h	5	Agency Use
					22	35h	1	Classification Code	22	35h	1	Class	22	35h	1	Class	22	35h	1	Class
					23-27	3Ah	5	Vehicle Type Code	23-27	3Ah	5	Vehicle Type	23-27	3Ah	5	Vehicle Type	23-27	3Ah	5	Vehicle Type
					28-31	3Bh-3Eh	4	Vehicle Axles	28-31	3Bh-3Eh	4	Vehicle Axles	28-31	3Bh-3Eh	4	Vehicle Axles	28-31	3Bh-3Eh	4	Vehicle Axles
					32	3Fh	1	Vehicle Weight	32	3Fh	1	Vehicle Weight	32	3Fh	1	Vehicle Weight	32	3Fh	1	Vehicle Weight
					33	40h	1	Vehicle Rear Tires	33	40h	1	Vehicle Rear Tires	33	40h	1	Vehicle Rear Tires	33	40h	1	Vehicle Rear Tires
					34-36	41h-43h	3	HOV Declaration	34-36	41h-43h	3	HOV Declaration	34-36	41h-43h	3	HOV Declaration	34-36	41h-43h	3	HOV Declaration
	37-40	44h-47h	4	VersionCode	37-40	44h-47h	4	Version	37-40	44h-47h	4	Version	37-40	44h-47h	4	Version	37-40	44h-47h	4	Version
	41-52	48h-4Eh	7	State Code	41-52	48h-53h	12	Agency	41-52	48h-53h	12	Agency	41-52	48h-53h	12	Agency	41-52	48h-53h	12	Agency
	48-52	4Fh-53h	5	Agency Code																
	53-80	54h-6Fh	28	Vehicle Code	53-80	54h-6Fh	28	Transponder Serial Number	53-80	54h-6Fh	28	Transponder Serial Number	53-80	54h-6Fh	28	Transponder Serial Number	53-80	54h-6Fh	28	Transponder Serial Number
	81-96	70h-7Fh	16	UII Validation (Hash Value)	81-96	70h-7Fh	16	UII Validation (Hash Value)	81-96	70h-7Fh	16	UII Validation (Hash Value)	81-96	70h-7Fh	16	UII Validation (Hash Value)	81-96	70h-7Fh	16	UII Validation (Hash Value)

Appendix B Transponder Filtering

The 6C standard allows ‘filters’ to be implemented by readers to separate a population of tags based on values of certain areas of the tag memory. This is useful in tolling environments to allow readers to only read/report 6C transponders that are programmed as tolling tags, as opposed to reading all 6C tags that may pass through a lane (e.g. tags used for retail, asset tracking, etc). To effectively filter all tolling tags in use as of August 2019 (with minor exceptions), three filters are required, detailed below:

1. Stored PC bits 9-16 = **0xB0** (6C Coalition V3.0 and all later versions)
2. UII bits 1-8 = **0xB0** (WSDOT V2.0 tags)
3. UII bits 1-8 = **0x35** (SRTA [old tags] and E470 [all])

With the following exceptions all tags are programmed to version 3.0 or above:

- SRTA tags prior to 2017 (~400k) are an older version that was the basis for V1 published by the 6C TOC
- E-470 tags distributed prior to November 2019 are very similar to these older SRTA tags
- WSDOT has about 750k version 2.0 tags distributed
- Utah DOT has a unique programming standard and may replace their tags prior to joining an IOP hub

Table 16: Legacy Toll Tag Information

Agency	6C Coalition Programming Version	Estimated Count (as of August 2023)
E470	Version 0.9	1,600,000
WSDOT	Version 2.0	1,600,000
SRTA	Version 0.9	187,000
UDOT	Unique to UDOT	78,000