

# MF1SPLUSx0y1

Mainstream contactless smart card IC for fast and easy solution development

Rev. 3.2 — 21 February 2011  
187032

Product short data sheet  
PUBLIC

## 1. General description

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Migrate classic contactless smart card systems to the next security level! MIFARE Plus brings benchmark security to mainstream contactless smart card applications. It is the only mainstream IC compatible with MIFARE Classic 1K (MF1ICS50) and MIFARE Classic 4K (MF1ICS70) which offers an upgrade path for existing infrastructures and services.

After the security upgrade, MIFARE Plus uses AES-128 (Advanced Encryption Standard) for authentication, data integrity and encryption. MIFARE Plus is based on open global standards for both air interface and cryptographic methods at the highest security level.

MIFARE Plus is available in two versions: MIFARE Plus S and MIFARE Plus X.

- The MIFARE Plus S (MF1SPLUSx0y1, described in this data sheet) is the standard version for straight forward migration of MIFARE Classic systems. It is configured to offer high data integrity.
- The MIFARE Plus X (MF1PLUSx0y1) offers more flexibility to optimize the command flow for speed and confidentiality. It offers a rich feature set including proximity checks against relay attacks.

## 2. Features and benefits

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- 2 kB or 4 kB EEPROM
- Simple fixed memory structure compatible with MIFARE Classic 1K and MIFARE Classic 4K
- Memory structure identical to MIFARE Classic 4K (sectors, blocks)
- Access conditions freely configurable
- Supports ISO/IEC 14443 Type A<sup>1</sup> UIDs (4-byte UID, 4 Byte NUID, 7-byte UID), optional support of random IDs
- Multi-sector authentication, Multi-block read and write
- AES-128 used for authenticity and integrity
- Anti-tearing mechanism for writing AES keys
- Keys can be stored as MIFARE CRYPTO1 keys (2 × 48-bit per sector) and as AES keys (2 × 128-bit per sector)
- Basic support of virtual card concept
- Communication speed up to 848 kbit/s

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1. ISO/IEC 14443-x used in this data sheet refers to ISO/IEC 14443 Type A.



- Number of single write operations: 200000 cycles (typical)
- Common Criteria Certification: EAL4+

### 3. Applications

- Public transportation
- Access management such as employee, school or campus cards
- Electronic toll collection
- Closed loop micro payment
- Car parking
- Internet cafés
- Loyalty programs

### 4. Quick reference data

**Table 1. Quick reference data**

| Symbol                        | Parameter         | Conditions  | Min      | Typ    | Max   | Unit  |
|-------------------------------|-------------------|---|----------|--------|-------|-------|
| $C_i$                         | input capacitance | $T_{amb} = 22\text{ °C}$ ; $f_i = 13.56\text{ MHz}$ ; $2.8\text{ V RMS}$                              | [1] 15.0 | 17.0   | 19.04 | pF    |
| $f_i$                         | input frequency   |   | -        | 13.56  | -     | MHz   |
| <b>EEPROM characteristics</b> |                   |   |          |        |       |       |
| $t_{ret}$                     | retention time    | $T_{amb} = 22\text{ °C}$  | 10       | -      | -     | year  |
| $N_{endu(W)}$                 | write endurance   | $T_{amb} = 22\text{ °C}$ ; excluding anti-tearing for AES keys or sector trailers in security level 3 | 100000   | 200000 | -     | cycle |

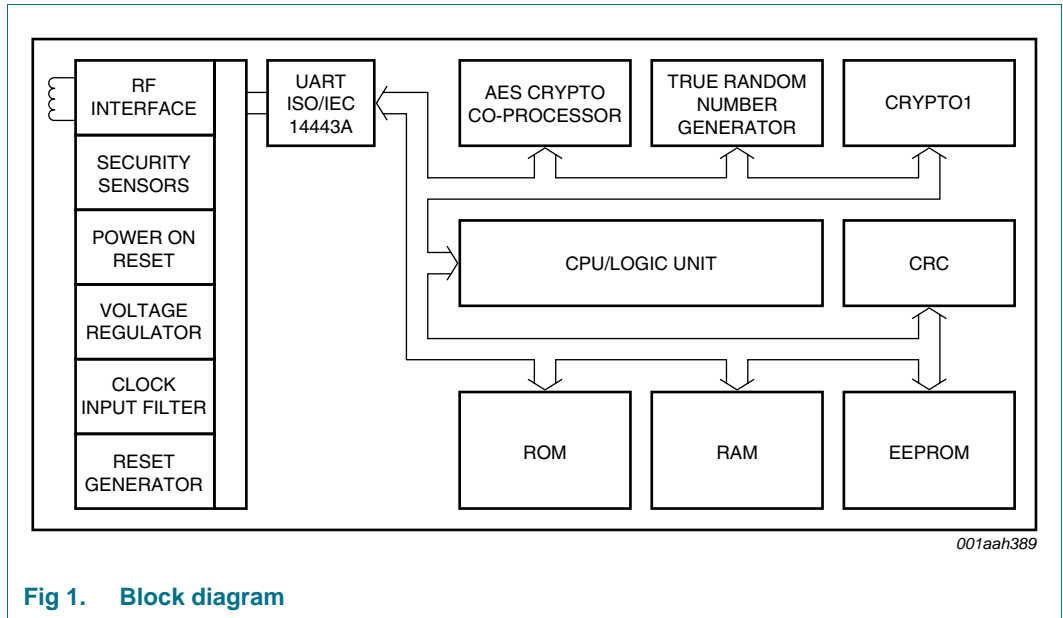
[1] Measured with LCR meter.

## 5. Ordering information

Table 2. Ordering information

| Type number        | Package         |       |  |          |
|--------------------|-----------------|-------|--|----------|
|                    | Commercial Name | Name  | Description  | Version  |
| MF1SPLUS8001DUD/03 | FFC             | -     | 8 inch wafer (sawn; 120 µm thickness, on film frame carrier; electronic fail die marking according to SECS-II format) see <a href="#">Ref. 3</a> , 4 kB EEPROM, 7-byte UID | -        |
| MF1SPLUS8011DUD/03 | FFC             | -     | 8 inch wafer (sawn; 120 µm thickness, on film frame carrier; electronic fail die marking according to SECS-II format) see <a href="#">Ref. 3</a> , 4 kB EEPROM, 4-byte UID | -        |
| MF1SPLUS8031DUD/03 | FFC             | -     | 8 inch wafer (sawn; 120 µm thickness, on film frame carrier; electronic fail die marking according to SECS-II format), 4K EEPROM, 4-byte NUID                              | -        |
| MF1SPLUS8001DA4/03 | MOA4            | PLLMC | plastic leadless module carrier package; 35 mm wide tape, 4 kB EEPROM, 7-byte UID  | SOT500-2 |
| MF1SPLUS8011DA4/03 | MOA4            | PLLMC | plastic leadless module carrier package; 35 mm wide tape, 4 kB EEPROM, 4-byte UID  | SOT500-2 |
| MF1SPLUS8031DA4/03 | MOA4            | PLLMC | plastic leadless module carrier package; 35 mm wide tape, 4K EEPROM, 4-byte NUID   | SOT500-2 |
| MF1SPLUS6001DUD/03 | FFC             | -     | 8 inch wafer (sawn; 120 µm thickness, on film frame carrier; electronic fail die marking according to SECS-II format) see <a href="#">Ref. 3</a> , 2 kB EEPROM, 7-byte UID | -        |
| MF1SPLUS6011DUD/03 | FFC             | -     | 8 inch wafer (sawn; 120 µm thickness, on film frame carrier; electronic fail die marking according to SECS-II format) see <a href="#">Ref. 3</a> , 2 kB EEPROM, 4-byte UID | -        |
| MF1SPLUS6031DUD/03 | FFC             | -     | 8 inch wafer (sawn; 120 µm thickness, on film frame carrier; electronic fail die marking according to SECS-II format), 2K EEPROM, 4byte NUID                               | -        |
| MF1SPLUS6001DA4/03 | MOA4            | PLLMC | plastic leadless module carrier package; 35 mm wide tape, 2 kB EEPROM, 7-byte UID  | SOT500-2 |
| MF1SPLUS6011DA4/03 | MOA4            | PLLMC | plastic leadless module carrier package; 35 mm wide tape, 2 kB EEPROM, 4-byte UID  | SOT500-2 |
| MF1SPLUS6031DA4/03 | MOA4            | PLLMC | plastic leadless module carrier package; 35 mm wide tape, 2K EEPROM, 4-byte NUID   | SOT500-2 |

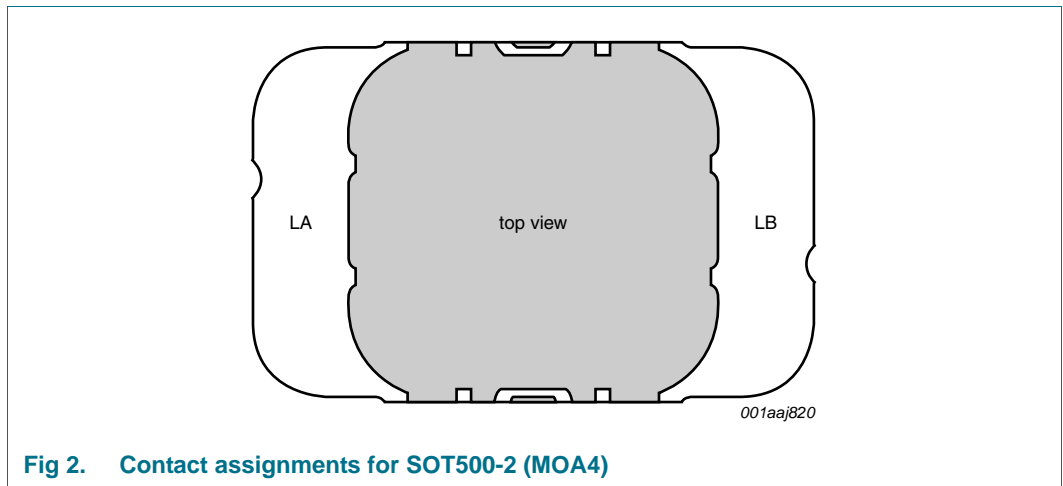
**6. Block diagram**



**Fig 1. Block diagram**

**7. Pinning information**

**7.1 Smart card contactless module**



**Fig 2. Contact assignments for SOT500-2 (MOA4)**

**Table 3. Bonding pad assignments to smart card contactless module**

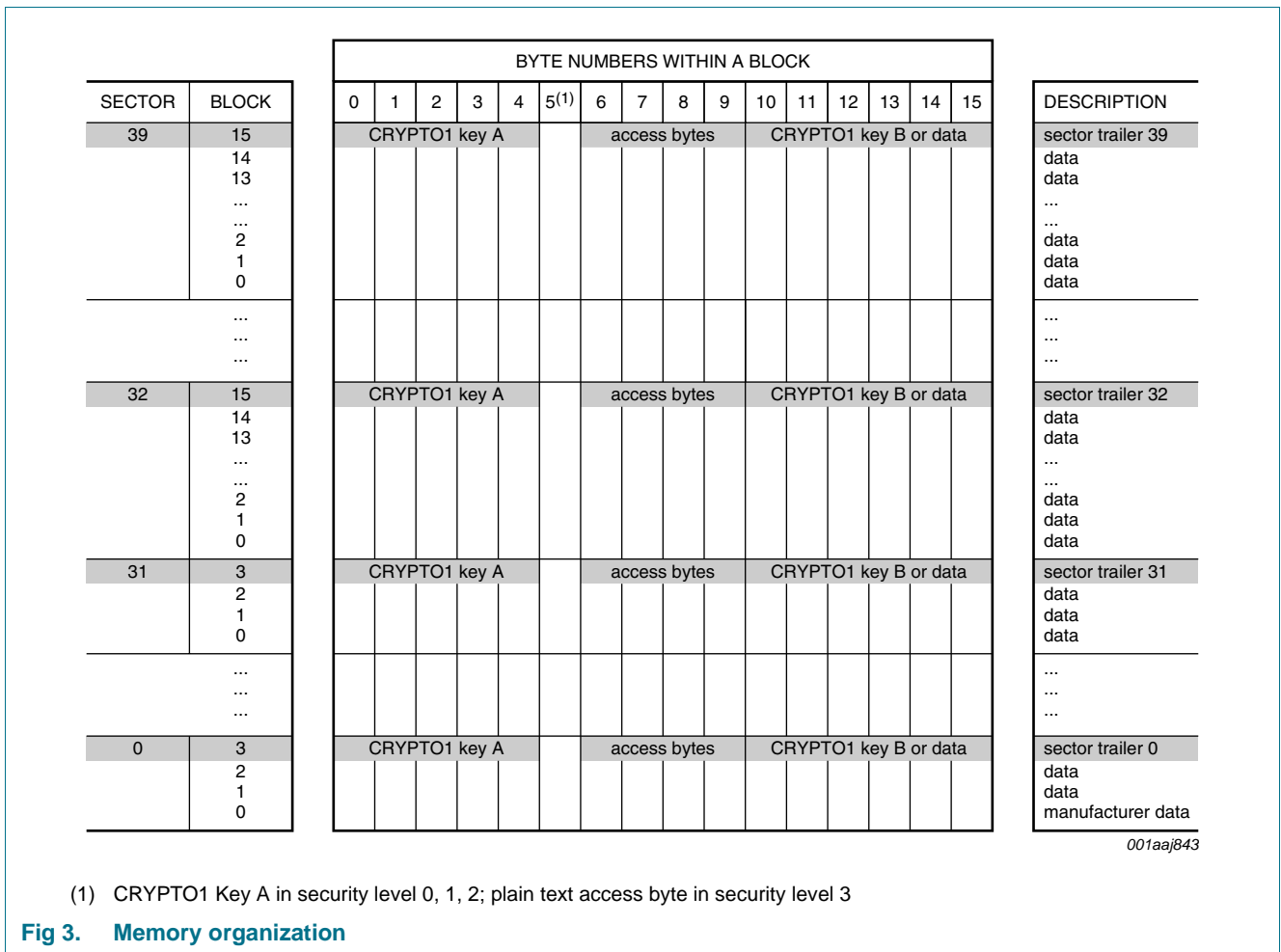
| Contactless interface module |        | MF1SPLUSx0y1DA4/z3         |
|------------------------------|--------|----------------------------|
| Antenna contacts             | Symbol | Description                |
| LA                           | LA     | antenna coil connection LA |
| LB                           | LB     | antenna coil connection LB |

## 8. Functional description

### 8.1 Memory organization

The 4 kB EEPROM memory (MF1SPLUS80x) is organized in 32 sectors of 4 blocks and in 8 sectors of 16 blocks. The 2 kB EEPROM memory (MF1SPLUS60x) is organized in 32 sectors of 4 blocks.

One block consists of 16 bytes.



#### 8.1.1 Manufacturer block

The first data block (block 0) of the first sector (sector 0) contains the PICC manufacturer data. This block is programmed and write protected at production test.

#### 8.1.2 Data blocks

Sectors 0<sub>D</sub> to 31<sub>D</sub> contain 3 blocks each and sectors 32<sub>D</sub> to 39<sub>D</sub> contain 15 blocks for data storage. The data blocks can be configured using the access bits as:

- read/write blocks for storing binary data
- value blocks (only available in security level 1)

Value blocks are special counters where the stored value can be manipulated with specific commands such as MF Increment, MF Decrement and MF Transfer.

These value blocks have a fixed data format enabling error detection and correction with backup management to be performed. Value blocks are only available in security level 1.

A successful mutual authentication is required to allow any data operation.

#### 8.1.2.1 Access conditions

The access conditions for every data block and the sector trailer itself are stored in the sector trailer of the corresponding sector.

The access bits control the rights of memory operations using the secret keys A and B. The access conditions may be altered after authentication with the relevant key and the current access condition allows this operation.

Furthermore, value blocks are configured using the access bits.

#### 8.1.3 AES keys

AES keys are not shown in the memory map. The keys are stored on top of the other data and can be updated and used by referencing the so-called Key Number. In security level 3, anti-tearing is supported for the update of AES keys as well as for the update of the sector trailer. This anti-tearing mechanism is done by the PICC itself. The EEPROM stays in a defined status, even if the PICC is removed from the electromagnetic field during the write operation.

#### 8.1.4 Multi-sector authentication

A new feature has been provided in security level 3 for data which is spread over multiple sectors to improve transaction performance.

Providing that such sectors are secured with identical keys (key value and key type) only one authentication is required to read and/or write data from these sectors. There is no need to re-authenticate when accessing any data within these sectors. Therefore it is possible to configure a card in such a way that operating with only one authentication is needed in security level 3 to access all sectors.

#### 8.1.5 Originality function

The originality function is implemented by an AES authentication with the originality key. The authentication is performed in ISO/IEC 14443-4 protocol layer.

### 8.2 Card activation and communication protocol

The ISO/IEC 14443-3 anticollision mechanism allows for simultaneous handling of multiple PICCs in the field. The anticollision algorithm selects each PICC individually and ensures that execution of a transaction with a selected PICC is performed correctly without data corruption from other PICCs in the field.

There are three different versions of the PICC. The UID is programmed into a locked part of the NV-memory which is reserved for the manufacturer:

- unique 7-byte serial number
- unique 4-byte serial number
- non-unique 4-byte serial number

Due to security and system requirements, these bytes are write-protected after being programmed by the PICC manufacturer at production.

**Remark:** The programmed 4-byte NUID serial number is not globally unique which has to be considered in the contactless system design. See [Ref. 11](#) for further information regarding handling of UIDs.

The customer must decide which UID length to use when ordering the product, see [Table 2](#) for ordering information.

During personalization, the PICC can be configured to support Random ID in security level 3. The user can configure whether Random ID or fixed UID shall be used. According to ISO/IEC 14443-3 (see [Ref. 5](#)), the first anticollision loop returns the Random Number Tag 08h, the 3-byte Random Number and the BCC, if Random ID is used. The retrieval of the UID in this case can be done using the Virtual Card Support Last command (see [Ref. 3](#)) or by reading out block 0.

### 8.2.1 Backwards compatibility protocol

The backwards compatibility of this product, as used in security level 1 and security level 2, runs on the same protocol layer as MIFARE Classic 1K and MIFARE Classic 4K. The protocol is formed out of the following components:

- Frame definition: according to ISO/IEC 14443-3
- Bit encoding: according to ISO/IEC 14443-2
- Error code handling: handling is proprietary as error codes are formatted in half bytes.
- Command specification: commands are proprietary. Please use the specification as in [Ref. 1](#) and [Ref. 2](#) and the additional commands which are only implemented in MIFARE Plus as described in this document and in [Ref. 3](#).

The following security levels can run on this protocol:

- Security Level 0
- Security Level 1

### 8.2.2 ISO/IEC 14443-4 Protocol

The ISO/IEC 14443-4 Protocol (also known as T=CL) is used in many processor cards. This protocol is used for the MIFARE Plus with the following security levels:

- Security Level 0: all commands
- Security Level 1: only the security level switch and originality function.
- Security Level 3: all commands

### 8.3 Security level switching

The MIFARE Plus S offers a unique feature to support migration from CRYPTO1 based systems to AES based operation. The migration on the card-side is done using different security levels supporting different cryptographic algorithms and protocols. There are three security levels:

- Security level 0: initial delivery configuration, used for card personalization
- Security level 1: backwards functional compatibility mode (with MIFARE Classic 1K and MIFARE Classic 4K) with an optional AES authentication
- Security level 3: 3-Pass authentication based on AES, data manipulation commands secured by AES encryption and an AES based MACing method.

The security level switching (i.e. from security level 1 to security level 3) is performed using the dedicated AES authentication switching keys.

The security level can only be switched from a lower level to a higher level, never in the opposite direction.

### 8.4 Security level 0

Security level 0 is the initial delivery configuration of the PICC. The card can be operated either using the backwards compatibility protocol or the ISO/IEC 14443-4 protocol.

In this level, the card can be personalized including the programming of user data as well as of CRYPTO1 and/or AES keys. In addition, the originality function can be used.

The following mandatory AES keys need to be written using the Write Perso command before the PICC can be switched to security level 1 or security level 3 (for L3 card).

Security level switching is performed using the Commit Perso command:

- Card Configuration Key
- Card Master Key
- Level 3 Switch Key

Using the originality function, it is possible to verify that the chip is a genuine NXP Semiconductors MIFARE Plus.

### 8.5 Security level 1

Security level 1 offers the same functionality as a MIFARE Classic 1K and MIFARE Classic 4K using the backwards compatibility protocol. The MIFARE Classic 1K and MIFARE Classic 4K products are specified in [Ref. 1](#) and [Ref. 2](#).

Furthermore, an optional AES authentication is available in this level without affecting the MIFARE Classic 1K and MIFARE Classic 4K functionality. The authenticity of the card can be proven using strong cryptographic means with this additional functionality.

The timings may differ from the MIFARE Classic 1K and MIFARE Classic 4K products.

Using the originality function, it is possible to verify that the chip is a genuine NXP Semiconductors MIFARE Plus.



## 8.6 Security level 3

The operation in security level 3 is solely based on the ISO/IEC 14443-4 protocol layer. The usage of the backwards compatibility protocol is not possible.

In security level 3, a mandatory AES authentication between PICC and reader is conducted, where two keys are generated as a function of the random numbers from the PICC and the reader as well as of the shared key. These two session keys are used to secure the data which is exchanged on the interface between the card and reader. One of the two keys is used to ensure the confidentiality of the command and the response while the other key ensures the integrity of the command and the response.

All commands carry a MAC, such that the PICC will only accept commands from the reader with which it is authenticated. Tampering of operands and messages is detected by checking the MAC. Also all responses contain a MAC, so that the reader on each response knows that neither the command nor the response has been tampered with.

Each response carries a MAC. When the appropriate MAC is received, due to linking of MACs, the reader knows that the command and commands before it was properly executed.

All commands between two consecutive first authenticate commands belong to one transaction and the MACing mechanism assures integrity of the whole transaction.

## 9. Look-up tables

### 9.1 Security level 0, 1, 3: ISO/IEC 14443-3

Table 4. ISO/IEC 14443-3

| Command   | Description  |
|---|--|
| REQA  | the REQA and ATQA commands are fully implemented according to ISO/IEC 14443-3.   |
| WUPA  | the WAKE-UP command is fully implemented according to ISO/IEC 14443-3.   |
| ANTICOLLISION/SELECT cascade level 1                        | the ANTICOLLISION and SELECT commands are fully implemented according to ISO/IEC 14443-3. The response is part 1 of the UID. |
| ANTICOLLISION/SELECT cascade level 2 for 7 byte UID version | the ANTICOLLISION and SELECT commands are fully implemented according to ISO/IEC 14443-3. The response is part 2 of the UID. |
| HALT  | the HALT command is fully implemented according to ISO/IEC 14443-3   |

## 9.2 Security level 0, 1, 3: ISO/IEC 14443-4

Table 5. ISO/IEC 14443-4

| Command  | Description   |
|----------|---|
| RATS     | the response to the RATS command identifies the PICC type to the PCD.   |
| PPS      | the PPS command allows an individual selection of the communication baud rate between PCD and PICC. It is possible for the MF1SPLUSx0y1 to individually set the communication baud rate independently of each other for both directions i.e. MF1SPLUSx0y1 allows a non-symmetrical information interchange speed. |
| DESELECT | deselection according to ISO/IEC 14443-4  |

Please find more information on ISO/IEC 14443 in [Ref. 5](#) as well as on the settings of ATQA, SAK and ATS in [Ref. 4](#).

## 9.3 Security level 0 command overview

Table 6. Security level 0 command overview

| Command                         | Description                                    |
|---------------------------------|--|
| Write Perso                     | pre-personalization of AES keys and all blocks |
| Commit Perso                    | switch to security level 1                     |
| First Authenticate (part 1)     | first authenticate                             |
| Following Authenticate (part 1) | following authenticate                         |
| Authenticate (part 2)           | second authentication step                     |

## 9.4 Security level 1 command overview

Table 7. Security level 1 command overview

| MF1ICS50, MF1ICS70, MF1ICS20 commands | Description               |
|---------------------------------------|---------------------------|
| MF Authenticate key A                 | authentication with key A |
| MF Authenticate key B                 | authentication with key B |
| MF Read                               | reading data              |
| MF Write                              | writing data              |
| MF Increment                          | incrementing a value      |
| MF Decrement                          | decrementing a value      |
| MF Restore                            | restoring a value         |
| MF Transfer                           | transferring a value      |

### Commands using backwards compatibility protocol, see [Section 8.2.1](#)

|                                 |   |
|---------------------------------|---|
| Following Authenticate (part 1) | following authenticate; protocol used as described in <a href="#">Section 8.2.1</a>     |
| Authenticate (part 2)           | second authentication step; protocol used as described in <a href="#">Section 8.2.1</a> |

Table 7. Security level 1 command overview ...continued

| MF1ICS50, MF1ICS70,<br>MF1ICS20 commands   | Description                |
|--|----------------------------|
| <b>Command set for security level switch and originality function using ISO/IEC 14443-4 protocol</b> |                            |
| First Authenticate (part 1)  | first authenticate         |
| Following Authenticate (part 1)  | following authenticate     |
| Authenticate (part 2)  | second authentication step |

## 9.5 Security level 3 command overview

Table 8. Security level 3 command overview

| Command                         | Description   |
|---------------------------------|---|
| <b>MIFARE Plus commands</b>     |   |
| First Authenticate (part 1)     | first authenticate  |
| Following Authenticate (part 1) | following authenticate  |
| Authenticate (part 2)           | second authentication step  |
| ResetAuth                       | reset the authentication step   |
| <b>READ commands</b>            |   |
| Read Plain MACed                | reading in plain, MAC on response, MAC on command   |
| <b>WRITE commands</b>           |   |
| Write MACed                     | writing encrypted, MAC on response, MAC on command  |
| Write Plain MACed               | writing in plain, MAC on response, MAC on command   |
| <b>Virtual card concept</b>     |   |
| Virtual Card Support Last       | check if the virtual card concept is supported, communicate PCD capabilities and retrieve the UID |
| Deselect Virtual Card           | deselect the virtual card   |

## 10. Limiting values

Table 9. Limiting values

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

| Symbol         | Parameter                           | Conditions | Min  | Max <sup>[1][2]</sup> | Unit |
|----------------|-------------------------------------|------------|------|-----------------------|------|
| $I_I$          | input current                       |            | -    | 30                    | mA   |
| $P_{tot}/pack$ | total power dissipation per package |            | -    | 200                   | mW   |
| $T_{stg}$      | storage temperature                 |            | -55  | 125                   | °C   |
| $T_{amb}$      | ambient temperature                 |            | -25  | 70                    | °C   |
| $V_{ESD}$      | electrostatic discharge voltage     | [3]        | 2    | -                     | kV   |
| $I_{lu}$       | latch-up current                    |            | ±100 | -                     | mA   |

[1] Stresses above one or more of the limiting values may cause permanent damage to the device.

[2] Exposure to limiting values for extended periods may affect device reliability.

[3] MIL Standard 883-C method 3015; Human body model: C = 100 pF, R = 1.5 kΩ.

## 11. Abbreviations

Table 10. Abbreviations and symbols

| Acronym | Description  |
|---------|--|
| AES     | Advanced Encryption Standard                           |
| EEPROM  | Electrically Erasable Programmable Read-Only Memory    |
| LCR     | L = inductance, Capacitance, Resistance (LCR meter)    |
| MAC     | Message Authentication Code                            |
| NUID    | Non-Unique IDentifier                                  |
| NV      | Non-Volatile memory                                    |
| PCD     | Proximity Coupling Device (Contactless Reader)         |
| PICC    | Proximity Integrated Circuit Card (Contactless Card)   |
| PPS     | Protocol Parameter Selection                           |
| RATS    | Request Answer To Select                               |
| REQA    | REQuest Answer   |
| SAK     | Select AcKnowledge, type A                             |
| SECS-II | SEMI Equipment Communications Standard part 2          |
| UID     | Unique IDentifier                                      |
| VC      | Virtual Card, one MIFARE Plus PICC is one virtual card |
| WUPA    | Wake-Up Protocol type A                                |

## 12. References

- [1] **Data sheet** — MF1ICS50 Functional specification, BU-ID Doc. No. 0010\*\*2.
- [2] **Data sheet** — MF1ICS70 Functional specification, BU-ID Doc. No. 0435\*\*.
- [3] **Data sheet** — M1PLUSx0y1 MIFARE Plus functional specification, BU-ID Doc. No. 1637\*\*.
- [4] **Application note** — MIFARE Type identification procedure, BU-ID Doc. No. 1843\*\*.
- [5] **Application note** — ISO 14443 PICC selection, BU-ID Doc. No. 1308\*\*.
- [6] **NIST Special Publication 800-38A** — Recommendation for block cipher modes of operation: methods and techniques, 2001.
- [7] **NIST Special Publication 800-38B** — Recommendation for block cipher modes of operation: The CMAC mode for authentication.
- [8] **ISO/IEC Standard** — ISO/IEC 14443 Identification cards - contactless integrated circuit cards - proximity cards.
- [9] **FIPS PUB 197 ADVANCED ENCRYPTION STANDARD** — Recommendation for block cipher modes of operation: Methods and techniques.
- [10] **ISO/IEC Standard** — ISO/IEC 9797-1 Information technology - security techniques - Message Authentication Codes (MACs) - Part 1: Mechanisms using a block cipher.
- [11] **MIFARE and handling of UIDs** — Application note, BU-ID Document number 1907\*\*[2](#)

2. \*\* ... document version number

## 13. Revision history

Table 11. Revision history

| Document ID            | Release date   | Data sheet status        | Change notice | Supersedes          |
|------------------------|--|--------------------------|---------------|---------------------|
| MF1SPLUSX0Y1_SDS v.3.2 | 20110221   | Product short data sheet | -             | MF1SPLUSX0Y1_SDS_31 |
| Modifications:         | <ul style="list-style-type: none"><li>Added description and ordering information for NUID Types in <a href="#">Section 2</a>, <a href="#">Section 5</a> and <a href="#">Section 8.2</a>.</li></ul> |                          |               |                     |
| MF1SPLUSX0Y1_SDS_31    | 20100419   | Product short data sheet | -             | 187030              |
| Modifications:         | <ul style="list-style-type: none"><li>Minor text and standardization modifications.</li></ul>  |                          |               |                     |
| 187030                 | 20100211   | Product short data sheet | -             | -                   |

## 14. Legal information

### 14.1 Data sheet status

| Document status <sup>[1][2]</sup> | Product status <sup>[3]</sup> | 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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