NT2H2331S0

NTAG 223 DNA StatusDetect - NFC T2T compliant IC with StatusDetect feature

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Product data sheet
COMPANY PUBLIC

1 General description

NTAG 223 DNA StatusDetect (in the data sheet short NTAG 223 DNA SD) is an innovative single-chip solution offering security, tamper detection and sensing, combined with cost-efficiency. The technology uses multi-layered protection to support a broad range of NFC-based applications that can be trusted to protect products, services, and IoT-driven user experiences at scale.

NTAG 223 DNA StatusDetect is an NFC Type 2 Tag compliant security IC with a 144 byte user memory, offering a new StatusDetect functionality to enable a broad range of passively powered, status-aware NFC applications. The IC uses AES-128 cryptography and is Common Criteria EAL3+ (AVA.VAN.2) certified.

The NTAG 223 DNA StatusDetect IC adds flexibility by offering two tamper evident modes: conductance or capacitance. There is no need for a dedicated app.

Conductive tamper detection uses a connected tamper loop that, when broken, irreversibly writes the once-open status into the IC memory upon IC start-up. It sends the open status to the cloud as part of the Secure Unique NFC (SUN) message –upon readout with an NFC-enabled device such as a cell phone.

With capacitive tamper detection, the NTAG 223 DNA StatusDetect IC needs to be connected to a sensing capacitor. Upon readout, the IC measures the capacitance and compares it to pre-configured limits. When these limits are exceeded, the open status s added to the SUN message. Capacitive tamper detection is well suited for integration into physical form factors, and it’s also harder for fraudsters to reconstruct.

Alternatively, the NTAG 223 DNA StatusDetect IC can be used as a simple passive sensing device to detect a change in a specific condition, such as humidity, liquid fill level or pressure. Changes in measured capacitor values are captured with an NFC reader, and are interpreted by a mobile or cloud-based application, e.g. if outside the pre-defined range.

NTAG 223 DNA StatusDetect IC comes with a Secure Unique NFC (SUN) message authentication. The IC can automatically add its UID and incremental tap counter to the programmed NDEF (NFC Data Exchange Format) message through ASCII mirroring, and uses an AES-128 key to secure the message with a cryptographic message authentication code (CMAC). The SUN functionality supports advanced protection to verify a tag’s authenticity and integrity, whilst also enabling secured unique user experiences served in real time.

NTAG 223 DNA StatusDetect offers in addition an ECC-based originality signature to assure tag origin. The originality signature can be further customized and permanently locked during tag initialization.

The NTAG 223 DNA StatusDetect is compliant with NFC Forum Type 2 Tag ([1]) and ISO/IEC14443 Type A part 1 to 3 ([2]).

1.1 Contactless energy and data transfer

Communication to NTAG 223 DNA SD can be established only when the IC is connected to an antenna. Form and specification of the coil is out of scope of this document, general recommendations can be found in the NTAG antenna design guide (see [4]).

When NTAG 223 DNA SD is positioned in the RF field, the high-speed RF communication interface allows the transmission of the data with a baud rate of 106 kbit/s.

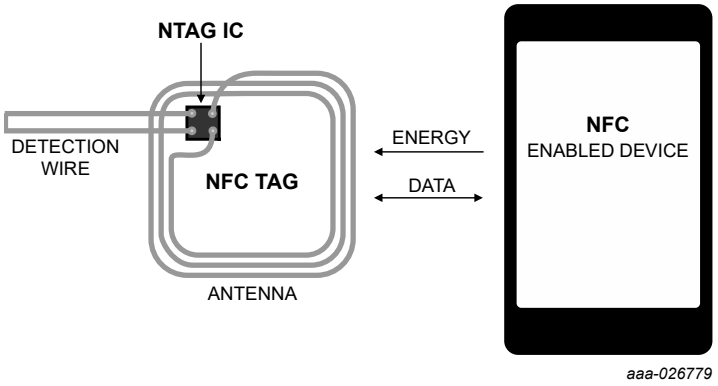


Figure 1. Contactless NTAG 223 DNA SD system with galvanic tag tamper

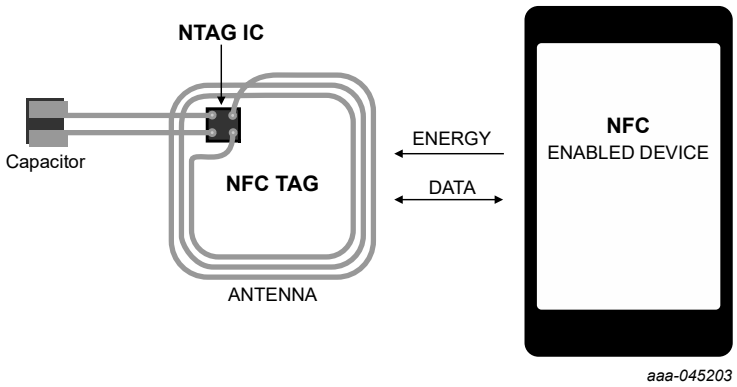


Figure 2. Contactless NTAG 223 DNA SD system with capacitor

1.2 Simple deployment and better user experience

NTAG 223 DNA SD offers specific features designed to improve integration into physical objects and enhance user experience:

- The fast read capability allows scanning the complete NDEF message with only one FAST_READ command, therefore reducing the overhead in high throughput production environments
- The RF performance allows for more flexibility in the choice of shape, dimension and material of form factors

1.3 Security

- EAL3+ AVA.VAN.2 Common Criteria certification
- Secure Unique NFC (SUN) message authentication for data authenticity and integrity protection
- Automatic NFC Tap Counter, which counts each tap
- NXP programmed 7-byte UID for each device
- Pre-programmed Capability Container with one time programmable bits
- Field programmable read-only locking function
- Pre-programmed ECC-based originality signature with an option to customize and permanently lock
- 32-bit password protection to prevent unauthorized memory access

Note: NTAG 223 DNA SD comes with an external CC EAL3+ certification targeting basic attack potential (AVA_VAN.2). Hence, the contactless IC does not claim to be completely resistant. In case of broader protection is required, products with a higher security certification should be considered.

1.4 NFC Forum Tag 2 Type compliance

NTAG 223 DNA SD IC provides full compliance with the NFC Forum Tag 2 Type technical specification (see [2]) and enables NDEF data structure (see [3]).

1.5 Anti-collision

An anti-collision function allows operating more than one tag in the field simultaneously. The anti-collision algorithm selects each tag individually. It ensures that the execution of a transaction with a selected tag is performed correctly without interference from another tag in the field.

2 Features and benefits

- Contactless transmission of data and supply energy
- Operating frequency of 13.56 MHz
- Data transfer of 106 kbit/s
- Data integrity of 16-bit CRC, parity, bit coding, bit counting
- Operating distance up to 100 mm (depending on various parameters as e.g. field strength and antenna geometry)
- 7-byte serial number (cascade level 2 according to ISO/IEC 14443-3)
- Automatic NFC counter triggered at the first read command after a reset
- StatusDetect feature which can be used in different modes
  - Conductive Tag Tamper, detecting if the tamper loop is open at startup
  - Capacitive Tag Tamper, detecting if the connected capacitance is outside the user-defined value range at start-up
  - Capacitive measurement, providing parameters to calculate the connected capacitance out of the measured values
- Secure Unique NFC (SUN) message authentication feature implemented via ASCII mirroring of the UID, NFC counter, Tag Tamper information and CMAC into the NDEF message in the user memory, which changes on every readout after a reset
- ECC-based originality signature, offering the option to customize and permanently lock the signature
- Fast read command
- True anti-collision
- 50 pF input capacitance

2.1 EEPROM

- 240 bytes organized in 60 pages with 4 bytes per page
- 144 bytes freely available user Read/Write area (36 pages)
- 4 bytes initialized capability container with one time programmable access bits
- Field programmable read-only locking function per page for the first 16 pages
- Field programmable read-only locking function above the first 16 pages per double page
- Configurable memory access password protection with optional limit of unsuccessful attempts
- Anti-tearing support for capability container (CC), lock bits and NFC counter
- Pre-programmed ECC-based originality signature, offering the possibility for customizing and permanently locking the signature
- Data retention time of 10 years
- Write endurance 100.000 cycles

3 Applications

NTAG 223 DNA StatusDetect tag ICs offer multi-layered protection to expand the reach of smart, trusted IoT objects.

- **Advanced anti-counterfeiting protection**
  Reliably verify authenticity of physical goods, anytime, anywhere using an NFC enabled phone. Also consider automated authentication of NFC tagged consumables and parts in embedded devices.
- **Improved supply chain visibility and control**
  Visibly help track products along the supply chain, and reduce grey market diversion and other fraud. Enable more transparent and secure supply chains.
- **Enhanced tamper detection**
  Detect whether a product has been interfered or opened prior to sales or usage. While conductive tamper evidence can protect labels or seals affixed to products, capacitive tamper evidence is better suited for integration into physical form factors e.g., closures.
- **Quality assurance through simple battery-free sensing**
  Ensure product quality remains intact, or capture and interpret digital sensing data, such as moisture or fill level, for varied healthcare, retail, and industrial applications.
- **Augmented user experiences**
  Use status awareness to prompt targeted messages, e.g. pre-/post-retail. Evolve the user experience by engaging with greater personalization, e.g. with tap-unique content and exclusive loyalty rewards.

4 Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_i	input frequency		-	13.56	-	MHz
C_i	input capacitance	T_{amb} = 22 °C, f_i = 13.56 MHz, 2.2 V RMS	-	50.0	-	pF
EEPROM characteristics						
t_{ret}	retention time	T_{amb} = 22 °C	10	-	-	year
$N_{endu(W)}$	write endurance	T_{amb} = 22 °C	100000	-	-	cycle

5 Ordering information

Table 2. Ordering information

Type number	Package		
	Name	Description	Version
NT2H2331S0DUD	FFC Bump	8 inch wafer, 120µm thickness, on film frame carrier, electronic fail die marking according to SECS-II format, Au bumps, 144 bytes user memory, 50 pF input capacitance	-

6 Block diagram

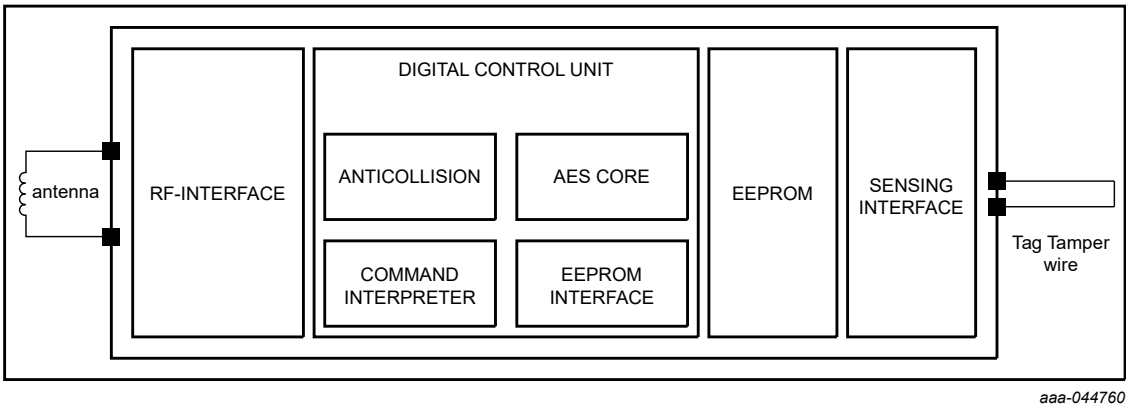


Figure 3. Block diagram of NTAG 223 DNA SD with Tag Tamper wire

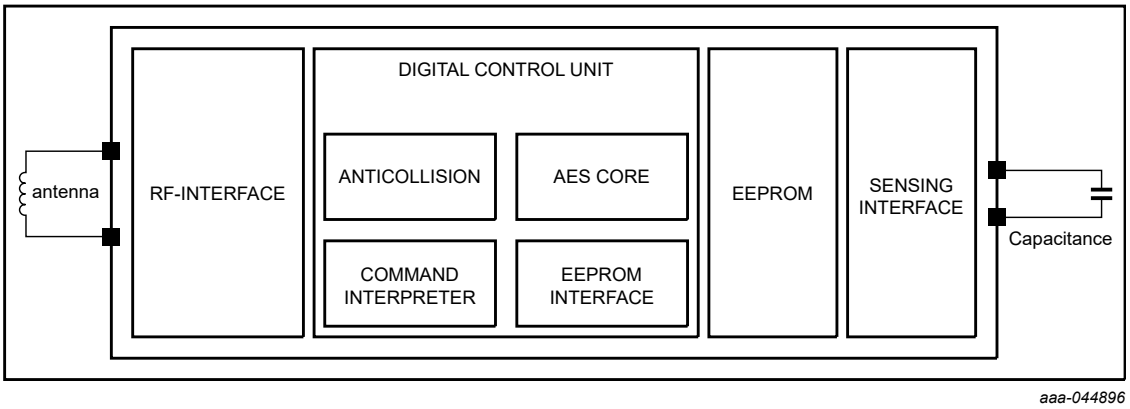


Figure 4. Block diagram of NTAG 223 DNA SD with capacitance

7 Pinning information

7.1 Pinning

The pinning of the NTAG 223 DNA SD wafer delivery is shown in section "Bare die outline" (see Section 14).

Table 3. Pin allocation table

Pin	Symbol	
LA	LA	Antenna connection LA
LB	LB	Antenna connection LB
DP	DP	Detection Pin
GND	GND	Ground

8 Functional description

8.1 Block description

NTAG 223 DNA SD ICs consist of a 240 bytes EEPROM, RF interface, Digital Control Unit (DCU) and sensing interface. Energy and data are transferred via an antenna consisting of a coil with a few turns which is directly connected to NTAG 223 DNA SD.

For tag tamper feature, a wire or capacitance needs to be connected to DP and GND pin.

No further external components are necessary. Refer to [4] for details on antenna design.

- RF interface:
  - modulator/demodulator
  - rectifier
  - clock regenerator
  - Power-On Reset (POR)
  - voltage regulator
- Anti-collision
- Command interpreter: processes memory access commands supported by the NTAG 223 DNA SD
- Crypto coprocessor: Advanced Encryption Standard (AES)
- EEPROM interface
- NTAG 223 DNA SD EEPROM : 240 bytes, organized in 60 pages of 4 bytes per page.
  - 10 bytes reserved for manufacturer data
  - 6 bytes used for the read-only locking mechanism and RFUI
  - 4 bytes available as capability container
  - 144 bytes user programmable read/write memory
  - 16 byte AES key
  - 60 bytes of configuration data and RFUI
- Sensing interface detection of open/closed status based on tag tamper wire or measurement of parameters to calculate the connected capacitance.

8.2 RF interface

The RF-interface is based on the ISO/IEC 14443 Type A standard.

During operation, the NFC device generates an RF field. The RF field must always be present with short pauses for data communication. It is used for both communication and as power supply for the tag.

For both directions of data communication, there is one start bit at the beginning of each frame. Each byte is transmitted with an odd parity bit at the end except for REQA and WUPA commands. The LSB of the byte with the lowest address of the selected block is transmitted first.

For a multi-byte parameter, the least significant byte is always transmitted first. As an example, when reading from the memory using the READ command, byte 0 from the addressed block is transmitted first. It is then followed by bytes 1 to byte 3 out of this block. The same sequence continues for the next block and all subsequent blocks.

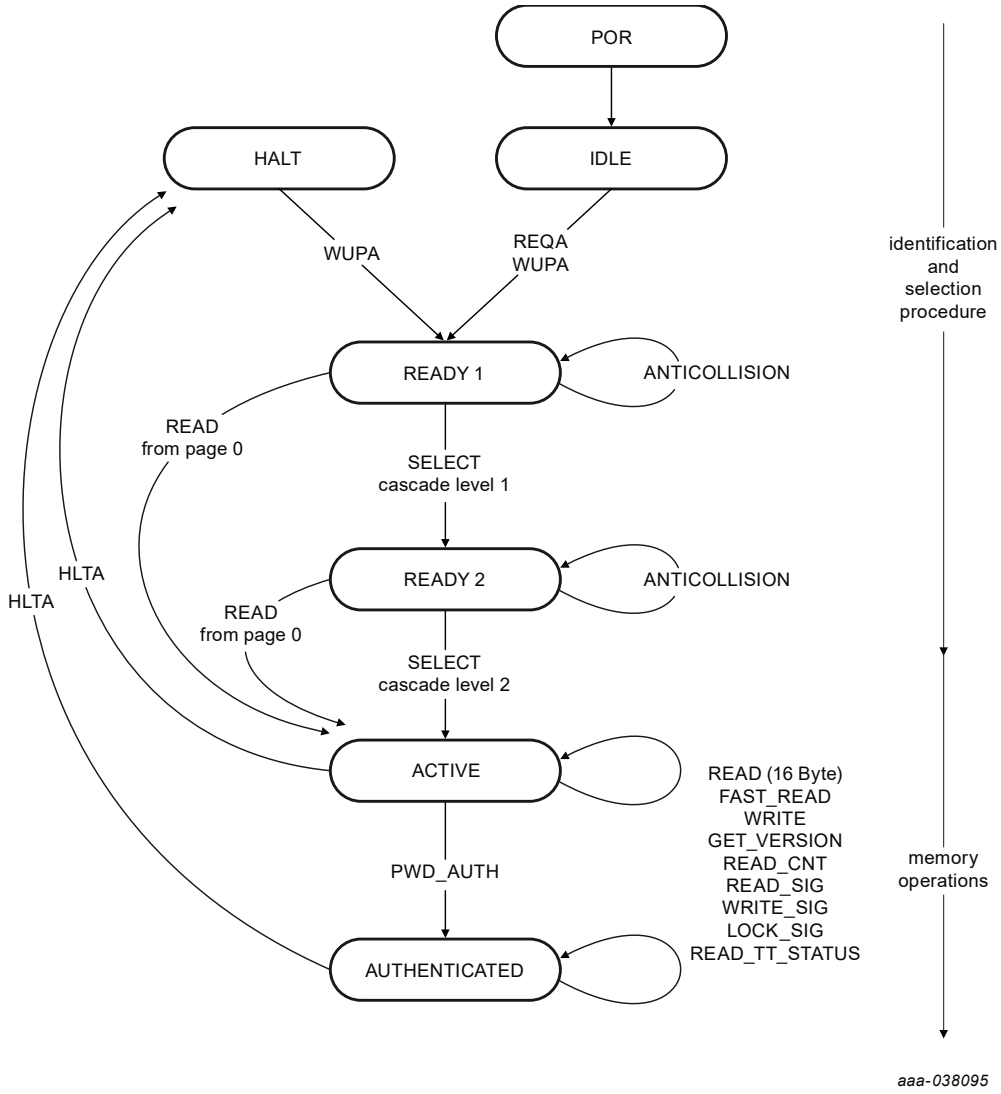
8.3 Data integrity

Following mechanisms are implemented in the contactless communication link between NFC device and NTAG to ensure very reliable data transmission:

- Bit count checking and bit coding to distinguish between "1", "0" and no information
- NAK1 response on user commands in case of parity or CRS error
- Parity bits for each byte
- 16-bit Cyclic Redundancy Check (CRC) according to ISO/IEC 14443-3, see [1], calculated over all preceding bytes in the same communication frame
- Channel monitoring (protocol sequence and bit stream analysis)
- Secure Unique NFC (SUN) CMAC mirror to protect the data integrity of the mirrored UID, NFC counter and Tag Tamper information

8.4 Communication principle

The NFC device initiates the commands and the Digital Control Unit of the NTAG 223 DNA SD decodes them. The command response is depending on the state of the IC and for memory operations also on the access conditions valid for the corresponding page.



Remark: In all states, the command interpreter returns to the idle state on receipt of an unexpected command. If the IC was previously in the HALT state, it returns to that state.

Figure 5. State diagram

8.4.1 IDLE state

After a reset, NTAG 223 DNA SD switches to the IDLE state. It only exits this state when a REQA or a WUPA command is received from the NFC device. Any other data received in this state is interpreted as an error and NTAG 223 DNA SD remains in the IDLE state.

After correctly executed HLTA command out of the ACTIVE or AUTHENTICATED state, the default waiting state changes from the IDLE state to the HALT state. This state can then be exited with a WUPA command or by a reset only.

8.4.2 READY1 state

In this state, the NFC device resolves the first part of the UID (3 bytes) using the ANTICOLLISION or SELECT commands in cascade level 1. This state is correctly exited after execution of either of the following commands:

- SELECT command from cascade level 1: the NFC device switches NTAG 223 DNA SD into READY2 state where the second part of the UID is resolved.
- READ command (from address 0): all anti-collision mechanisms are bypassed and the NTAG 223 DNA SD switches directly to the ACTIVE state.

Remark: The response of NTAG 223 DNA SD to the cascade level 1 SELECT command is a byte with b3 set to 1. In accordance with ISO/IEC 14443, this bit indicates that the anti-collision cascade procedure has not yet finished.

If more than one NTAG is in the NFC device field, a READ command from address 0 selects all NTAG 223 DNA SD devices. In this case, a collision occurs due to different serial numbers. Any other data received in the READY1 state is interpreted as an error and depending on its previous state NTAG 223 DNA SD returns to the IDLE or the HALT state.

8.4.3 READY2 state

In this state, NTAG 223 DNA SD supports the NFC device in resolving the second part of its UID (4 bytes) with the cascade level 2 ANTICOLLISION command. This state is usually exited using the cascade level 2 SELECT command.

Alternatively, READY2 state can be skipped using a READ command (from address 0) as described for the READY1 state.

Remark: The response of NTAG 223 DNA SD to the cascade level 2 SELECT command is the Select Acknowledge (SAK) byte. In accordance with ISO/IEC 14443, this byte indicates if the anti-collision cascade procedure has finished. NTAG 223 DNA SD is now uniquely selected and only this device communicates with the NFC device even when other contactless devices are present in the NFC device field.

If more than one NTAG 223 DNA TT is in the NFC device field, a READ command from address 0 selects all NTAG 223 DNA SD devices. In this case, a collision occurs due to the different serial numbers.

Any other data received when the device is in state READY2 is interpreted as an error. Depending on its previous state, the NTAG 223 DNA SD returns to either the IDLE state or the HALT state.

8.4.4 ACTIVE state

Some memory operations and other functions like the originality signature read-out can be operated in the ACTIVE state.

The ACTIVE state is exited with the HLTA command. Upon reception of an HLTA command, the NTAG 223 DNA SD transits to the HALT state. An invalid command received when the device is in this state is interpreted as an error. Depending on its previous state, NTAG 223 DNA SD returns to either the IDLE state or the HALT state.

NTAG 223 DNA SD transits to the AUTHENTICATED state after successful password verification using the PWD_AUTH command.

8.4.5 AUTHENTICATED state

In this state, also operations on memory pages, which are configured as password protected, can be accessed on top of the operation that is allowed in ACTIVE state on pages that are not access protected.

The AUTHENTICATED state is exited with the HLTA command and upon reception NTAG 223 DNA SD transits to the HALT state. An invalid command received when the device is in this state is interpreted as an error. Depending on its previous state, NTAG 223 DNA SD returns to either the IDLE state or the HALT state.

8.4.6 HALT state

HALT and IDLE states constitute the two wait states implemented in NTAG 223 DNA SD. An already processed NTAG 223 DNA SD can be set into the HALT state using the HLTA command. In the anti-collision phase, this state helps the NFC device to distinguish between processed tags and tags yet to be selected. NTAG 223 DNA SD can only exit this state on execution of the WUPA command or reset. Any other data received when the device is in this state is interpreted as an error and NTAG 223 DNA TT state remains unchanged.

8.5 Memory organization

The EEPROM memory is organized in pages with 4 bytes per page. NTAG 223 DNA SD has 60 pages in total. The memory organization can be seen in Table 4, and the functionality of the different memory sections is described in the following sections.

Table 4. Memory organization NTAG 223 DNA SD

<table>
<tr><th colspan="2">Page Adr</th><th colspan="4">Byte number within a page</th><th rowspan="2">Description</th></tr>
<tr><th>Dec</th><th>Hex</th><th>0</th><th>1</th><th>2</th><th>3</th></tr>
<tr><td>0</td><td>0h</td><td colspan="4">serial number</td><td rowspan="3">Manufacturer data and static lock bits</td></tr>
<tr><td>1</td><td>1h</td><td colspan="4">serial number</td></tr>
<tr><td>2</td><td>2h</td><td>serial number</td><td>internal</td><td>lock bits</td><td>lock bits</td></tr>
<tr><td>3</td><td>3h</td><td colspan="4">Capability Container CC</td><td>Capability Container</td></tr>
<tr><td>4</td><td>4h</td><td colspan="4" rowspan="5">user memory</td><td rowspan="5">user memory</td></tr>
<tr><td>5</td><td>5h</td></tr>
<tr><td>...</td><td></td></tr>
<tr><td>38</td><td>26h</td></tr>
<tr><td>39</td><td>27h</td></tr>
<tr><td>40</td><td>28h</td><td colspan="3">dynamic lock bits</td><td>RFUI</td><td>Dynamic lock bits</td></tr>
<tr><td>41</td><td>29h</td><td colspan="4">CFG_0</td><td rowspan="7">Configuration pages</td></tr>
<tr><td>42</td><td>2Ah</td><td colspan="4">CFG_1</td></tr>
<tr><td>43</td><td>2Bh</td><td colspan="4">PWD</td></tr>
<tr><td>44</td><td>2Ch</td><td colspan="2">PACK</td><td colspan="2">RFUI</td></tr>
<tr><td>45</td><td>2Dh</td><td>SUNCMAC_CFG</td><td colspan="3">RFUI</td></tr>
<tr><td>46</td><td>2Eh</td><td>TT_CTT_CFG</td><td colspan="3">RFUI</td></tr>
<tr><td>47</td><td>2Fh</td><td colspan="3">NFC_CNT_LIM</td><td>RFUI</td></tr>
</table>

Table 4. Memory organization NTAG 223 DNA SD*...continued*

Page Adr		Byte number within a page				Description
Dec	Hex	0	1	2	3	
48	30h	RFUI				
...	...					
51	33h					
52	34h	SUNCMAC_KEY				
52	35h					
54	36h					
55	37h					
56	38h	CTT_CFG_0				
57	39h	CTT_CFG_1				
58	3Ah	RFUI				
59	3Bh	RFUI				

The structure of manufacturing data, lock bytes, capability container and user memory pages are compatible to NTAG 213 and NTAG 213 TT.

8.5.1 UID/serial number

The unique 7-byte serial number (UID) and its two check bytes are programmed into the first 9 bytes of memory: It covers page addresses 00h, 01h and the first byte of page 02h. The second byte of page address 02h is reserved for internal data. These bytes are programmed and write protected in the production test.

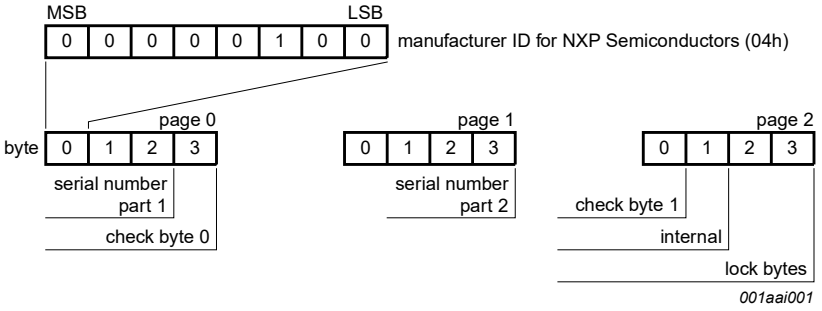


Figure 6. UID/serial number

In accordance with ISO/IEC 14443-3, check byte 0 (BCC0) is defined as CT ⊕ SN0 ⊕ SN1 ⊕ SN2. Check byte 1 (BCC1) is defined as SN3 ⊕ SN4 ⊕ SN5 ⊕ SN6.

SN0 holds the Manufacturer ID for NXP Semiconductors (04h) in accordance with ISO/IEC 14443-3.

8.5.2 Static lock bytes

The bits of byte 2 and byte 3 of page 02h represent the field programmable read-only locking mechanism. Each page from 03h (CC) to 0Fh can be individually locked by

setting the corresponding locking bit Lx to logic 1 to prevent further write access. The locked page becomes read-only memory.

The three least significant bits of lock byte 0 are the block-locking bits. Bit 2 deals with pages 0Ah to 0Fh, bit 1 deals with pages 04h to 09h and bit 0 deals with page 03h (CC). Once the block-locking bits are set, the locking configuration for the corresponding memory area is frozen.

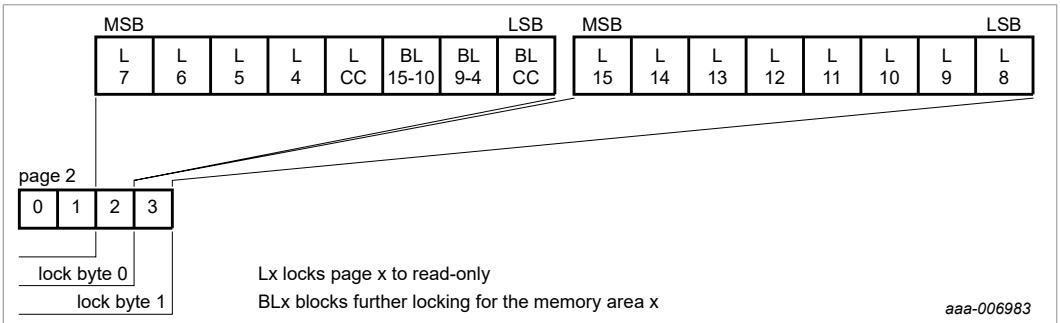


Figure 7. Static lock bytes 0 and 1 (page addresses are decimal)

For example if BL15-10 is set to logic 1, then bits L15 to L10 (lock byte 1, bit[7:2]) can no longer be changed. A WRITE command to block 02h, sets the static locking and block-locking bits. Data bytes 2 and 3 of the WRITE command, and the contents of the actual lock bytes stored in the memory, are a bit-wise OR. The result becomes the new content of the lock bytes. This process is irreversible. If a bit is set to logic 1, it cannot be changed back to logic 0.

The content of bytes 0 and 1 of page 02h is unaffected by the corresponding data bytes of the WRITE command.

The default value of the static lock bytes is 00 00h.

Any write operation to the static lock bytes is tearing-proof.

8.5.3 Dynamic Lock Bytes

To lock the pages of NTAG 223 DNA SD starting at page address 10h until page 27h, so called dynamic lock bytes are used. Dynamic lock bytes are located at page 28h. Three lock bytes cover the memory area of 96 data bytes. The granularity of one lock bit is 2 pages for NTAG 223 DNA SD (Figure 8). The programming of dynamic lock bits is irreversible. If a bit is set to logic 1, it cannot be changed back to logic 0.

Remark: It is recommended to set all bits marked with RFUI to 0, when writing to the dynamic lock bytes.

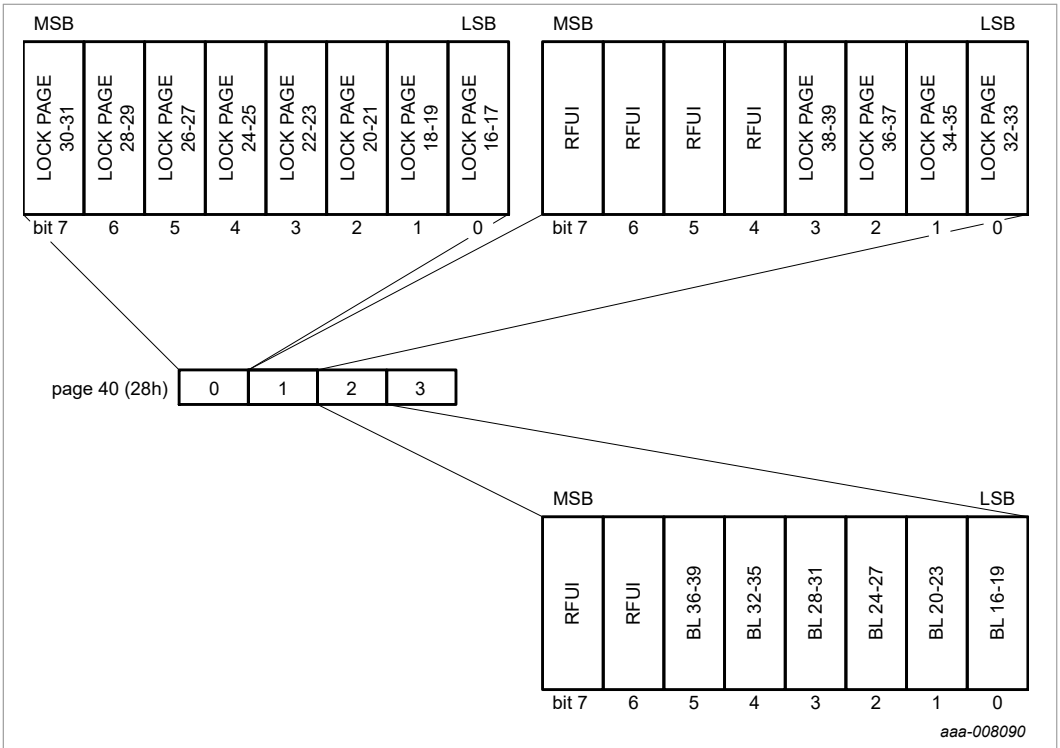


Figure 8. NTAG 223 DNA SD Dynamic lock bytes 0, 1 and 2 (page addresses are decimal)

The default value of the dynamic lock bytes is 00 00 00h. The value of byte 3 is always 00h when read.

Any write operation to the dynamic lock bytes is tearing-proof.

8.5.4 Capability Container (CC bytes)

The Capability Container CC (page 3) is programmed during the IC production according to the NFC Forum Type 2 Tag specification (see [2]). These bytes may be modified by a WRITE command.

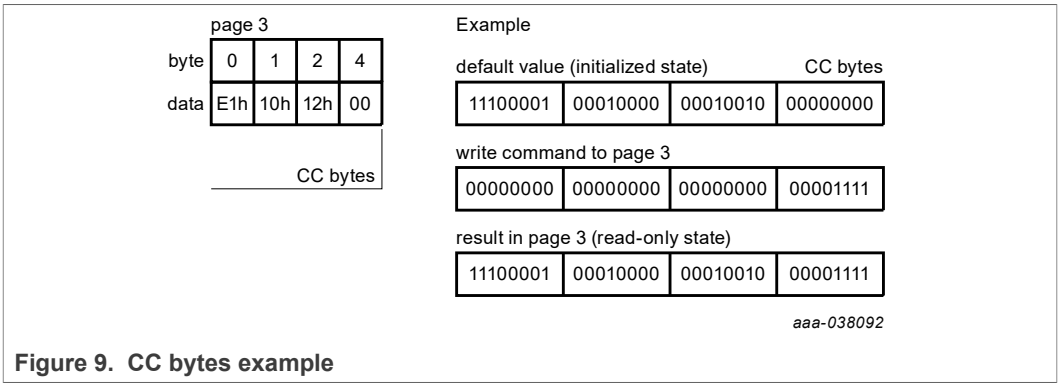


Figure 9. CC bytes example

The parameter bytes of the WRITE command and the current contents of the CC bytes are bit-wise OR'ed. The result is the new CC bytes content. This process is irreversible and once a bit is set to logic 1, it cannot be changed back to logic 0.

Byte 2 in the capability container defines the available memory size for NDEF messages. The configuration at delivery is shown in Table 5.

Table 5. NDEF memory size

IC	Value in byte 2	NDEF memory size
NTAG 223 DNA SD	12h	144 bytes

Any write operation to the CC bytes is tearing-proof.

The default values of the CC bytes at delivery are defined in Section 8.5.6.

8.5.5 Data pages

Pages 04h to 27h for NTAG 223 DNA SD are the 144 byte user memory read/write area.

The access to a part of the user memory area can be restricted using a password verification. See Section 8.10 for further details.

The default values of the data pages at delivery are defined in Section 8.5.6.

8.5.6 Memory content at delivery

The capability container in page 03h and the data pages 04h and 05h of NTAG 223 DNA SD are pre-programmed as defined in Table 6.

Table 6. Memory content at delivery NTAG 223 DNA TT

Page Address	Byte number within page			
	0	1	2	3
03h	E1h	10h	12h	00h
04h	01h	03h	A0h	0Ch
05h	34h	03h	00h	FEh

The default content of the data pages from page 06h and onwards is not defined at delivery.

8.5.7 Configuration pages

Pages 29h to 3Bh for NTAG 223 DNA SD are used to configure the memory access restriction, to configure the ASCII mirror feature and tag tamper feature for galvanic or capacitive measurement. The location of the configuration elements is defined in Table 7.

Table 7. Configuration Pages

Page Address		Byte number			
Dec	Hex	0	1	2	3
41	29h	CFG_B0	TT	MIRROR_PAGE	AUTH0
42	2Ah	CFG_B1	RFUI	AUTHLIM0	AUTHLIM1
43	2Bh	PWD			
44	2Ch	PACK		RFUI	RFUI
45	2Dh	CMAC_CFG	RFUI	RFUI	RFUI

Table 7. Configuration Pages*...continued*

Page Address		Byte number			
Dec	Hex	0	1	2	3
46	2Eh	TT_CTT_CFG	RFUI	RFUI	RFUI
47	2Fh	NFC_CNT_LIM			RFUI
48	30h	RFUI			
49	31h				
50	32h				
51	33h				
52	34h	SUNCMAC_KEY			
53	35h				
54	36h				
55	37h				
56	38h	CTT_DIFF_LIMIT	RFUI		
57	39h	CTT_DIFF_CAL	CTT_UPPER_LIMIT	CTT_LOWER_LIMIT	RFUI
58	3Ah	RFUI	RFUI	RFUI	RFUI
59	3Bh	RFUI	RFUI	RFUI	RFUI

Table 8. CFG_B0 configuration byte

Bit number							
7	6	5	4	3	2	1	0
MIRROR_EN	CTT_CFILT		MIRROR_BYTE		TT_MEAS_INVLD	RFUI	RFUI

Table 9. TT (Tag Tamper) configuration byte

Bit number							
7	6	5	4	3	2	1	0
MEAS_DBL_RANGE	CTT_CURR_TRIM					RTT_CTT_SEL	CTT_SHOW_VALUE

Table 10. User memory protection AUTH0 configuration byte

Bit number							
7	6	5	4	3	2	1	0
RFUI	AUTH0 [6:0]						

Table 11. CFG_B1 configuration byte

Bit number							
7	6	5	4	3	2	1	0
PROT	LOCK_ USR_CFG	RTT_ TEST_EN	NFC_ CNT_EN	RFUI	RFUI	SHOW_ STORED_ TT_ STATUS	SHOW_ ACT_TT_ STATUS

Table 12. AUTHLIM0 configuration byte

Bit number							
7	6	5	4	3	2	1	0
AUTH_LIM [7:0]							

Table 13. AUTHLIM1 configuration byte

Bit number							
7	6	5	4	3	2	1	0
RFUI						AUTH_ LIM [9]	AUTH_ LIM [8]

Table 14. CMAC_CFG configuration byte

Bit number							
7	6	5	4	3	2	1	0
LOCK_ SUNCMAC_ KEY	RFUI	BLOCK_ LOCK_ KEY	RFUI				

Table 15. TT_CTT_CFG configuration byte

Bit number							
7	6	5	4	3	2	1	0
STORE_ TT_ STATUS	LOCK_ CTT_CFG	BLOCK_ LOCK_TT	RFUI				

Table 16. Configuration parameter descriptions

Field	Bit	Values at delivery	Description
MIRROR_EN	1	0b	Enables or disables the ASCII mirror functionality, if a valid MIRROR_PAGE address is set. This bit can be changed if LOCK_USR_CFG is not set. 0b ... ASCII mirror disabled 1b ... UID, NFC counter, TT and CMAC ASCII mirror enabled

Table 16. Configuration parameter descriptions*...continued*

Field	Bit	Values at delivery	Description
CTT_CFILT	2	00b	CTT_CFILT allows to add an internal capacitor to DP and GND pin. This functionality can only be used if RTT_CTT_SEL bit is set (CTT mode). This functionality can be used if the external connected capacitor is small and the trim value after calibration is below 20 (decimal) in case of normal measurement range (MEAS_DBL_RANGE is not set). These bits can be changed if LOCK_USR_CFG is not set. 00b … 0 pF 01b … 1 pF 10b … 2 pF 11b … 3 pF
MIRROR_BYTE	2	00b	2 bits define the byte position within the page defined by the MIRROR_PAGE address (beginning of mirror) where the ASCII mirror shall begin. These bits can be changed if LOCK_USR_CFG is not set.
TT_MEAS_ INVLD	1	0b	TT_MEAS_INVLD bit defines how the Tag Tamper status shall be indicated in case of an invalid CTT measurement (e.g. DP and GND are connected). This bit can be changed if LOCK_USR_CFG is not set. 0b ... Invalid CTT measurement is indicated as TAMPERED and stored permanently if the STORE_TT_STATUS bit is set 1b ... Invalid CTT measurement is indicated as INVALID
MEAS_DBL_ RANGE	1	0b	MEAS_DBL_RANGE bit set to 1 doubles the current defined in CTT _CURR_ TRIM for measurement in CTT mode. This bit can be changed if LOCK_USR_ CFG is not set. 0b ... current as defined by CTT _CURR_TRIM 1b ... current defined by CTT _CURR_TRIM will be doubled
CTT_CURR_ TRIM	5	01111b	CTT_CURR_TRIM defines the value of the current used for Tag Tamper measurement in CTT mode. These bits can be changed if LOCK_USR_CFG is not set. 00000b … ~1 nA 11111b … ~31 nA
RTT_CTT_SEL	1	0b	Selection of Resistive (Galvanic) or Capacitive Tag Tamper (RTT or CTT) detection. This bit can be changed if LOCK_USR_CFG is not set. 0b ... Enable RTT (Resistive Tag Tamper) 1b … Enable CTT (Capacitive Tag Tamper)
CTT_SHOW_ VALUE	1	1b	CTT_SHOW_VALUE enables or disables the CTT measurement details in the Tag Tamper ASCII mirror and READ_TT_STATUS command. This bit is only valid if RTT_CTT_SEL is set (CTT enabled). This bit can be changed if LOCK_USR_ CFG is not set. 0b … Bytes TT0 to TT3 are masked with 00h. In AUTHENTICATED state, Bytes TT0 to TT3 provide the CTT details of the last measurement on READ_TT_ STATUS command 1b … Bytes TT0 to TT3 provide the CTT details of the last measurement. For bytes TT0 to TT3 containing CTT measurement details see Table 63
MIRROR_PAGE	8	00h	MIRROR_PAGE address defines the page for the beginning of the mirroring. This byte can be changed if LOCK_USR_CFG is not set. A value >03h enables the ASCII mirror feature. The maximum valid value is 1Bh. If the ASCII mirror in given communication state is exceeding the accessible user memory, the ASCII mirror is disabled.

Table 16. Configuration parameter descriptions*...continued*

Field	Bit	Values at delivery	Description
AUTH0	7	3Ch	AUTH0 defines the page address from which the password verification is required. Valid address range for byte AUTH0 is from 00h to 3Bh. If AUTH0 is set to a page address outside the valid address range, the AES authentication protection is effectively disabled, but still keeping password verification procedure working. This byte can be changed if LOCK_USR_CFG is not set.
PROT	1	1b	PROT bit is defining the type of protection of the password protected memory part assuming the AUTH0 byte value is within the range of 00h and 3Bh. This bit can be changed if LOCK_USR_CFG is not set. 0b ... write access only is protected by the password verification 1b ... read and write access is protected by the password verification
LOCK_USR_CFG	1	0b	LOCK_USR_CFG permanently locks the configuration elements in blocks 29h, 2Ah, and 2Fh after subsequent reset. If the bit is set to 1b it cannot be set back to 0b. 0b ... configuration elements in blocks 29h, 2Ah, and 2Fh are not locked 1b ... configuration elements in blocks 29h, 2Ah, and 2Fh are permanently locked
RTT_TEST_EN	1	0b	Enables or disables the RTT test option to check the internal RTT circuitry on the label/inlay. This bit can be changed if LOCK_USR_CFG is not set. 0b ... RTT normal operating mode 1b ... RTT test operating mode (TT loop internally open) The test is only valid if • RTT_CTT_SEL is not set (RTT is enabled) In that case Detection pin DP will be disconnected from the internal circuitry on the next startup of the IC and the actual Tag Tamper status on a READ_TT_STATUS shall indicated the OPEN state. If the actual Tag Tamper state is not open, the Tag Tamper feature is not working properly.
NFC_CNT_EN	1	0b	NFC_CNT_EN enables or disables the incrementation of the NFC counter. This bit can be changed if LOCK_USR_CFG is not set. 0b ... NFC counter increment disabled 1b ... NFC counter increment enabled If the NFC counter increment is enabled, the NFC counter will be automatically increased by 1 at the first READ or FAST_READ command after a reset until the limiting value is reached (refer to Section 8.7)
SHOW_STORED_TT_STATUS	1	1b	This bit defines if the stored Tag Tamper information shall be provided in the ASCII mirror and READ_TT_STATUS command. This bit can be changed if LOCK_USR_CFG is not set. 0b ... Stored Tag Tamper status is masked with 30h in the ASCII mirror and 0x0h in the READ_TT_STATUS command 1b ... Stored Tag Tamper status is provided in the ASCII mirror and the READ_TT_STATUS command
SHOW_ACT_TT_STATUS	1	1b	This bit defines if the actual Tag Tamper information shall be provided in the ASCII mirror and READ_TT_STATUS command. This bit can be changed if LOCK_USR_CFG is not set. 0b ... Actual Tag Tamper status is masked with 30h in the ASCII mirror and 0h in the READ_TT_STATUS command 1b ... Actual Tag Tamper status is provided in the ASCII mirror and the READ_TT_STATUS command

Table 16. Configuration parameter descriptions...*continued*

Field	Bit	Values at delivery	Description
AUTH_LIM	10	000h	Limitation of failed password verification attempts. Valid value range for byte AUTH_LIM is from 00h to 3FEh. AUTH_LIM can be changed if LOCK_USR_CFG is not set. 000h ... limiting of failed password verification attempts disabled 001h - 3FEh ... maximum number of failed password verification attempts
PWD	32	FFFFFFFFh	32-bit password used for memory access protection
PACK	16	0000h	16-bit password acknowledge used during the password verification process
LOCK_ SUNCMAC_KEY	1	0b	LOCK_SUNCMAC_KEY permanently locks the SUNCMAC_KEY in blocks 34h-37h. If the bit is set to 1b, it cannot be set back to 0b. 0b ... SUNCMAC_KEY in blocks 34h-37h is not locked 1b ... SUNCMAC_KEY in blocks 34h-37h is locked
BLOCK_LOCK_ KEY	1	0b	BLOCK_LOCK_KEY permanently locks the block 2Dh containing LOCK_ SUNCMAC_KEY. If the bit is set to 1b, it cannot be set back to 0b. 0b ... LOCK_SUNCMAC_KEY in block 2Dh is not locked 1b ... LOCK_SUNCMAC_KEY in block 2Dh is locked permanently
STORE_TT_ STATUS	1	0b	STORE_TT_STATUS enables the permanent storage of the Tag Tamper status as open, if a tag tamper event has been detected at startup. This bit can be changed if BLOCK_LOCK_TT is not set. If the bit is set to 1b, it cannot be set back to 0b. 0b ... TT status is not stored permanently 1b ... TT status is stored permanently as open if a tag tamper event has been detected at startup.
LOCK_CTT_ CFG	1	0b	LOCK_CTT_CFG locks the CTT user configuration elements CTT_DIFF_LIMIT in block 38h and CTT_DIFF_CAL, CTT_UPPER_LIMIT, CTT_LOWER_LIMIT in block 39h. If the bit is set to 1b, it cannot be set back to 0b. 0b … CTT user configuration elements in Block 38h and 39h are not locked 1b ... CTT user configuration elements in Block 38h and 39h are locked permanently
BLOCK_LOCK_ TT	1	0b	BLOCK_LOCK_TT locks LOCK_CTT _CFG and STORE_TT_STATUS in block 2Eh. If the bit is set to 1b, it cannot be set back to 0b 0b ... LOCK_CTT _CFG and STORE_TT_STATUS are not locked 1b ... LOCK_CTT _CFG and STORE_TT_STATUS are locked permanently
NFC_CNT_LIM	24	FFFFFFh	NFC_CNT_LIM defines the maximum value of the NFC counter (refer to Section 8.7). This bit can be changed if LOCK_USR_CFG is not set. 000000h … NFC counter limit is same as FFFFFFh 000001h - FFFFFFh … once the NFC counter has reached the NFC counter limit the counter will not be increased and will return with NAK on the first READ or FAST_READ command after a reset. After that the IC returns to theIDLE/HALT state.
SUNCMAC_KEY	128	All 0h	SUNCMAC key refers to Section 8.9
CTT_DIFF_LIMIT	8	14h	CTT_DIFF_LIMIT defines the "Measurement Difference Limit" during measurement in CTT mode. CTT_DIFF_LIMIT shall be set before the CTT measurement. This byte can be changed if LOCK_CTT_CFG is not set.
CTT_DIFF_CAL	8	00h	CTT_DIFF_CAL defines the 8-bit binary signed magnitude of calibration value of DifferenceMeasurement in CTT mode. CTT_DIFF_CAL shall be 0h at the start of Calibration (Sensor) mode. Refer to Capacitive tag tamper measurement. This byte can be changed if LOCK_CTT_CFG is not set.

Table 16. Configuration parameter descriptions*...continued*

Field	Bit	Values at delivery	Description
CTT_UPPER_LIMIT	8	37h	CTT_UPPER_LIMIT defines the upper Tamper threshold used during tamper decision in CTT mode as maximum difference between calibration measurement counter value and capacitive tamper measurement counter value. CTT_UPPER_LIMIT shall be set before STORE_TT_STATUS is enabled. This byte can be changed if LOCK_CTT_CFG is not set.
CTT_LOWER_LIMIT	8	37h	CTT_LOWER_LIMIT defines the lower Tamper threshold used during tamper decision in CTT mode as maximum difference between calibration measurement counter value and capacitive tamper measurement counter value. CTT_LOWER_LIMIT shall be set before STORE_TT_STATUS is enabled. This byte can be changed if LOCK_CTT_CFG is not set.
RFUI	-	not defined	Reserved for future use

Remark: The LOCK_USR_CFG, LOCK_SUNCMAC_KEY, BLOCK_LOCK_KEY, LOCK_CTT_CFG, BLOCK_LOCK_TT bits activate the permanent write protection of the corresponding configuration memory sections. If write protection is enabled, each write attempt to locked elements leads immediately to a NAK response.

8.6 StatusDetect feature

The tag tamper functionality allows two modes of operation:

- Galvanic (Resistive) Tag Tamper mode (refer to Section 8.6.1)
  In the galvanic Tag Tamper mode, the NTAG 223 DNA SD is checking the status of connected wire between DP and GND during start-up of the IC.
- Capacitive Tag Tamper mode (refer to Section 8.6.2)
  In the capacitive Tag Tamper mode, the NTAG 223 DNA SD is measuring parameters during the start-up of the IC of the connected capacitance between DP and GND. This mode also includes the Capacitive Sensor mode (refer to Section 8.6.3)

The StatusDetect mode of operation is stored in EEPROM in the configuration word, only one mode can be active, the mode can be changed until the configuration is locked.

The permanent storage of the tamper status during power-up of the IC is activated by setting a bit in the configuration register, as long this bit is not set there is no permanent storage of the tamper status.

8.6.1 Galvanic Tag Tamper

NTAG 223 DNA SD features a Galvanic (Resistive) Tag Tamper function. Once Galvanic Tag Tamper mode of of the StatusDetect feature is enabled RTT_CTT_SEL bit set to 0b), NTAG 223 DNA SD detects at the start-up of the IC, if the tag tamper wire is open or closed.

In case of detecting an open tag tamper wire after the NTAG 223 DNA SD tag is powered by an RF field and STORE_TT_STATUS is set to 1, this open status will be permanently stored in the IC.

The Tag Tamper status can be read with

- READ_TT_STATUS command (see Section 10.10) or
- ASCII mirror feature including the Tag Tamper status (see Section 8.8.3).

If the tag tamper wire has never been detected as open during start-up and SHOW_ STORED_TT_STATUS (see Section 8.5.7) is enabled:

- The READ_TT_STATUS command responds with TTS bits 7-4 as 3h
- If the Tag Tamper ASCII mirror is enabled, the TTS bits 7-4 mirror byte will show 43h (ASCII "C")

Once the tag tamper wire has been detected as open during start-up and STORE_TT_STATUS is enabled:

- NTAG 223 DNA SD stores permanently that the tag tamper wire has been opened
- On a READ_TT_STATUS command, the NTAG 223 DNA SD responds with TTS bits 7-4 as Fh if SHOW_ STORED_TT_STATUS is enabled
- If the Tag Tamper ASCII mirror and SHOW_ STORED_TT_STATUS is enabled, the stored TTS mirror byte will show 4Fh (ASCII "O") (see Section 8.8)

If the actual Tag Tamper status is closed and SHOW_ACT_TT_STATUS (see Section 8.5.7) is enabled

- The READ_TT_STATUS command responds with TTS bits 3-0 as 3h
- If the Tag Tamper ASCII mirror is enabled, the actual TTS mirror byte will show 43h (ASCII "C")

If the actual Tag Tamper status is open and SHOW_ACT_TT_STATUS (see Section 8.5.7) is enabled

- The READ_TT_STATUS command responds with TTS bits 3-0 as Fh
- If the Tag Tamper ASCII mirror is enabled, the actual TTS mirror byte will show 4Fh (ASCII "O")

If the actual Tag Tamper status is an invalid measurement

- The READ_TT_STATUS command responds with TTS bits 3-0 as 9h
- If the Tag Tamper ASCII mirror is enabled, the actual TTS mirror byte will show 49h (ASCII "I")

Parameters on the detection for open and closed of the tag tamper wire connected to DP and GND pad are specified in Section 12.

Remark: To avoid interferences induced by the RF field during the measurement of the tag tamper, it is recommended to keep the area covered by the tag tamper wire connected to DP and GND as small as possible. The area may not be larger than 2.5 cm^2 depending on the RF field strength used in the application under worst case conditions.

8.6.2 Capacitive Tag Tamper

Once Capacitive Tag Tamper mode of the StatusDetect feature is enabled the Capacitive Tag Tamper status is measured at each power-up of the IC. If permanent storage is enabled with the STORE_TT_STATUS bit, the status is permanently stored as tampered in EEPROM in case the difference between the measured capacitor value and the calibrated value exceeds the defined limits. The limits to detect a tamper event in the capacity tag tamper mode are defined with the upper limit in byte CTT_UPPER_LIMIT and the lower limit in byte CTT_LOWER_LIMIT.

To measure the external capacitor connected to DP and GND, the external capacitor is charged with the measurement current. In parallel, an internal capacitor is charged with a fixed current. In order to achieve the highest accuracy the charging time of the

internal and external capacitor should be in a similar range. The DifferenceMeasurement is providing a signed value indicating the difference between the internal and external capacitor measurement. This is done by optimizing the measurement current CTT_CURR_TRIM during calibration in the Capacitive Tag Tamper mode or by choosing the optimum CTT_CURR_TRIM value based on the expected capacitor value in the capacitive sensor mode so that the DifferenceMeasurement value (stored in CTT_DIFF_CAL after calibration) becomes a minimum. After the calibration, the final DifferenceMeasurement value needs to be written CTT_DIFF_CAL after calibration (see [8]).

The charging times are measured with counters.

The Capacitive Tag Tamper calibration is necessary for the initialization of the Capacitive Tag Tamper functionality during production in the final application. The calibration measurement delivers a reference result which must be stored in the EEPROM. This reference result is used for detection of a Tag Tamper event at the start-up and stores this information permanently if the STORE_TT_STATUS bit is enabled.

Details on the calibration are provided in an Application Note (see [8]).

At each start-up, the NTAG 223 DNA SD executes the capacitance measurement with the calibrated values. If the maximum difference between calibration measurement counter value and capacitive tamper measurement counter value exceeds the CTT_LOWER_LIMIT or the CTT_UPPER_LIMIT, the NTAG 223 DNA TT detects a tag tamper event. Detailed setting of CTT_LOWER_LIMIT and CTT_UPPER_LIMIT are provided in an Application Note (see [8]).

The Tag Tamper status can be read with

- READ_TT_STATUS command or
- ASCII mirror feature including the Tag Tamper status (see Section 8.8.3).

If no tag tamper event has been detected during start-up and SHOW_ STORED_TT_STATUS (see Section 8.5.7) is enabled:

- The READ_TT_STATUS command response with TTS bits 7-4 as 3h
- If the Tag Tamper ASCII mirror is enabled, the TTS bits 7-4 mirror byte will show 43h (ASCII "C")

Once the tag tamper event has been detected during start-up and STORE_TT_STATUS is enabled:

- NTAG 223 DNA SD stores permanently that the tag tamper event has been detected
- On a READ_TT_STATUS command, the NTAG 223 DNA SD responds with TTS bits 7-4 as Fh if SHOW_ STORED_TT_STATUS is enabled
- If the Tag Tamper ASCII mirror and SHOW_ STORED_TT_STATUS is enabled, the stored TTS mirror byte will show 4Fh (ASCII "O") (see Section 8.8.3)

If the actual Tag Tamper status is closed and SHOW_ACT_TT_STATUS (see Section 8.5.7) is enabled

- The READ_TT_STATUS command response with TTS bits 3-0 as 3h
- If the Tag Tamper ASCII mirror is enabled, the actual TTS mirror byte will show 43h (ASCII "C")

If the actual Tag Tamper status is open

- The READ_TT_STATUS command response with TTS bits 3-0 as Fh

- If the Tag Tamper ASCII mirror is enabled, the actual TTS mirror byte will show 4Fh (ASCII "O")

If the actual Tag Tamper status is an invalid measurement

- The READ_TT_STATUS command responds with TTS bits 3-0 as 9h
- If the Tag Tamper ASCII mirror is enabled, the actual TTS mirror byte will show 49h (ASCII "I")

If CTT_SHOW_VALUE is enabled, the capacitance measurement parameters are mirrored by the ASCII mirror or can be read with the READ_TT_STATUS command.

8.6.3 Capacitive sensor mode

The capacitive sensor mode works similar to the Capacitive Tag Tamper mode, but in this mode the CTT_UPPER_LIMIT, CTT_LOWER_LIMIT and STORE_TT_STATUS are not required if Capacitive Tag Tamper functionality is not needed.

In the capacitive sensor mode, the NTAG 223 DNA SD is executing a measurement of the connected capacitance with the defined parameters (for details see [8]).

The most accurate measurement is achieved following the procedure similar to the calibration of the capacitive tag tamper by adjusting the measurement current. Details on the procedure are provided in an Application Note (see [8]).

After the calibration procedure with the initial capacitance (see [8]), the capacitance can be calculated with the following formula:

C = ((0.977 * (1 + CTT_CURR_TRIM)*(1 + MEAS_DBL_RANGE * 1.45) * (CounterValue2_ext * 1/3.39) / 600) - CTT_CFILT (in pF)

After the calibration with the initial capacitance the values shall be stored in the configuration memory. On the following measurements at the start-up, the IC will provide the DifferenceMeasurement value, MEAS_DBL_RANGE, CTT_CURR_TRIM, CTT_CFILT with the READ_TT_STATUS command or mirrored in the user memory if ASCII mirror function is enabled.

Details on the calibration initial capacitance are provided in an Application Note (see [8]).

To calculate the difference between the calibrated and actual measurement use the following formula:

C_{diff} = ((0.977 * (1 + CTT_CURR_TRIM) * (1 + MEAS_DBL_RANGE * 1.45)) * (DifferenceMeasurement * 1/3.39) / 600)

8.7 NFC counter function

NTAG 223 DNA SD features an NFC counter function. This function enables NTAG 223 DNA SD to automatically increase the 24-bit counter value by 1, triggered by the first valid

- READ command or
- FAST-READ command

if the NFC counter value is smaller than FF FF FFh and the NFC_CNT_LIM (see Section 8.5.7) is disabled or higher than the NFC counter value after the NTAG 223 DNA SD tag is powered by an RF field.

Once the NFC counter has reached the maximum value of FF FF FFh hex or the NFC counter value is same or higher than the NFC_CNT_LIM value, the NFC counter does not increase anymore. On READ or FAST_READ after reset the NAK answer is returned and NTAG223 DNA SD becomes effectively unusable.

The NFC counter increment is enabled or disabled with the NFC_CNT_EN bit (see Section 8.5.7).

The actual NFC counter value can be read with

- READ_CNT command or
- NFC counter mirror feature

8.8 ASCII mirror function

NTAG 223 DNA SD features an ASCII mirror function. This function enables NTAG 223 DNA SD to virtually mirror

- 7 byte UID (see Section 8.5.1)
- 3 byte NFC counter value (see Section 8.7)
- 5 byte Tag Tamper information (see Section 8.6)
- 8 byte SUNCMAC

into the physical memory of the IC in ASCII code. On the READ or FAST READ command to the involved user memory pages, NTAG 223 DNA SD responds with the virtual memory content of the UID and/or NFC counter value and or Tag Tamper message in ASCII code.

The required length of the reserved physical memory for the mirror functions and the order for the ASCII mirrors is specified in Table 11. If the ASCII mirror exceeds the accessible user memory area, the data will not be mirrored.

Table 17. Required memory placeholder space for ASCII mirror

ASCII mirror and order	Required number of bytes in the physical memory
UID + NFC counter + TT message mirror + SUNCMAC	49 bytes (14 bytes for UID + 1 byte separation + 6 bytes NFC counter value + 1 byte separation + 10 bytes TT information + 1 byte separation + 16 byte SUNCMAC value)

The MIRROR_PAGE value defines the page where the ASCII mirror shall start and the MIRROR_BYTE value defines the starting byte within the defined page.

The ASCII mirror function is enabled with MIRROR_EN set to 1b and MIRROR_PAGE value >03h.

The ASCII mirror elements are separated automatically with an "x" character (78h ASCII code).

Remark: Please note that the number of bytes (see Table 17) of the ASCII mirror shall not exceed the boundary of the user memory. Therefore it is required to use only valid values for MIRROR_BYTE and MIRROR_PAGE to ensure a proper functionality. If the ASCII mirror exceeds the user memory area, the ASCII mirrors shall be disabled.

8.8.1 UID ASCII mirror function

This function enables NTAG 223 DNA SD to virtually mirror the 7 byte UID in ASCII code into the physical memory of the IC. The length of the UID ASCII mirror requires 14 bytes

to mirror the UID in ASCII code. On the READ or FAST READ command to the involved user memory pages, NTAG 223 DNA SD responds with the virtual memory content of the UID in ASCII code.

For an example see Table 20.

8.8.2 NFC counter mirror function

This function enables NTAG 223 DNA SD to virtually mirror the 3 byte NFC counter value in ASCII code into the physical memory of the IC. The length of the NFC counter mirror requires 6 bytes to mirror the NFC counter value in ASCII code. On the READ or FAST READ command to the involved user memory pages, NTAG 223 DNA SD responds with the virtual memory content of the NFC counter in ASCII code.

For an example see Table 21.

Remark: To enable the NFC counter increment itself (see Section 8.7), the NFC_CNT_EN bit shall be set to 1b.

8.8.3 Tag Tamper mirror function

The Tag Tamper mirror function enables NTAG 223 DNA SD to virtually mirror the 5 byte Tag Tamper information in ASCII code into the physical memory of the IC. The mirrored data are coming from the measurement on the measurement during start-up, when the NTAG 223 DNA SD is powered via the RF field. The Tag Tamper mirror requires 10 bytes of the user memory to mirror the Tag Tamper information in ASCII code. On the READ or FAST READ command to the involved user memory pages, NTAG 223 DNA SD responds with the virtual memory content of the Tag Tamper information in ASCII code. The content of the Tag Tamper information depends on if galvanic, capacitive tag tamper or capacitive sensor mode is enabled.

Remark: To enable the Tag Tamper feature itself, see Section 8.6.

The 5 byte mirrored Tag Tamper information is same as the response on the READ_TT_STATUS for Galvanic Tag Tamper (see Table 62) or Capacitive Tag Tamper/ Sensor (see Table 63).

Table 18. Tag Tamper mirror bytes ASCII

	ASCII bytes									
Des-c ription	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Tag Tamper Information	TTS [7-4]	TTS [3-0]	TT3 [7-4]	TT3 [3-0]	TT2 [7-4]	TT2 [3-0]	TT1 [7-4]	TT1 [3-0]	TT0 [7-4]	TT0 [3-0]
Example hex	43	4F	30	30	30	30	30	30	30	30
Example ASCII	C	O	0	0	0	0	0	0	0	0

ASCII byte 1 (TTS [7-4]) defines the stored Tag Tamper status and ASCII byte 2 (TTS [3-0]) define the current Tag Tamper status measured at the start-up of the NTAG 223 DNA TT as shown in Table 19

Table 19. Tag Tamper status ASCII bytes 1 and byte 2

Tag Tamper Status	TT status mirrored hex data	TT status mirrored ASCII data
Closed	0x43	C
Open	0x4F	O
Invalid	0x49	I

The meaning of ASCII bytes 3 (TT3 [7-4]) to byte 10 ([TT0[3-0]) is according to the definition for Galvanic Tag Tamper (see Table 62) or Capacitive Tag Tamper/Sensor (see Table 63).

8.8.4 SUNCMAC mirror function

The SUNCMAC is calculated over the UID, NFC counter and Tag Tamper information. This function enables NTAG 223 DNA SD to virtually mirror the 8 byte SUNCMAC in ASCII code into the physical memory of the IC. The length of the SUNCMAC ASCII mirror requires 16 bytes to mirror the SUNCMAC in ASCII code.

To validate the mirrored data of UID, NFC counter and Tag Tamper information see Section 8.9

8.9 SUNCMAC

8.9.1 SUNCMAC calculation

The 8-byte SUNCMAC is calculated using AES according to the CMAC standard described in NIST Special Publication 800-38B (refer to [9]). Padding is applied according to this standard.

The MAC used in NTAG 223 DNA SD is truncated by using only the 8 even-numbered bytes out of the 16 bytes output as described NIST Special Publication 800-38B (refer to [9]) when represented in most-to-least-significant order.

The initialization vector used for the SUNCMAC computation is the zero byte IV as prescribed in NIST Special Publication 800-38B (refer to [9]).

The SUNCMAC is defined as follows:

SUNCMAC = MACt (SUNCMAC_KEY; DynamicSUNData)

with DynamicSUNData being the data in hex values (not mirrored ASCII values) of the UID, NFC counter and Tag Tamper.

The data from the mirrored information for the SUNCMAC calculation needs to be transferred as shown below.

14 Byte UID need to be transferred from ASCII to Hex value as shown in Table 20.

Table 20. UID mirrored data example

UID mirror data	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9	Byte 10	Byte 11	Byte 12	Byte 13	Byte 14
Mirrored data in hex	30	34	45	31	34	31	31	32	34	43	32	38	38	30
Mirrored ASCII character	0	4	E	1	4	1	1	2	4	C	2	8	8	0

For this example, the data of the UID for the SUNCMAC calculation are 04E141124C2880h.

6 Byte NFC counter mirror needs to be transferred from ASCII to Hex value as shown in Table 21.

Table 21. NFC counter mirrored data example

NFC counter mirror data	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
Mirrored data in hex	30	30	30	34	41	46
Mirrored ASCII character	0	0	0	4	A	F

For this example, the data of the NFC Counter value for SUNCMAC calculation is 0004AFh.

10 Byte Tag Tamper mirror needs to be transferred from ASCII to Hex value as shown in Table 22.

Table 22. TT information mirrored data example

NFC counter mirror data	Byte 1	Byte 2	Byte 3	...	Byte 10
Mirrored data in hex	43	4F	30	30	30
Mirrored ASCII character	C	O	0	0	0

The first 2 bytes of the mirrored TT information are the TT status information for the stored and current Tag Tamper status and need to be transferred for the SUNCMAC calculation as in Table 23:

Table 23. TT status

TT status mirrored hex data	TT status mirrored ASCII data	TT status hex data for SUNCMAC calculation
43h	C	0x3
4Fh	O	0xF
49h	I	0x9
30h	0	0x0

For this example, the data for the Tag Tamper information for the SUNCMAC calculation are 3F00000000h.

For the example, the DynamicSUNData for the SUNCMAC calculation is 04E141124C28800004AF3F00000000h.

8.9.2 Programming of the SUNCMAC key

The 16 bytes of the AES key are programmed to memory pages from 34h to 37h. The keys are stored in memory as shown in the table below. The key itself can be written during personalization or at any later stage using the WRITE command. For both commands, byte 0 is always sent first.

Table 24. SUNCMAC_KEY memory configuration

Page Address		Byte Number			
Dec	Hex	0	1	2	3
52	34h	K00	K01	K02	K03

Table 24. SUNCMAC_KEY memory configuration *...continued*

Page Address		Byte Number			
Dec	Hex	0	1	2	3
53	35h	K04	K05	K06	K07
54	36h	K08	K09	K10	K11
55	37h	K12	K13	K14	K15

On example of SUNCMAC_KEY = 000102030405060708090A0B0C0D0E0Fh, the command sequence needed for key programming with WRITE command is:

- A2 34 0F 0E 0D 0C CRC
- A2 35 0B 0A 09 08 CRC
- A2 36 07 06 05 04 CRC
- A2 37 03 02 01 00 CRC

The memory content after those WRITE commands is shown in the table below:

Table 25. SUNCMAC_KEY memory configuration based on example configuration

Page Address		Byte Number			
Dec	Hex	0	1	2	3
52	34h	0F	0E	0D	0C
53	35h	0B	0A	09	08
54	36h	07	06	05	04
55	37h	03	02	01	00

The content of memory pages holding the SUNCMAC key can never be directly read neither by READ nor by FAST READ commands.

8.10 Password verification protection

The memory write or read/write access to a configurable part of the memory can be constrained by a positive password verification. The 32-bit secret password (PWD) and the 16-bit password acknowledge (PACK) response are typically programmed into the configuration pages at the tag personalization stage.

The AUTH_LIM parameter specified in Section 8.5.7 can be used to limit the negative verification attempts.

In the initial state of NTAG 223 DNA SD, password protection is disabled by an AUTH0 value of 3Ch. PWD and PACK are freely writable in this state. Access to the configuration pages and any part of the user memory can be restricted by setting AUTH0 to a page address within the available memory space. This page address is the first one protected.

Remark: The password protection method provided in NTAG223 DNA TT has to be intended as an easy and convenient way to prevent unauthorized memory accesses. If a higher level of protection is required, cryptographic methods can be implemented at application layer to increase overall system security.

8.10.1 Programming of PWD and PACK

The 32-bit PWD and the 16-bit PACK have to be programmed into the configuration pages, see Section 8.5.7. The password as well as the password acknowledge are

written LSByte first. This byte order is the same as the byte order used during the PWD_AUTH command and its response.

The PWD and PACK bytes can never be read out of the memory. Instead of transmitting the real value on any valid READ or FAST_READ command, only 00h bytes are replied.

If the password verification does not protect the configuration pages, PWD and PACK can be written with normal WRITE commands.

If the configuration pages are protected by the password configuration, PWD and PACK can be written after a successful PWD_AUTH command.

The PWD and PACK are writable even if the LOCK_USR_CFGK bit is set to 1b. Therefore it is recommended to set AUTH0 to the page where the PWD is located after the password has been written. This page is 2Bh for NTAG 223 DNA SD.

Remark: To improve the overall system security, it is advisable to diversify the password and the password acknowledge using a die individual parameter of the IC, that is the 7-byte UID available on NTAG 223 DNA SD.

8.10.2 Limiting failed authentication attempts

To prevent brute-force attacks on the password, the maximum allowed number of failed password attempts can be set using AUTH_LIM. This mechanism is disabled by setting AUTHLIM to a value of 000h, which is also the initial state of NTAG 223 DNA SD.

If AUTH_LIM is not equal to 000h, each failed authentication attempt is internally counted and stored. The count operation features anti-tearing support. As soon as this internal counter reaches the number specified in AUTH_LIM, any further failed password attempt leads to a permanent locking of the protected part of the memory for the specified access rights. Specifically, whether the provided password is correct or not, each subsequent PWD_AUTH fails.

Any successful password verification, before reaching the limit of failed password attempts, decrements the internal counter by value 10h. In case the counter is at value of 10h or below the counter is reset.

Remark: To reduce the risk for brute-force attacks, a limitation of failed authentication attempts is recommended.

8.10.3 Protection of configuration pages

The configuration pages can be protected by the password authentication as well. The protection level is defined with the PROT bit.

The protection is enabled by setting the AUTH0 byte to a value that is within the addressable memory space before relevant configuration page address.

8.11 Originality signature

The NTAG 223 DNA SD offers a feature to verify the origin of a tag confidently, using the ECC-based originality signature stored in a hidden part of memory. The originality signature can be read with the READ_SIG command.

The purpose of the ECC originality check during (pre-)personalization is to protect customer investments by identifying mass penetration of non-NXP originated NTAG 223 DNA SD ICs into an infrastructure. As individual signatures can still be copied, it does not completely prevent hardware copy or emulation of individual NTAG 223 DNA SD

ICs. As such, a valid signature is not a full guarantee. Therefore, this signature validation should be complemented with a check to detect if multiple ICs with the sameUID are being introduced in the system.

The NTAG 223 DNA SD provides the possibility to customize the originality signature to personalize the IC individually for specific application.

At delivery, the NTAG 223 DNA SD is pre-programmed with the NXP originality signature described below. This signature is locked in the dedicated memory. If needed, the signature can be unlocked with the LOCK_SIG command. It is reprogrammed with a custom-specific signature using the WRITE_SIG command during the personalization process by the customer. The signature can be permanently locked afterward with the LOCK_SIG command to avoid further modifications.

Remark: If no customized originality signature is required, it is recommended to lock the NXP signature permanently during the initialization process with the LOCK_SIG command.

8.11.1 Originality Signature at delivery

At the delivery, the NTAG 223 DNA SD is programmed with an NXP digital signature based on standard Elliptic Curve Cryptography (curve name secp192r1), according to the ECDSA algorithm. The use of a standard algorithm and curve ensures easy software integration of the originality check procedure in NFC devices.

Each NTAG 223 DNA SD UID is signed with an NXP private key and the resulting 48-byte signature is stored in a hidden part of the NTAG 223 DNA SD memory during IC production.

This signature can be retrieved using the READ_SIG command and verified in the NFC device by using the corresponding ECC public key provided by NXP. In case the NXP public key is stored in the NFC device, the complete signature verification procedure can be performed offline.

To verify the signature, for example with the use of the public domain cryptolibrary OpenSSL, the tool domain parameters are set to secp192r1. It is defined within the standards for elliptic curve cryptography SEC ([6]).

Details on how to check that the NXP signature value is provided in following application note ([5]). It is foreseen to offer an online and offline way to verify originality of NTAG 223 DNA SD.

9 Command overview

NTAG 223 DNA SD activation follows the part 2 and part 3 of ISO/IEC 14443 Type A. After NTAG 223 DNA SD has been selected, it can either be deactivated using the ISO/IEC 14443 HLTA command, or the NTAG 223 DNA SD commands (e.g. READ or WRITE) can be performed. For more details about the card activation, refer to [1].

9.1 NTAG 223 DNA SD command overview

All available commands for NTAG 223 DNA SD are shown in Table 26.

Table 26. Command overview

Command[1]	ISO/IEC 14443	NFC FORUM	Command code (hexadecimal)
Request	REQA	SENS_REQ	26h (7 bit)
Wake-up	WUPA	ALL_REQ	52h (7 bit)
Anti-collision CL1	Anti-collision CL1	SDD_REQ CL1	93h 20h
Select CL1	Select CL1	SEL_REQ CL1	93h 70h
Anti-collision CL2	Anti-collision CL2	SDD_REQ CL2	95h 20h
Select CL2	Select CL2	SEL_REQ CL2	95h 70h
Halt	HLTA	SLP_REQ	50h 00h
GET_VERSION	-	-	60h
READ	-	READ	30h
FAST_READ	-	-	3Ah
WRITE	-	WRITE	A2h
READ_CNT	-	-	39h
PWD_AUTH	-	-	1Bh
READ_SIG	-	-	3Ch
WRITE_SIG	-	-	A9h
LOCK_SIG	-	-	ACh
READ_TT_STATUS[2]	-	-	A4h

[1] Unless otherwise specified, all commands use the coding and framing as described in [1].
[2] The response to this command is different compared to the NTAG 213 TT

9.2 Timings

The command and response timings shown in this document are not to scale and values are rounded to 1 µs.

All given command and response transmission times refer to the data frames including start of communication and end of communication. They do not include the encoding (like the Miller pulses). An NFC device data frame contains the start of communication (1 "start bit") and the end of communication (one logic 0 + 1-bit length of unmodulated carrier). An NFC tag data frame contains the start of communication (1 "start bit") and the end of communication (1-bit length of no subcarrier).

The minimum command response time is specified according to [1] as an integer n which specifies the NFC device to NFC tag frame delay time. The frame delay time from NFC tag to NFC device is at least 87 µs. The maximum command response time is specified as a timeout value. Depending on the command, the T_{ACK} value specified for command responses defines the NFC device to NFC tag frame delay time. It does this for either the 4-bit ACK value specified in Section 9.3 or for a data frame.

All command timings are according to ISO/IEC 14443-3 frame specification as shown for the Frame Delay Time in Figure 9. For more details, refer to [1].

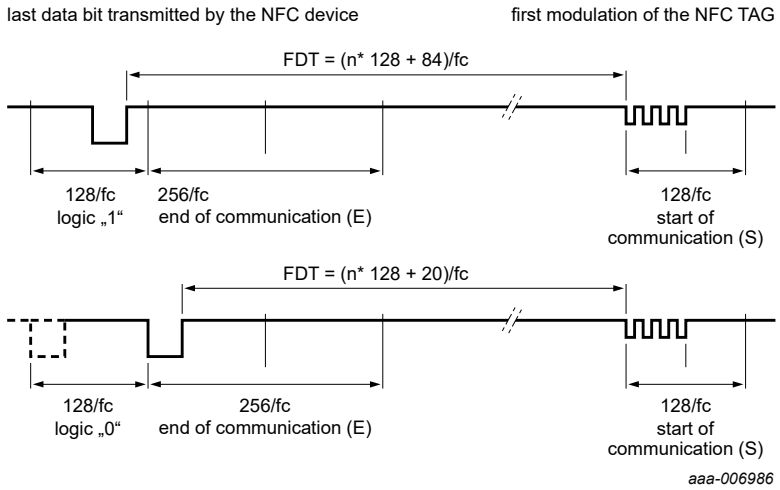


Figure 10. Frame Delay Time (from NFC device to NFC tag)

Remark: Due to the coding of commands, the measured command timings usually exclude (a part of) the end of communication. This factor shall be considered when comparing the specified with the measured times.

9.3 NTAG ACK and NAK

NTAG uses a 4-bit ACK / NAK as shown in Table 27.

Table 27. ACK and NAK values

Code (4 bit)	ACK/NAK
Ah	Acknowledge (ACK)
0h	NAK for invalid argument (i.e. invalid page address)
1h	NAK for parity or CRC error
4h	NAK for failed authentication counter overflow or NFC counter exceeding the limit
5h	NAK for EEPROM write error
6h	NAK if valid page indicators are corrupted for the given tearing protected pages. This can be due to memory content corruption caused by an attack.
7h	NAK for EEPROM write error

9.4 ATQA and SAK responses

NTAG 223 DNA SD replies to a REQA or WUPA command with the ATQA value shown in Table 28. It replies to a Select CL2 command with the SAK value shown in Table 29. The 2-byte ATQA value is transmitted with the least significant byte first (44h).

Table 28. ATQA response of the NTAG 223 DNA TT

		Bit number														
Sales type	**Hex value**	**16**	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
NT2H2331S0	00 44h	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0

Table 29. SAK response of the NTAG 223 DNA TT

		Bit number							
Sales type	**Hex value**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
NT2H2331S0	00h	0	0	0	0	0	0	0	0

Remark: The ATQA coding in bits 7 and 8 indicate the UID size according to [1] independent from the settings of the UID usage.

Remark: The bit numbering in the ISO/IEC 14443 starts with LSB = bit 1 and not with LSB = bit 0. So 1 byte counts bit 1 to bit 8 instead of bit 0 to 7.

10 NTAG commands

10.1 GET_VERSION

The GET_VERSION command is used to retrieve information on the NTAG family, the product version, storage size and other product data required to identify the specific NTAG IC.

This command is also available on other NTAG products to have a common way of identifying products across platforms and evolution steps.

The GET_VERSION command has no arguments and replies the version information for the specific NTAG IC type. The command structure is shown in Figure 11 and Table 30.

Table 33 shows the required timing.

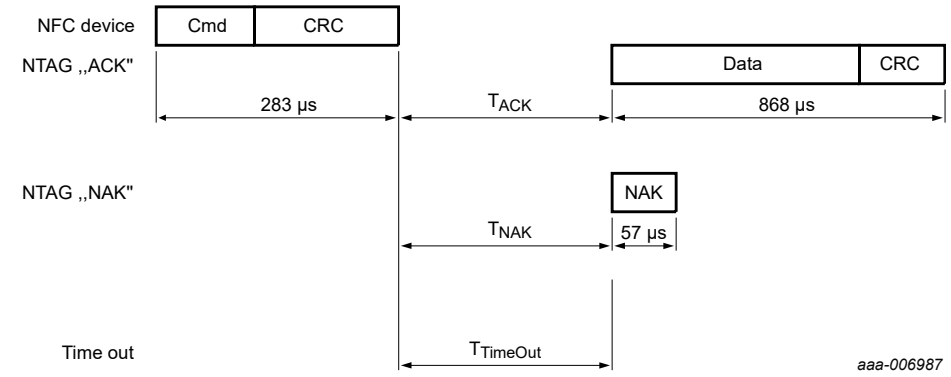


Figure 11. GET_VERSION command

Table 30. GET_VERSION command

Name	Code	Description	Length
Cmd	60h	Get product version	1 byte
CRC	-	CRC according to [1]	2 bytes

Table 31. GET_VERSION response

Name	Code	Description	Length
Data	-	Product version information (see Table 32)	8 bytes
CRC	-	CRC according to [1]	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 32. GET_VERSION data response for NTAG 223 DNA SD

Byte no.	Description	NTAG 223 DNA SD	Interpretation
0	fixed Header	00h	
1	vendor ID	04h	NXP Semiconductors
2	product type	04h	NTAG
3	product subtype	08h	50 pF with Tag Tamper feature
4	major product version	04h	4
5	minor product version	00h	V0
6	storage size	0Fh	see following information
7	protocol type	03h	ISO/IEC 14443-3 compliant

The most significant 7 bits of the storage size byte are interpreted as an unsigned integer value n. As a result, it codes the total available user memory size as 2^n. If the least significant bit is 0b, the user memory size is exactly 2^n. If the least significant bit is 1b, the user memory size is between 2^n and 2^{n+1}.

The user memory for NTAG 223 DNA SD is 144 bytes. This memory size is between 128 bytes and 256 bytes. Therefore, the most significant 7 bits of the value 0Fh, are interpreted as 7d and the least significant bit is 1b.

Table 33. GET_VERSION timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
GET_VERSION	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

10.2 READ

The READ command requires a start page address, and returns 16 bytes of four NTAG 223 DNA SD pages. For example, if address (Addr) is 03h then the content pages 03h, 04h, 05h, 06h are returned. So call roll-over mechanism applies if the READ command address is near the end of the accessible memory area. The same mechanism also applies if at least part of the addressed pages is within a password protected area. For details on the command structure, refer to Figure 12 and Table 34.

Table 36 shows the required timing.

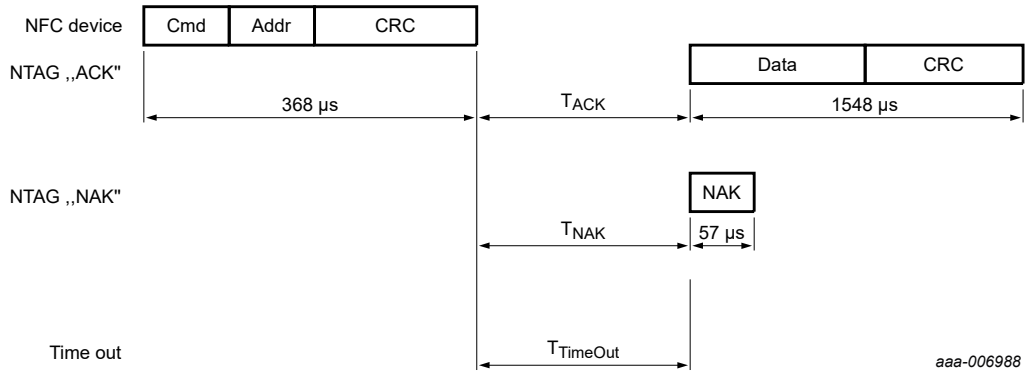


Figure 12. READ command

Table 34. READ command

Name	Code	Description	Length
Cmd	30h	read four pages	1 byte
Addr	-	start page address	1 byte
CRC	-	CRC according to [1]	2 bytes

Table 35. READ response

Name	Code	Description	Length
Data	-	Data content of the addressed pages	16 bytes
CRC	-	CRC according to [1]	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 36. READ timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
READ	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

In the initial state of NTAG 223 DNA SD, all memory pages in the range from 00h until 3Bh are allowed as Addr parameter to the READ command.

Addressing a memory page beyond address 3Bh results in a NAK response from NTAG 223 DNA TT.

A roll-over mechanism is implemented to continue reading from page 00h once the end of the accessible memory is reached. For example reading from address 39h on an NTAG 223 DNA SD results in pages 39h, 3Ah, 3Bh and 00h being returned.

The following conditions apply if part of the memory is password protected for read access:

- if NTAG 223 DNA SD is in the ACTIVE state
  - addressing a page which is equal or higher than AUTH0 results in a NAK response
  - addressing a page lower than AUTH0 results in data being returned with the roll-over mechanism occurring just one page before the AUTH0 defined page
- if NTAG 223 DNA SD is in the AUTHENTICATED state
  - the READ command behaves like on an NTAG 223 DNA SD without access protection

Remark: PWD and PACK values cannot be read out of the memory. When reading from the pages holding those two values, all 00h bytes are replied to the NFC device instead.

10.3 FAST_READ

The FAST_READ command requires a start page address and an end page address and returns the bytes of the addressed pages. For example if the start address is 03h and the end address is 07h then pages 03h, 04h, 05h, 06h and 07h are returned. If either start or end address is out of the accessible area, NTAG 223 DNA SD replies a NAK. For details on the command structure, refer to Figure 13 and Table 37.

Table 39 shows the required timing.

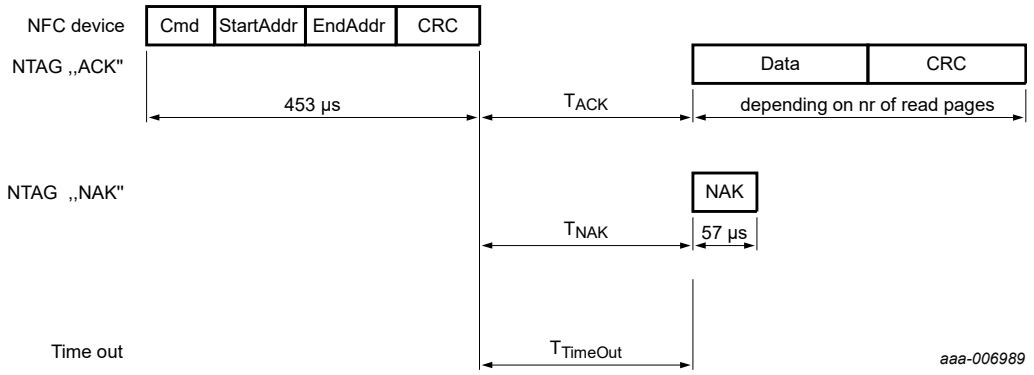


Figure 13. FAST_READ command

Table 37. FAST_READ command

Name	Code	Description	Length
Cmd	3Ah	read multiple pages	1 byte
StartAddr	-	start page address	1 byte
EndAddr	-	end page address	1 byte
CRC	-	CRC according to Ref. 1	2 bytes

Table 38. FAST_READ response

Name	Code	Description	Length
Data	-	data content of the addressed pages	n*4 bytes
CRC	-	CRC according to Ref. 1	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 39. FAST_READ timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
FAST_READ	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

In the initial state of NTAG 223 DNA SD, all memory pages in the range from 00h to 3Bh are allowed as StartAddr parameter to the FAST_READ command.

Addressing a memory page beyond address 3Bh results in a NAK response from NTAG 223 DNA TT.

The EndAddr parameter must be equal to or higher than the StartAddr otherwise NAK response is provided.

The following conditions apply if part of the memory is password protected for read access:

- if NTAG 223 DNA SD is in the ACTIVE state
  - if any requested page address is equal or higher than AUTH0 a NAK is replied
- if NTAG 223 DNA SD is in the AUTHENTICATED state
  - the FAST_READ command behaves like on an NTAG 223 DNA SD without access protection

Remark: PWD and PACK values cannot be read out of the memory. When reading from pages holding those two values, all 00h bytes are replied to the NFC device instead.

Remark: The FAST_READ command is able to read out the whole accessible memory. Nevertheless, receive buffer of the NFC device must be able to handle the requested amount of data as there is no chaining possibility.

10.4 WRITE

The WRITE command requires a block address, and writes 4 bytes of data into the addressed NTAG 223 DNA TT page. The WRITE command is shown in Figure 14 and Table 40.

Table 42 shows the required timing.

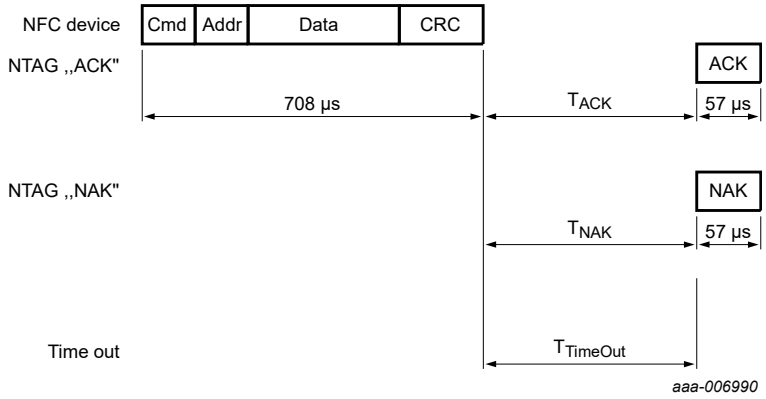


Figure 14. WRITE command

Table 40. WRITE command

Name	Code	Description	Length
Cmd	A2h	write one page	1 byte
Addr	-	page address	1 byte
Data	-	data	4 bytes
CRC	-	CRC according to [1]	2 bytes

Table 41. WRITE response

Name	Code	Description	Length
ACK/NAK	see Table 27	see Section 9.3	4 bits

Table 42. WRITE timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
WRITE	n=9[1]	$T_{TimeOut}$	10 ms

[1] Refer to Section 9.2.

In the initial state of NTAG 223 DNA SD, page address 02h to 3Bh are valid Addr parameters to the WRITE command.

Addressing a memory page beyond address 3Bh results in a NAK response from NTAG 223 DNA SD.

Pages which are locked against writing cannot be reprogrammed using WRITE command. The locking mechanisms include static and dynamic lock bits as well as specific lock bits of different configuration elements.

The following conditions apply if part of the memory is password protected for write access:

- if NTAG 223 DNA SD is in the ACTIVE state
  - writing to a page which address is equal or higher than AUTH0 results in a NAK response
- if NTAG 223 DNA SD is in the AUTHENTICATED state
  - the WRITE command behaves like on an NTAG 223 DNA SD without access protection

NTAG 223 DNA SD features tearing protected write operations to specific memory content. The following pages are protected against tearing events during a WRITE operation:

- page 02h containing static lock bits
- page 03h containing CC bits
- page 28h containing the additional dynamic lock bits for the NTAG 223 DNA SD

10.5 READ_CNT

The READ_CNT command is used to read out the current value of the NFC one-way counter of the NTAG 223 DNA SD. The command has a single argument specifying the counter number and returns the 24-bit counter value of the corresponding counter. The command structure is shown in Figure 15 and Table 43.

Table 45 shows the required timing.

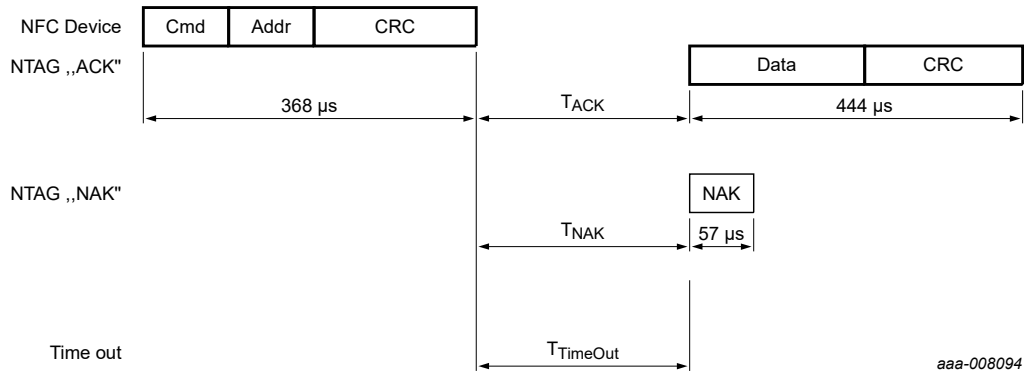


Figure 15. READ_CNT command

Table 43. READ_CNT command

Name	Code	Description	Length
Cmd	39h	read counter	1 byte
Addr	02h	NFC counter address	1 byte
CRC	-	CRC according to [1]	2 bytes

Table 44. READ_CNT response

Name	Code	Description	Length
Data	-	counter value	3 bytes
CRC	-	CRC according to [1]	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 45. READ_CNT timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
READ_CNT	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

10.6 PWD_AUTH

A protected memory area can be accessed only after a successful password verification using the PWD_AUTH command. The AUTH0 configuration byte defines the protected area. It specifies the first page that the password mechanism protects. The level of protection can be configured using the PROT bit either for write protection or read/write protection. The PWD_AUTH command takes the password as parameter and, if successful, returns the password authentication acknowledge, PACK. By setting the AUTH_LIM configuration bits to a value larger than 000b, the number of unsuccessful password verifications can be limited. Each unsuccessful authentication is then counted in a counter featuring anti-tearing support. After reaching the limit of unsuccessful attempts, the memory access specified in PROT, is no longer possible. The PWD_AUTH command is shown in Figure 16 and Table 46.

Table 48 shows the required timing.

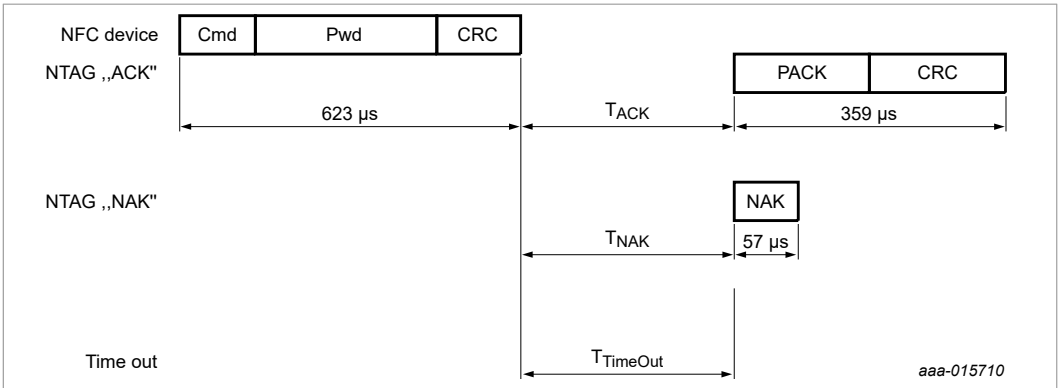


Figure 16. PWD_AUTH command

Table 46. PWD_AUTH command

Name	Code	Description	Length
Cmd	1Bh	password authentication	1 byte
Pwd	-	password	4 bytes
CRC	-	CRC according to [1]	2 bytes

Table 47. PWD_AUTH response

Name	Code	Description	Length
PACK	-	password authentication acknowledge	2 bytes
CRC	-	CRC according to [1]	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 48. PWD_AUTH timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
PWD_AUTH	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

Remark: It is recommended to change the password from its delivery state at tag issuing and set the AUTH0 value to the PWD page.

10.7 READ_SIG

The READ_SIG command returns an IC-specific, 48 byte ECC signature, to verify the originality signature with the public key. The signature is pre-programmed at chip production and can be changed (see Section 10.8) if the originality signature has been unlocked with the LOCK_SIG command (see Section 10.9). The command structure is shown in Figure 17 and Table 49.

Table 51 shows the required timing.

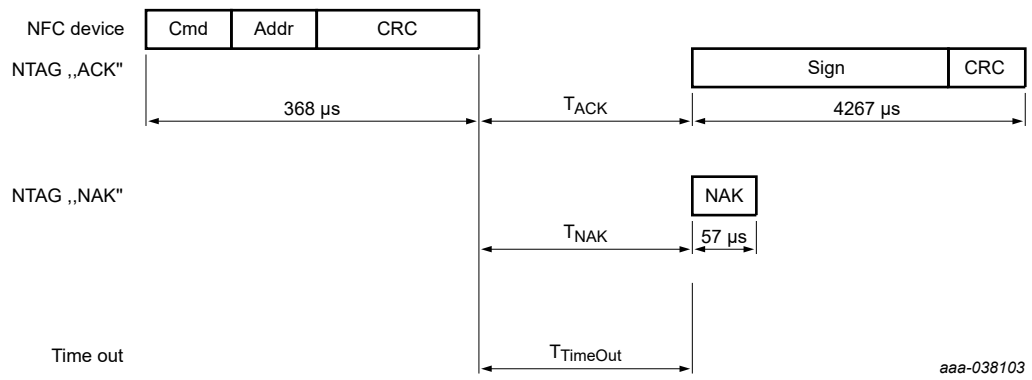


Figure 17. READ_SIG command

Table 49. READ_SIG command

Name	Code	Description	Length
Cmd	3Ch	read ECC signature	1 byte
Addr	00h	RFU, is set to 00h	1 byte
CRC	-	CRC according to [1]	2 bytes

Table 50. READ_SIG response

Name	Code	Description	Length
Signature	-	ECC signature	48 bytes
CRC	-	CRC according to [1]	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 51. READ_SIG timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
READ_SIG	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

Details on how to check that the signature value is provided in the following Application note[5].

10.8 WRITE_SIG

The WRITE_SIG command allows the writing of a customized originality signature into the dedicated originality signature memory.

The WRITE_SIG command requires an originality signature block address (Table 55), and writes 4 bytes of data into the addressed originality signature block. The WRITE_SIG command is shown in Figure 18 and Table 52.

Table 54 shows the required timing.

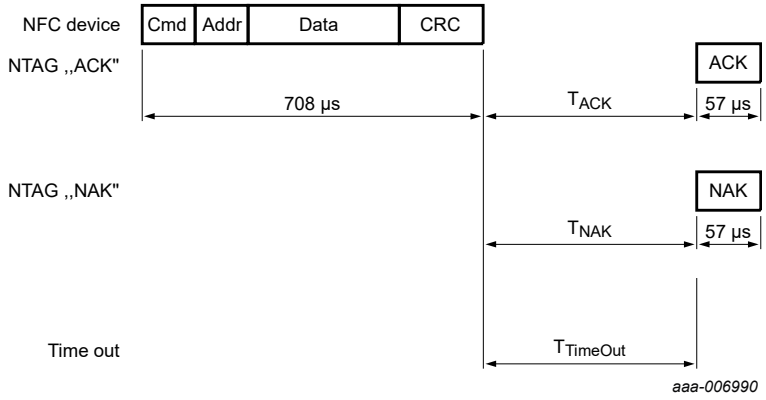


Figure 18. WRITE_SIG command

Table 52. WRITE_SIG command

Name	Code	Description	Length
Cmd	A9h	write one originality signature block	1 byte
Addr	-	block address	1 byte
Data	-	signature bytes to be written	4 bytes
CRC	-	CRC according to [1]	2 bytes

Table 53. WRITE_SIG response

Name	Code	Description	Length
ACK/NAK	see Table 27	see Section 9.3	4 bits

Table 54. WRITE_SIG timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
WRITE_SIG	n = 9[1]	$T_{TimeOut}$	10 ms

[1] Refer to Section 9.2.

In the initial state of NTAG 223 DNA SD, the originality signature block address 00h to 0Bh are valid Addr parameters to the WRITE_SIG command.

Addressing a memory block beyond address 0Bh results in a NAK response from NTAG 223 DNA SD.

Table 55. Blocks for the WRITE_SIG command

Originality signature block	byte 0	byte 1	byte 2	byte 3
00h	LSByte			
01h				
...				
0Ah				
0Bh				MSByte

10.9 LOCK_SIG

The LOCK_SIG command allows the user to unlock, lock or permanently lock the dedicated originality signature memory.

The originality signature memory can only be unlocked if the originality signature memory is not permanently locked.

Permanently locking of the originality signature with the LOCK-SIG command is irreversible and the originality signature memory can never be unlocked and reprogrammed again.

The LOCK_SIG command is shown in Figure 19 and Table 56.

Table 58 shows the required timing.

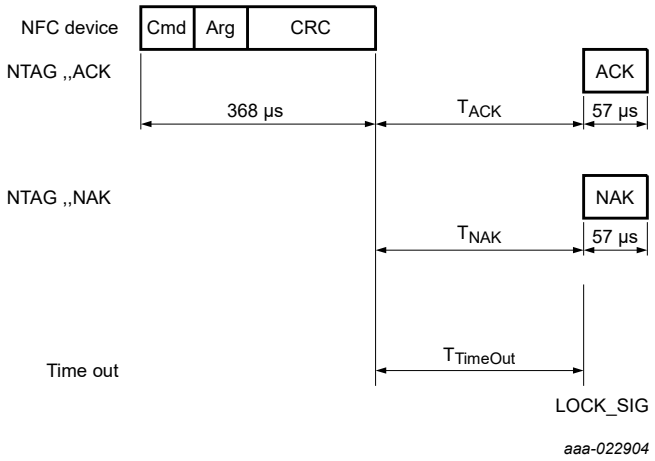


Figure 19. LOCK_SIG command

Table 56. LOCK_SIG command

Name	Code	Description	Length
Cmd	ACh	lock signature	1 byte
Arg	-	locking action	1 byte
		00h - unlock	
		01h - lock	
		02h - permanently lock	
CRC	-	CRC according to [1]	2 bytes

Table 57. LOCK_SIG response

Name	Code	Description	Length
ACK/NAK	see Table 27	see Section 9.3	4 bits

Table 58. LOCK_SIG timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
LOCK_SIG	n = 9[1]	$T_{TimeOut}$	10 ms

[1] Refer to Section 9.2.

10.10 READ_TT_STATUS

The READ_TT_Status command provides the information about the tag tamper status which is detected when the NTAG 223 DNA SD is powered by an RF field. The response on The READ_TT_STATUS includes

- 1 byte about the actual and stored status of the tag tamper detected during start-up.

- In capacitive mode (RTT_CTT_SEL is set to 1b) 4 byte of measured capacitance parameters, if CTT_SHOW_VALUE is set to 1b, otherwise 4 byte are fixed to all 00h. In resistive tag tamper mode (RTT_CTT_SEL is set to 0b), 4 byte are fixed to all 00h.

For details on those cases and the command structure, refer to Figure 20 and Table 59.

Table 61 shows the required timing.

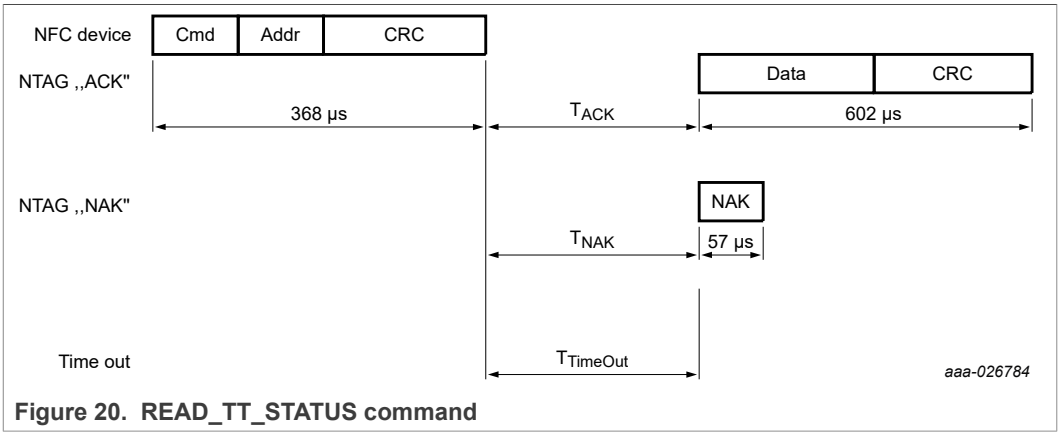


Figure 20. READ_TT_STATUS command

Table 59. READ_TT_STATUS command

Name	Code	Description	Length
Cmd	A4h	read Tag Tamper Status	1 byte
Addr	00h	RFU, is set to 00h	1 byte
CRC	-	CRC according to [1]	2 bytes

Table 60. READ_TT_STATUS response

Name	Code	Description	Length
Data	-	Tag Tamper Status	5 bytes
CRC	-	CRC according to [1]	2 bytes
NAK	see Table 27	see Section 9.3	4 bits

Table 61. READ_TT_STATUS timing

These times exclude the end of communication of the NFC device.

	$T_{ACK/NAK}$ min	$T_{ACK/NAK}$ max	$T_{TimeOut}$
READ	n=9[1]	$T_{TimeOut}$	5 ms

[1] Refer to Section 9.2.

Table 62. READ_TT_STATUS response in RTT mode

Byte no.	Description	Bits	Interpretation
0 - 3	TT0 - TT3	7-0	0x00h fixed value

Table 62. READ_TT_STATUS response in RTT mode*...continued*

Byte no.	Description	Bits	Interpretation
4	TTS stored	7-4	Stored Tag Tamper status, if SHOW_STORED_TT_STATUS is enabled 0x3h … Stored Tag Tamper Status was CLOSED at one start-up 0xFh … Stored Tag Tamper Status was OPEN at one start-up If SHOW_STORED_TT_STATUS is disabled, the value is masked with 0x0h
	TTS actual	3-0	Actual Tag Tamper status at last start-up, if SHOW_ACT_TT_STATUS is enabled 0x3h … Tag Tamper Status was CLOSED at last start-up 0xFh … Tag Tamper Status was OPEN at last start-up 0x9h … Tag Tamper Status was INVALID at last start-up If SHOW_ACT_TT_STATUS is disabled, the value is masked with 0x0h

Remark: The status of the tag tamper wire is only measured during the start-up phase of the NTAG 223 DNA SD.

Table 63. READ_TT_STATUS response in CTT mode

Byte no.	Description	Bits	Interpretation
0	TT0	7-3	Measurement current setting from value CTT_CURR_TRIM
		2	Double measurement range setting form MEAS_DBL_RANGE
		1-0	Internal ballast capacitor settings from CTT_CFILT
1	TT1	7-2	*DifferenceMeasurement* [5-0]
		1-0	RFU
2	TT2	7-6	*CounterValue2_ext* [1-0]
		5-0	*DifferenceMeasurement* [11-6]
3	TT3	7-0	*CounterValue2_ext* [9-2]
4	TTS stored	7-4	Stored Tag Tamper status, if SHOW_STORED_TT_STATUS is enabled 0x3h … Stored Tag Tamper Status was CLOSED at one start-up 0xFh … Stored Tag Tamper Status was OPEN at one start-up If SHOW_STORED_TT_STATUS is disabled, the value is masked with 0x0h

Table 63. READ_TT_STATUS response in CTT mode*...continued*

Byte no.	Description	Bits	Interpretation
	TTS actual	3-0	Actual Tag Tamper status at last start-up, if SHOW_ACT_TT_STATUS is enabled 0x3h … Tag Tamper Status was CLOSED at last start-up 0xFh … Tag Tamper Status was OPEN at last start-up 0x9h … Tag Tamper Status was INVALID at last start-up If SHOW_ACT_TT_STATUS is disabled, the value is masked with 0x0h

Remark: CTT is only measured during the start-up phase of the NTAG 223 DNA SD.

If CTT_SHOW_VALUE is disabled, TT0 to TT3 are masked with 00h in ACTIVE state and provide the details of the last measurement in AUTHENTICATED state.

11 Limiting values

Stresses exceeding one or more of the limiting values can cause permanent damage to the device. Exposure to limiting values for extended periods can affect device reliability.

Table 64. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter		Min	Max	Unit
$P_{d,max}$	maximum power dissipation		-	120	mW
$I_{LA-LB,max}$	maximum input current		-	40	mA
V_{ind}	maximum voltage on DP in resistive tag tamper mode		-	0.5	V
	maximum voltage on DP in capacitive tag tamper mode		-	0.25	V
T_{stg}	storage temperature		-55	125	°C
T_{amb}	ambient temperature		-25	+70	°C
V_{ESD}	electrostatic discharge voltage on LA/LB, DP/GND	[1]	-	2	kV

[1] ANSI/ESDA/JEDEC JS-001; Human body model: C = 100 pF, R = 1.5 kΩ

CAUTION

This device has limited built-in ElectroStatic Discharge (ESD) protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the gates.

12 Characteristics

Table 65. Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_i	input frequency		-	13.56	-	MHz
C_i	input capacitance[1]	T_{amb} = 22 °C	-	50.0	-	pF
R_{on}	resistance tag taper closed	DP - GND	-	-	50	Ω
R_{off}	resistance tag tamper open	DP - GND	1 M	-	-	Ω
C_{ext}	capacitive sensing range	DP - GND	0	-	11	pF
	capacitive sensing resolution	DP - GND	-	10	-	bit
	capacitive sensitivity[2]	ideal regression sensitivity curve	-	0.13	-	pF
	noise[2]	RMS noise at T_{amb} = 22 °C	-	0.086	-	pF
	integral non-linearity[2]	error between the measured capacitance and best fit line on 25%-85%of the sensing capacitance range at T_{amb} = 22 °C	-	0.15	-	pF
	effective number of bits (ENOB)[2]		-	6	-	bit
EEPROM characteristics						
t_{ret}	retention time	T_{amb} = 22 °C	10	-	-	year
$N_{endu(W)}$	write endurance	T_{amb} = 22 °C	100.000	-	-	cycle

[1] f_i = 13.56 MHz; 2 V RMS
[2] Parameter applies to *DifferenceMeasurement* with same *CTT_CURR_TRIM* value as after calibration (see Section 8.6.3)

13 Wafer specification

For more details on the wafer delivery forms, see [7].

Table 66. Wafer specifications NTAG 223 DNA TT

Wafer	
diameter	200 mm typical (8 inches)
maximum diameter after foil expansion	210 mm
thickness	
NT2H2331S0DUD	120 µm ± 15 µm
flatness	not applicable
Potential Good Dies per Wafer (PGDW)	42521
Wafer backside	
material	Si
treatment	ground and stress relieve
roughness	R_a max = 0.5 µm
	R_t max = 5 µm
Chip dimensions	
step size[1]	x = 832 µm
	y = 832 µm
gap between chips[1]	typical = 20 µm
	minimum = 5 µm
Passivation	
type	sandwich structure
material	PSG / nitride
thickness	500 nm / 600 nm
Au bump (substrate connected to VSS)	
material	> 99.9 % pure Au
hardness	35 to 80 HV 0.005
shear strength	> 70 MPa
height	18 µm
height uniformity	within a die = ±2 µm
	within a wafer = ±3 µm
	wafer to wafer = ±4 µm
flatness	minimum = ±1.5 µm
size	LA, LB, GND, DP = 60 µm × 60 µm
size variation	±5 µm
under bump metallization	sputtered TiW

[1] The step size and the gap between chips may vary due to changing foil expansion

13.1 Fail die identification

Electronic wafer mapping covers the electrical test results and additionally the results of mechanical/visual inspection. No ink dots are applied.

14 Delivery

The customer purchasing a product of the NTAG 223 DNA SD family has to make sure that they receive the evaluated version. This section describes the measures that are needed to ensure delivery of the evaluated version.

The evaluated version of the NTAG 223 DNA SD can be ordered from NXP by referencing the respective commercial type name as listed in Section 5.

NXP offers two ways of delivery of the product:

1. The customer collects the product themselves at the NXP site.
2. The product is sent by NXP to the customer and protected by special measures.

These methods are described in the Section 14.2 and Section 14.2 respectively.

14.1 Delivery as a wafer

When the product is delivered as wafer, there reside functional and non-functional ICs on the wafer. The non-functional ICs cannot be used but have to be handled securely, too. These ICs must be destroyed to such an extent that no analysis or misuse is possible after destruction. The non-functional ICs (scrap) shall be handled secure until the destruction.

Information about non-functional items is accessible via the eMAP-Portal (http://wmt.nxp.com). The Access sheet with the Login data is enclosed with the delivery to allow the download of the electronic wafer map file. In this case, the information about non-functional ICs is stored in a so-called wafer map file. The electronic wafer map file covers the electrical test results and additionally the results of mechanical/visual inspection.

14.2 Delivery Method One: The customer collects the product themselves

The customer fetches the product from the following location:

NXP Semiconductors (Thailand)

303 Chaengwattana Rd.Laksi

Bangkok

10210 Thailand

This method guarantees that the customer gets authentic products.

14.3 Delivery Method Two: The Product is sent by NXP and protected by special measures

To guarantee that the product is not manipulated during the delivery, NXP has defined three security measures:

1. The product is delivered in parcels sealed with special tapes. The customer can examine these tapes in order to make sure that they have not been manipulated.
2. The customer shall identify the product as described in Section 10.1.
3. The customer should check the originality by verification of the Originality Signature Section 8.11.1.

These measures shall be applied to ensure that a genuine chip is in use. The product is delivered directly to the customer or via the Global Distribution Center:

NXP Semiconductors Netherlands B.V.

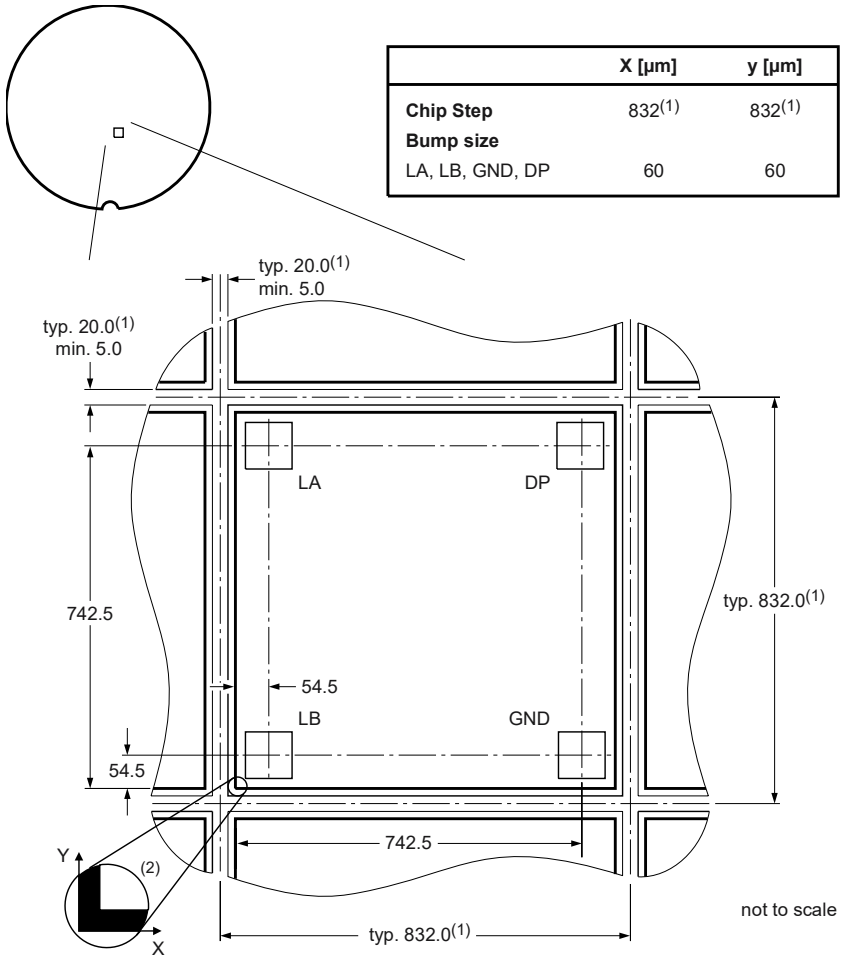
(Global Distribution Centre)

c/o CEVA Logistics (Malaysia) Sdn Bhd

Lot 9A Jalan Tiang U8/92, Bukit Jelutong Industrial Park, 40150 Shah Alam, Selangor Darul Ehsan, MALAYSIA

15 Bare die outline

For more details on the wafer delivery forms, see [7].



(1) the air gap and thus the step size may vary due to varying foil expansion
(2) all dimensions in µm, pad locations measured from metal ring edge (see detail)

aaa-038104

Figure 21. Bare die outline NTAG 223 DNA SD

16 Abbreviations

Table 67. Abbreviations and symbols

Acronym	Description
ACK	Acknowledge
ATQA	Answer to request, Type A
CRC	Cyclic Redundancy Check
CC	Capability container
CT	Cascade Tag (value 88h) as defined in ISO/IEC 14443-3 Type A
ECC	Elliptic Curve Cryptography
EEPROM	Electrically Erasable Programmable Read-Only Memory
FDT	Frame Delay Time
FFC	Film Frame Carrier
IC	Integrated Circuit
LSB	Least Significant Bit
MSB	Most Significant Bit
NAK	Not Acknowledge
NFC device	NFC Forum device
NFC tag	NFC Forum tag
NV	Non-Volatile memory
REQA	Request command, Type A
RF	Radio Frequency
RFUI	Reserver for Future Use - Implemented
RMS	Root Mean Square
SAK	Select acknowledge, type A
SECS-II	SEMI Equipment Communications Standard part 2
TiW	Titanium Tungsten
UID	Unique IDentifier
WUPA	Wake-up Protocol type A

17 References

[1] **ISO/IEC 14443**
International Organization for Standardization

[2] **NFC Forum Tag 2 Type Operation, Technical Specification**
NFC Forum, 31.05.2011, Version 1.1

[3] **NFC Data Exchange Format (NDEF), Technical Specification**
NFC Forum, 24.07.2006, Version 1.0

[4] **AN11276 NTAG Antenna Design Guide**
Application note, Document number 2421**[1]

[5] **AN11350 NTAG Originality Signature Validation**
Application note, Document number 2604**[1]

[6] **Certicom Research. SEC 2**
Recommended Elliptic Curve Domain Parameters, version 2.0, January 2010

[7] **General specification for 8" wafer on UV-tape; delivery types**
Delivery Type Description, Document number 1005**[1]

[8] **AN12999 NTAG 22x DNA StatusDetect - Capacitive sensing guidelines**
Application note, Document number 7093**[1]

[9] **NIST Special Publication 800-38B**
National Institute of Standards and Technology (NIST). Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication.
http://csrc.nist.gov/publications/nistpubs/800-38B/SP_800-38B.pdf

1 ** ... document version number

18 Revision history

Table 68. Revision history

Document ID	Release date	Data sheet status	Supersedes
NT2H2331S0 v.3.0	20220218	Product data sheet	NT2H2331S0 v.2.0
Modifications:	• Data sheet status changed to "Product data sheet", security status changed to "Company public"		
NT2H2331S0 v.2.0	20220205	Preliminary data sheet	NT2H2331S0 v.1.1
Modifications:	• Added value for "30h" in Table 23 • Updated formula for better fit between the absolute value of the measured capacitor between single and double measurement range in Section 8.6.3 • Editorial changes		
NT2H2331S0 v.1.1	20211220	Objective data sheet	NT2H2331S0 v.1.0
Modifications:	• Updated section "General description" (see Section 1) • Updated section "Applications" (see Section 3) • PGDW updated in section "Wafer specification" (see Table 66)		
NT2H2331S0 v.1.0	20211125	Objective data sheet	NT2H2331S0 v.0.7
Modifications:	• General update		
NT2H2331S0 v.0.7	28.10.2020	Objective data sheet	NT2H2331S0 v.0.6
Modifications:	• General update		
NT2H2331S0 v.0.6	28.09.2020	Objective data sheet	
Modifications:	• First draft		

19 Legal information

19.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

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Tables

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