

Using Texas Instruments Tag-it™ HF-I Transponder Technology for NFC Vicinity Applications

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Embedded RF & MCU-RF

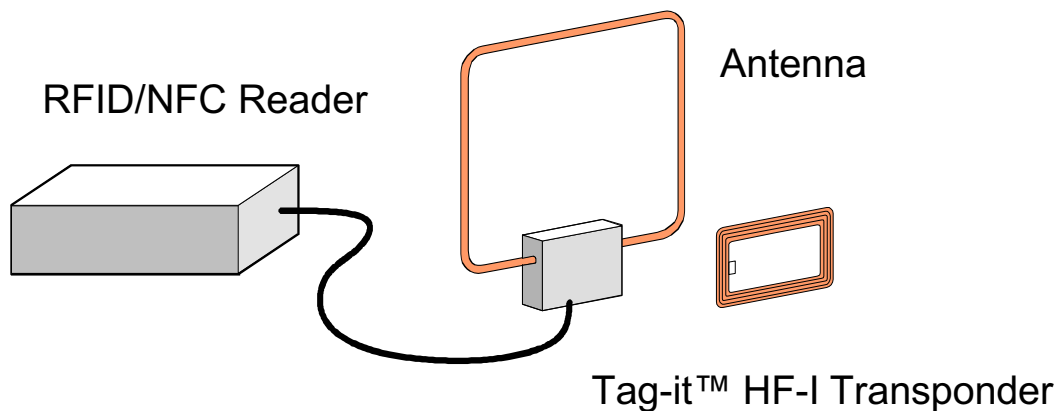
ABSTRACT

Texas Instruments' Tag-it™ HF-I family of transponders and silicon (inlays, encapsulated devices and wafers) consist of 13.56 MHz high frequency (HF) devices that are compliant with the ISO/IEC15693 and ISO/IEC18000-3 (Mode 1) global open standards.

The NFC Forum has specified the NFC data exchange format (NDEF) for using tag memory to store text, a uniform resource identifier (URI) or images (i.e., portable network graphics (PNG) or joint photographic experts group (JPEG) file types). This application report is intended to guide users and developers who are interested in also using them for NFC vicinity applications.

The Tag-it HF-I transponder inlay and silicon wafer offerings are well suited for a variety of applications including but not limited to: product authentication, library applications, supply chain management, asset management, and ticketing/stored value applications.

Texas Instruments TRF796x and TRF797x family of RFID/NFC reader/writer ICs coupled with any of the broad portfolio of Texas Instruments microcontrollers (i.e., MSP430™, C2000™, Stellaris®, Sitara™, DaVinci™ or OMAP™) can be used with the above mentioned transponders, inlays or transponder ICs to create complete RFID/NFC system.



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1 Tag-it HF-I Memory Maps

1.1 Plus Devices

The Tag-it HF-I Plus Transponder IC offers a full 2048 bits (256 bytes) of user memory, plus a 64 bit UID, DSFID and AFI fields, along with factory and user lock bits. User data is written to and read from memory blocks, which use a non-volatile EEPROM silicon technology. The user memory is organized in 64 individual 4 byte blocks (memory locations 0-63). Each block is separately programmable by the factory or the user and can be locked to protect data from modification. Once the data has been locked, it cannot be changed. The memory map for this device is shown in [Figure 1](#).

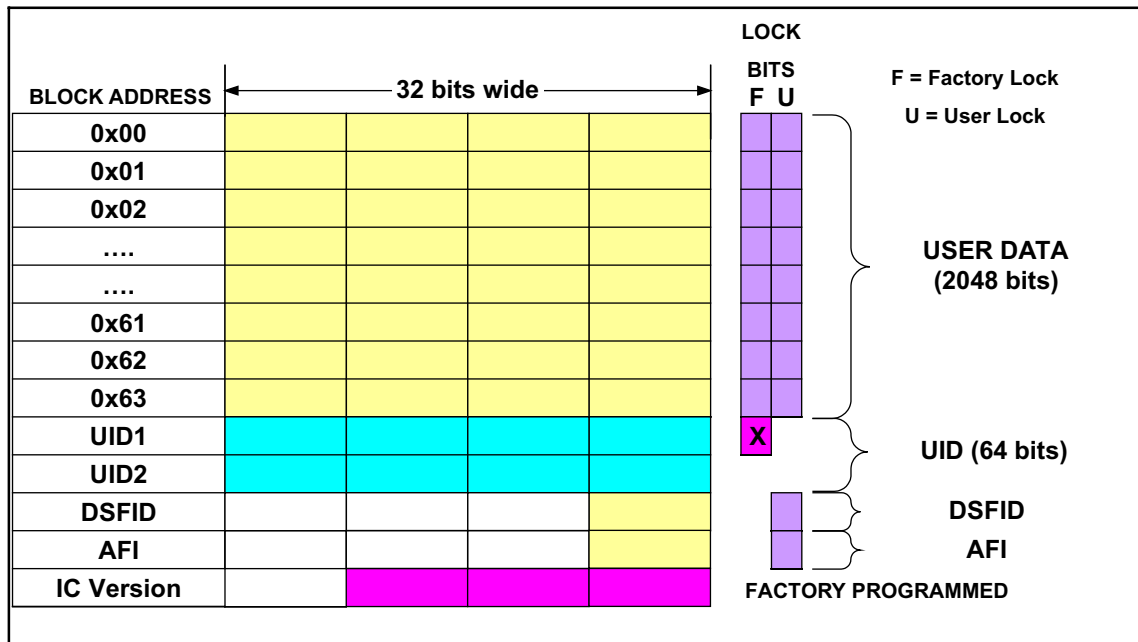


Figure 1. Tag-it HF-I Plus Memory Map

1.2 Pro Devices (with password write protect and kill features)

The Tag-it HF-I Pro Transponder IC offers a full 256 bits (32 bytes) of user memory, a 64 bit UID, an AFI field, plus a Password field along with factory and user lock bits. User data is written to and read from memory blocks, which use a non-volatile EEPROM silicon technology. The user memory is organized in eight individual 4 byte blocks (memory locations 0-7). Each block is separately programmable by the factory or the user and can be locked to protect data from modification. Once the password field is written and locked, data in blocks that have been locked can be changed by using the Write Block with Password Command. The memory map for this device is shown in Figure 2. This device also has a Kill command implemented for sensitive applications with “life cycles”, so it can be rendered completely unreadable.

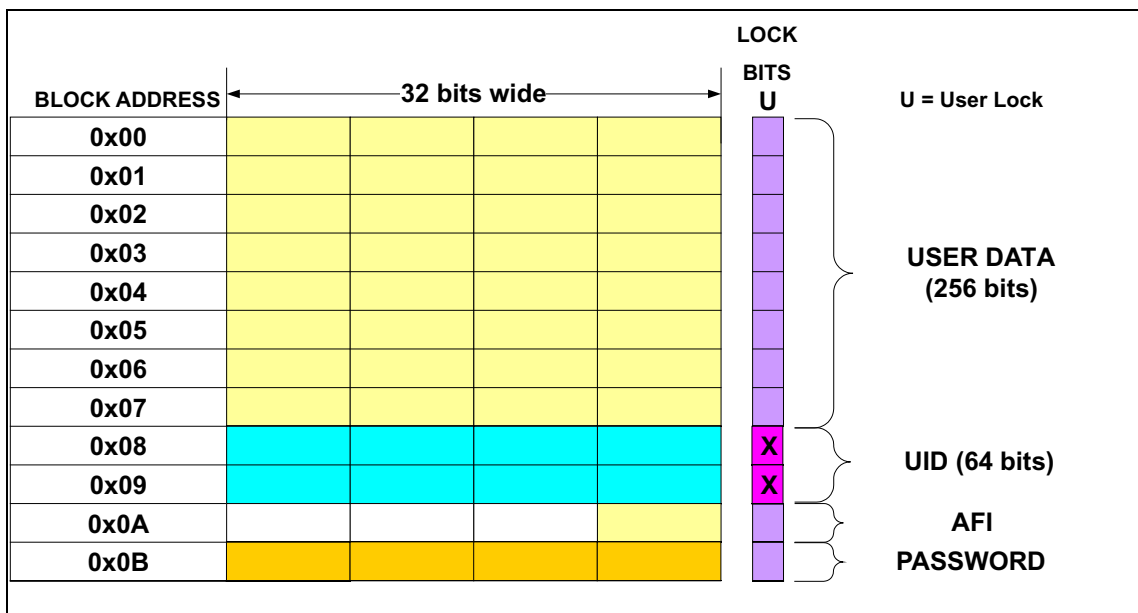


Figure 2. Tag-it HF-I Pro Memory Map

1.3 Standard Devices

The Tag-it HF-I Standard Transponder IC also offers a full 256 bits (32 bytes) of user memory, a 64 bit UID, AFI field, along with factory and user lock bits. User data is written to and read from memory blocks, which use a non-volatile EEPROM silicon technology. The user memory is organized in eight individual 4 byte blocks (memory locations 0-7). Each block is separately programmable by the factory or the user and can be locked to protect data from modification. Once the data has been locked, it cannot be changed. The memory map for this device is shown in Figure 3.

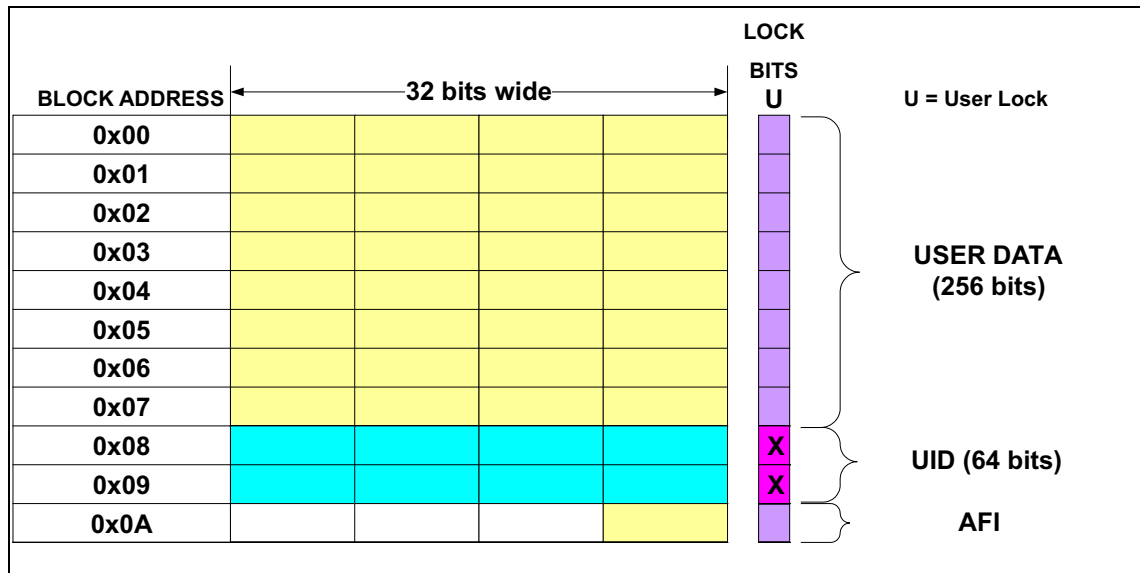


Figure 3. Tag-it HF-I Standard Memory Map

2 Tag-it HF-I Unique Identification (UID) Coding

The 64 bit UID is defined by the ISO15693 standard and contains two mandatory bytes to indicate that it is an ISO15693 device (MSByte = 0xE0) and the manufacturer of the silicon (next MSByte = 0x07 = TI, see ISO7816-6 for full list of silicon vendors recognized).

Texas Instruments UID coding complies and also uses the third most significant byte to indicate the product ID/functionality, as shown in Figure 4.

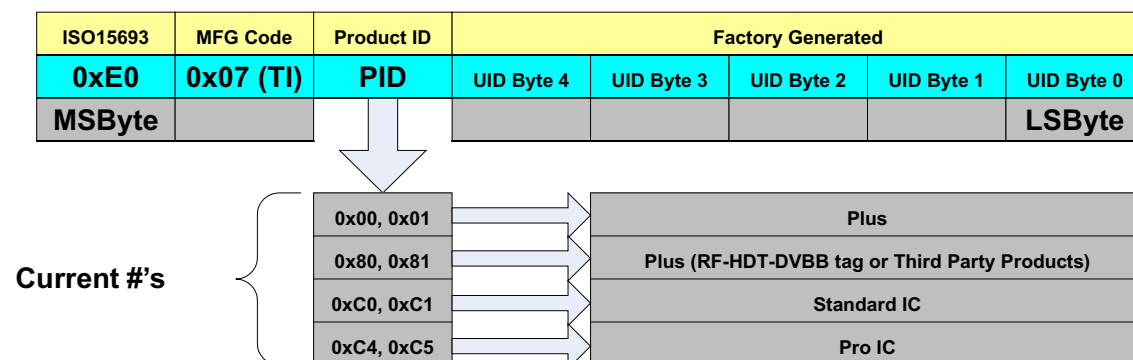


Figure 4. Tag-it HF-I UID Coding (all products)

3 Tag-it HF-I User Memory Contents (as shipped)

Texas Instruments, as part of the 100% final test of each transponder or IC wafer shipped, programs all user memory blocks, DSFID and AFI bytes to 0x00, then reads back and does a compare to ensure the memory cells are functional. This means that anyone wanting to utilize TI Tag-it HF-I transponders in an NFC application must first NDEF format the devices so they will be recognized.

4 Tag-it HF-I Implemented Commands

4.1 Plus Devices

Table 1. Command Set for Tag-it HF-I Plus Transponders ⁽¹⁾

Request	Request Code	Inventory	Addressed	Non Addressed	Select	AFI	OptionFlag
ISO 15693 Mandatory Commands							
Inventory	0x01	√	-	-	-	√	0
Stay Quiet	0x02	-	√	-	-	-	0
ISO 15693 Optional Commands							
Read_Single_Block	0x20	√	√	√	√	√	0/1
Write_Single_Block	0x21	-	√	√	√	-	1
Lock_Block	0x22	-	√	√	√	-	1
Read_Multi_Blocks	0x23	√	√	√	√	√	0/1
Write_Multi_Blocks	0x24	-	-	-	-	-	-
Select Tag	0x25	-	√	-	-	-	0
Reset to Ready	0x26	-	√	√	√	-	0
Write_AFI	0x27	-	√	√	√	-	1
Lock_AFI	0x28	-	√	√	√	-	1
Write DSFID	0x29	-	√	√	√	-	1
Lock DSFID	0x2A	-	√	√	√	-	1
Get_System_info	0x2B	√	√	√	√	√	0
Get_M_Blkc_Sec_St	0x2C	√	√	√	√	√	0
TI Custom Commands							
Write_2_Blocks	0xA2	-	√	√	√	-	1
Lock_2_Blocks	0xA3	-	√	√	√	-	1

⁽¹⁾ √ = Implemented, - = Not applicable, 0/1 = Option Flag needed

NOTE: The Option Flag (Bit 7) of the ISO/IEC15693-3 defined Request Flags must be set to 1 for all Write and Lock commands to respond properly. For reliable programming, a programming time ≥ 10 ms is recommended before you send the end of frame (EOF) to request the response from the Transponder.

4.2 Pro Devices (with password write protect feature)

Table 2. Command Set for Tag-it™ HF-I Pro Transponders ⁽¹⁾

Request	Request Code	Inventory	Addressed	Non Addressed	AFI	OptionFlag
ISO 15693 Mandatory Commands						
Inventory	0x01	√	-	-	√	0/-
Stay Quiet	0x02	-	√	-	-	0/-
ISO 15693 Optional Commands						
Read_Single_Block	0x20	-	√	√	-	-/1
Write_Single_Block	0x21	-	√	√	-	-/1
Lock_Block	0x22	-	√	√	-	-/1
TI Custom Commands						
Kill	0xA4	-	√	-	-	-/1
WriteSingleBlockPwd	0xA5	-	√	-	-	-/1

⁽¹⁾ √ = Implemented, - = Not applicable, 0/1 = Option Flag needed

NOTE: The Option Flag (Bit 7) of the ISO/IEC15693-3 defined Request Flags must be set to 1 for all Write and Lock commands to respond properly. For reliable programming, a programming time ≥ 10 ms is recommended before you send the end of frame (EOF) to request the response from the Transponder.

4.3 Standard Devices

Table 3. Command Set for Tag-it HF-I Standard Transponders ⁽¹⁾

Request	Request Code	Inventory	Addressed	Non Addressed	AFI	OptionFlag
ISO 15693 Mandatory Commands						
Inventory	0x01	√	-	-	√	0/-
Stay Quiet	0x02	-	√	-	-	0/-
ISO 15693 Optional Commands						
Read_Single_Block	0x20	-	√	√	-	-/1
Write_Single_Block	0x21	-	√	√	-	-/1
Lock_Block	0x22	-	√	√	-	-/1

⁽¹⁾ √ = Implemented, - = Not applicable, 0/1 = Option Flag needed

NOTE: The Option Flag (Bit 7) of the ISO/IEC15693-3 defined Request Flags must be set to 1 for all Write and Lock commands to respond properly. For reliable programming, a programming time ≥ 10 ms is recommended before you send the end of frame (EOF) to request the response from the Transponder.

5 NDEF Formatting of Tag-it HF-I Transponders

Before any ISO15693 device can be used as NFC-V tag, it must be formatted appropriately so that it can be recognized as NFC-V transponder with NDEF capabilities. This can be accomplished simply by issuing a write single block (with the correct values, see below) to Block 0 of the transponder to be formatted.

The NDEF Capability Container is a four byte field in block 0 of TI Tag-it HF-I transponders. Within this block (Block 0), in the context of using it as an NFC tag, the individual bytes have meaning as shown below in [Figure 5](#) and [Table 4](#).

	CC0	CC1	CC2	CC3
Block 0	0x00	0x00	0x00	0x00

Figure 5. Unformatted Capability Container (Block 0)

Table 4. Capability Container Byte Definitions

Byte Name	Byte Number	Bit(s)	Function
CC0	0	0:07	NDEF Message Present (Magic Number)
CC1	1	6:07	Version Number (Major)
		4:05	Version Number (Minor)
		2:03	Read Access Condition (will always be 00b)
		0:01	Write Access Condition (can be changed)
CC2	2	0:07	Total User Memory Size of Transponder, including CCBlock. (CC2 (convert hex value to decimal first) x 8 = User Memory Size in bytes).
CC3	3	3:07	RFU
		2	1: CC2 Overflow (Memory Size exceeds 2040 bytes) 0: CC2 value is sufficient
		1	RFU
		0	1: IC supports Read Multiple Blocks Command (0x23) 0: IC does not support Read Multiple Blocks Command (0x23), must use Read Single Block Command (0x20)

5.1 Plus Devices

Based on [Table 4](#), the correct values to be programmed into Block 0 of the Plus transponder IC for NDEF Formatting the Capability Container are shown in [Figure 6](#).

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x20	0x01
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 256 bytes	Supports Read Multiple Blocks

Figure 6. Formatted Capability Container Byte (Block 0)

5.2 Pro Devices (with password write protect feature)

Based on [Table 4](#), the correct values to be programmed into Block 0 of the Pro transponder IC for NDEF Formatting the Capability Container are shown in [Figure 7](#).

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x04	0x00
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 32 bytes	Does not support Read Multiple Blocks

Figure 7. Formatted Capability Container Byte (Block 0)

5.3 Standard Devices

Based on [Table 4](#), the correct values to be programmed into Block 0 of the Standard transponder IC for NDEF Formatting the Capability Container are shown in [Figure 8](#).

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x04	0x00
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 32 bytes	Does not support Read Multiple Blocks

Figure 8. Formatted Capability Container Byte (Block 0)

5.4 Empty NDEF Message TLV and TLV Terminator

To complete the NDEF formatting procedure on the transponder, Block 1 must then also be filled with correct values to indicate that it has an empty NDEF message along with the terminator. A Type, Length and Value (TLV) data format is used here. See [Table 5](#) for format field definitions and [Table 6](#) type byte definitions to complete formatting.

Table 5. TLV Byte Definitions

	Type	Length	Value
Length	1 byte	1:3 byte(s)	= Length indicated in previous byte
Description	TLV Block Type (see Table 6)	Length of NDEF Message (0x00 : 0xFFFE) (0xFFFF and above is RFU)	Record Header, NDEF Message Content and TLV Terminator (see Table 7)

Table 6. TLV Byte Definitions

TLV Byte Name	Value	Description
Null TLV	0x00	Pad
Lock Control TLV	0x01	
Memory Control TLV	0x02	
NDEF Message TLV	0x03	Transponder contains NDEF Message
Proprietary TLV	0xFD	
Terminator TLV	0xFE	End of Message

The basic example of an NDEF formatted (but empty) Plus transponder is shown in [Figure 9](#). A formatted, but also empty example of a Pro or Standard transponder, is shown in [Figure 10](#).

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x20	0x00
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 32 bytes	Does not support Read Multiple Blocks
Block 1	0x03	0x00	0xFE	0x00
	NDEF Message Present	Empty	TLV Terminator	Start of Available Memory

Figure 9. NDEF Formatted, Empty Tag-it HF-I Plus Transponder

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x04	0x00
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 32 bytes	Does not support Read Multiple Blocks
Block 1	0x03	0x00	0xFE	0x00
	NDEF Message Present	Empty	TLV Terminator	Start of Available Memory

Figure 10. NDEF Formatted, Empty Tag-it HF-I Pro or Standard Transponder

5.5 NDEF Message Programming Example

In the previous sections, the basic NDEF formatting of the transponder was completed. The next step to take would be to program an NDEF message onto the transponder so it will be ready to serve as an NFC device in the field. [Table 7](#) shows the Value Byte definitions as specified in the NFC Data Exchange Document (NDEF) under the heading of Record Header Layout.

Table 7. Value (Record Header Layout) Byte Definitions

NAME	BIT Placement	Function
Message Begin (MB)	1xxx xxxx (Bit 7, MSbit)	Indicates the start of the NDEF message
Message End (ME)	x1xx xxxx (Bit 6)	Indicates the end of the NDEF message
Chunk Flag (CF)	xx1x xxxx (Bit 5)	Indicates that the following message is either the first record chunk or a middle record chunk of a chunked payload.
Short Record (SR)	xxx1 xxxx (Bit 4)	Indicates the PAYLOAD_LENGTH field is a single byte (octet)
Short Record (IL)	xxxx 1xxx (Bit 3)	Indicates the ID_LENGTH field is present in the header as a single byte (octet), if this is a 0, this field is omitted from the header and the record
Type Name Format (TNF)	xxxx x111 (Bit 0:2, LSbit)	Indicates the structure of the value of the TYPE Field. (See Table 8 .)

Table 8. Type Name Format (TNF) Field Values

Type Name Format (TNF)	Value (in binary and decimal)
Empty	000 = 0
NFC Forum well known type (NFC RTD)	001 = 1
Media Type as defined in RFC 2046 (RFC 2046)	010 = 2
Absolute URI as defined in RFC 3986 (RFC 3986)	011 = 3
NFC Forum external type (NFC RTD)	100 = 4
Unknown	101 = 5
Unchanged (see NDEF_1.0 document, section 2.3.3 – used for middle or terminating chunks)	110 = 6
RFU (Reserved)	111 = 7

Building up the transponder user memory further as an NFC device properly formatted and with a URI record, the following examples can be shown, as seen in [Figure 11](#) and [Figure 12](#). The first example shows URI Record Type programmed on the transponder user memory for pointing towards <http://www.google.com> and the second example shows URI record type programmed on the transponder user memory for pointing towards <http://www.ti.com>.

Where (from Block 1, per NDEF and RTD_URI Specifications):

0x03 = NDEF Message Present, 0x13 = Length, 0xD1 = Record Header, 0x01 = Type Length, 0x0B = Payload Length, 0x55 = Record Type (U), 0x01 = URI Header ID = <http://www>., next ten bytes are 0x67, 0x6F, 0x6F, 0x67, 0x6C, 0x65, 0x2E, 0x63, 0x6F, 0x6D to represent “google.com” (in hex), then the TLV Terminator 0xFE, to end the message.

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x04	0x00
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 32 bytes	Does not support Read Multiple Blocks
Block 1	0x03	0x13	0xD1	0x01
	NDEF Message Present	Length (19 bytes)	Record Header	Type Length
Block 2	0x0B	0x55	0x01	0x67
	Payload Length	Record Type U (URI)	URI Header Identifier	g
Block 3	0x6F	0x6F	0x67	0x6C
	o	o	g	l
Block 4	0x65	0x2E	0x63	0x6F
	e	.	c	o
Block 5	0x6D	0xFE	0x00	0x00
	m	TLV Terminator	Empty (Don't Care)	Empty (Don't Care)

Figure 11. URI Record Example for Tag-it HF-I Pro or Standard Transponders

The following shows similar being done with the Plus transponder, where (also from Block 1, per NDEF and RTD_URI Specifications):

0x03 = NDEF Message Present, 0x0B = Length, 0xD1 = Record Header, 0x01 = Type Length, 0x07 = Payload Length, 0x55 = Record Type (U), 0x01 = URI Header ID = <http://www.>, next six bytes are 0x74, 0x69, 0x2E, 0x63, 0x6F, 0x6D to represent “ti.com” (in hex), then the TLV Terminator 0xFE, to end the message.

	CC0	CC1	CC2	CC3
Block 0	0xE1	0x40	0x20	0x00
	NDEF Message Present (Magic Number)	Version #, Read/Write Access Conditions	User Memory = CC2 value x 8 = 32 bytes	Does not support Read Multiple Blocks
Block 1	0x03	0x0B	0xD1	0x01
	NDEF Message Present	Length (11 bytes)	Record Header	Type Length
Block 2	0x07	0x55	0x01	0x74
	Payload Length	Record Type U (URI)	URI Header Identifier	t
Block 3	0x69	0x2E	0x63	0x6F
	i	.	c	o
Block 4	0x6D	0xFE	0x00	0x00
	m	TLV Terminator	Empty (Don't Care)	Empty (Don't Care)

Figure 12. URI Record Example for Tag-it HF-I Plus Transponder

6 References

- ISO/IEC15693-2 (Vicinity Cards - Air Interface and Initialization)
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=39695 (this is ISO web store - link to obtain the spec)
- ISO/IEC15693-3 (Vicinity Cards - Anti-Collision and Transmission Protocol)
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43467 (this is ISO web store - link to obtain the spec)
- ISO/IEC7816 (Register of IC Manufacturers) ISO Recognized Manufacturing IDs
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=38780 (this is ISO web store - link to obtain the spec)
- NFC Data Exchange Format (NDEF) (NFCForum-TS-NDEF_1.0)
http://www.nfc-forum.org/specs/spec_license (this is click through license agreement for non-members to obtain the spec, same for all the other licenses below).
- NFC Record Type Definition (NFCForum-TS-RTD_1.0) http://www.nfc-forum.org/specs/spec_license.
Generic Control Record Type Definition (NFCForum-TS-GenericControl_RTD_1.0)

- Generic Control Record Type Definition (NFCForum-TS-GenericControl_RTD_1.0)
http://www.nfc-forum.org/specs/spec_license
- URI Record Type Definition (NFCForum-TS-RTD_URI_1) http://www.nfc-forum.org/specs/spec_license
- Text Record Type Definition (NFCForum-TS-RTD_Text_1.0)
http://www.nfc-forum.org/specs/spec_license
- Smart Poster Record Type Definition (NFCForum-SmartPoster_RTD_1.0)
http://www.nfc-forum.org/specs/spec_license
- Signature Record Type Definition (NFCForum-TS-Signature_RTD-1.0)
http://www.nfc-forum.org/specs/spec_license
- Type 2 Tag Operation Specification (NFCForum-TS-Type-2-Tag_1.1)
http://www.nfc-forum.org/specs/spec_license
- *Tag-it™ HF-I Plus Transponder Inlays Reference Guide (SCBU004)*
- *Tag-it™ HF-I Transponder IC TMS37112 Reference Guide (SCBU011)*
- *Tag-it™ HF-I Plus Transponder Chip/Inlays Extended Commands and Options Reference Guide (SCBU003)*
- *Tag-it™ HF-I Pro Transponder Inlays Reference Guide (SCBU009)*
- *Tag-it HF-I Pro Transponder IC Reference Guide (SCBU045)*
- *Tag-it™ HF-I Standard Transponder Inlays Reference Guide (SCBU006)*
- *Tag-it HF-I Standard Transponder IC Reference Guide (SCBU047)*

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