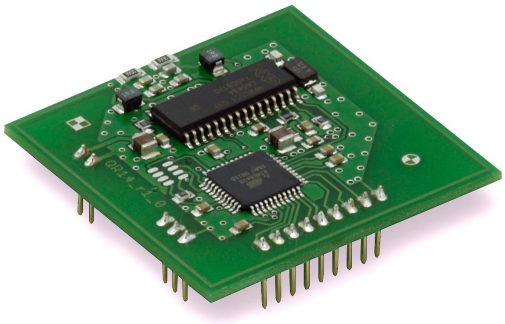
Protocol Guide

for metraTec Readers and Modules using MIFARE® Technology
Firmware version r2.11



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List of Abbreviations

ATQA	Answer to request, ISO 14443A – a number code showing some information on the card. See Appendix for examples.
PICC	Proximity IC Card (the official word for transponder card)
SAK	„Select Acknowledge“ – a number code showing some information on the card, e.g. type of card, etc. See Appendix for examples.
UID	Unique ID (of every ISO14443 Transponder)
SL0 / SL1 / SL2 /SL3:	Security level 0-3 (MIFARE Plus® Protocol)

1. Introduction

This document describes the metraTec firmware protocol for all metraTec RFID readers that work with RFID transponders according to ISO14443A/MIFARE® protocols MIFARE Classic, MIFARE Ultralight®, MIFARE DESFire®, and MIFARE Plus®.(by NXP B. V.). This includes the DeskID MF USB, the QR14 OEM module as well as several custom reader units.
The target audience for this document are programmers, who need to communicate with the reader and want to write their own software for this task. This software can be written in any programming language, such as C#, Java, Delphi, Ansi-C, and even directly in IEC/EN (6)1131-3 Code, e.g. with CoDeSys.

The reader firmware offers an ASCII based programming interface. The instructions are identified by an easy to remember, three character string usually followed by mandatory parameters and/or optional parameters. The response format depends on the type and result of an instruction.

This manual starts with all commands that the reader supports. These instructions are divided into several main groups:

- Reader Instructions
- Tag Manipulation Instructions, divided into:
  - General ISO14443A instructionsspecific commands of the MIFARE Classic protocol

All Instructions have Error-Codes which are described in the Appendix. The Appendix also includes further information on the memory structure and security model of transponders using MIFARE technology, including access rights and access key – a topic that can be quite complex. If you haven't worked with ISO14443A or transponders using MIFARE technology before, you should read this first.

1.1. General Procedure

The general process for reading or writing data to or from a transponder using MIFARE technology is always the same and consists of the following steps. While there might be several ways to complete the same task including more complex ones, the following list shows the easiest and quickest way:

1. Save the right key to use in the reader crypto unit, using the STK command. This is only necessary if the correct key has not been permanently stored in the reader using the SSK command before.
2. Tell the reader which key to use (Temp Key or one of the up to 24 permanent keys) using the SKU command.
3. Use an inventory command (INV) to find all cards in the field. The result will give you the UIDs of all the transponders in the field.
4. Select the card you want to use with the SEL command – either manually by using the UID you got in the step before or by using the automatic mode.
5. To use Iso14443A-4 commands (SL1,2,3 for MIFARE Plus protocol) send RATS
6. After activating the card with the select command / RATS command you have to authenticate to the block you want to read/write data to/from using the AUT command.

7. If successful, you can start reading and writing data to the memory of the transponder using the RDT (read date) or write data (WDT) command.

1.2. Further Documents

For an even deeper understanding of the operating principle it might be useful to read all datasheets and norms regarding your transponder IC, esp. ISO 14443-3.

2. Communication Principle

The communication between the reader and the host system is based on ASCII strings. Each string is terminated with a carriage-return and will be transmitted with MSB fist.

NOTE

Please make sure that you really send a carriage-return character as the last character – not more and not less. Many programs (including Hyperterm and some Unix/Linux programs) use carriage-return + line-feed as end of line character which leads to problems after the first command, since the LF is treated as first character of the following command which results in the error „unknown command" (UCO).

The communication from the reader to the host system (i.e. the response) is the same as above but in most cases the response from the reader comprises more than one line.

General line:

```
Instruction<SPACE>Parameter<Space>Parameter<CR>
```

Example without Parameter:

```
REV<CR>
```

in ANSI C:

char Rev[4] = {'R','E','V',13};

The first values which will be sent is 'R' (52h), followed by 45h, 56h, 0dh. Some instructions may be specified with parameters, which are separated by a space (20h).

Example with Parameter

```
INV<SPACE>SSL<CR>
```

char Inv[8] = {'I','N','V',0x20,'S', 'S', 'L' ,0x0D};

2.1. Helpful Tools

For debugging purpose it is very helpful to use a program to "sniff" the communication between the host and the reader. Depending on the type of communication and hardware you use, this could be:

- If you communicate via a (real or virtual) COM-Port: a Com-Port Monitor (several free version available in the net for 32bit systems)
- If you use Ethernet or other TCP/IP-based communication, like WiFi: a packet sniffing tool, e.g. wireshark/ethereal, which is available for almost every platform

- If you use a direct UART connection or something at a similar low level: a hardware logic analyzer

3. Reader Instructions

This list gives an overview of all the existing instructions that directly influence the reader itself. All commands that are connected to the transponder, can be found in the next chapter.

Command	Name	Description
RST	Reset	Resets the Reader
REV	Revision	Returns hardware and software version
RSN	Read Serial Number	Returns the serial Number, format JJJJMMDDHHMMSS01
STB	Standby	Sends the reader into standby/sleep mode for power saving
WAK	Wake Up	Ends standby/sleep mode
RIP	Read Input Pin	Reads the state of an input pin
WOP	Write Output Pin	Writes the state of an output pin
CON	CRC on	Turns on CRC checking of computer / reader communication
COF	CRC off	Turns off CRC checking of computer / reader communication
EOF	End of Frame	Turns on the End of Frame Delimiter
NOF	No End of Frame	Turns off the End of Frame Delimiter
SSK	Set Static Key	Saves up to 24 keys in the EEPROM of the reader
STK	Set Temporary Key	Save one key in the readers master key buffer
SKU	Set Key to Use	Sets which key should be used to authenticate a tag
VBL	Verbose Level	Use this to set different amounts of responses
SRF	Set RF Signal	Allows you to control the RF signal in more detail
MOD	Set Mode	Switches between MIFARE Classic and MIFARE Plus protocol SL0/1/3

Table 1: Overview of reader manipulation instructions

3.1. Reset (RST)

The reset command resets the reader. The Reset command has no parameters. After sending the RST command the HF power is turned off and the reader has to be initialized again.

Instruction:

```
RST<CR>
```

Response, if successful:

```
OK!<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.2. Revision (REV)

The revision command requests the device type and hard- and software revision of the reader. The reader returns its device type and it's hard- and software revision. Revision has no parameters and returns no error codes.

Instruction:

```
REV<CR>
```

Response, if successful:

```
PRODUCT_NAME<SPACE>HW_revision[4bytes]SW_revision[4bytes]<CR>
```

15 Bytes product name (filled with Spaces) + 4 bytes HW-Revision + 4 Bytes Software-Revision + <CR>

Possible Error Response:

```
UPA<CR>
```

Example for a response:

```
DESKID_ISO<5 Times Space>01000101<CR>
```

Interpretation: Product name: DESKID_ISO

Hardware-Revision: 01.00

Software-Revision: 01.01

3.3. Read Serial Number (RSN)

The RSN command gets the serial number of the Reader. It will be printed via Uart interface can be needed for support reasons and has the form JJJJMMDDHHMMSS01 (Date and Time stamp).

3.4. Standby (STB)

The standby command sets the reader in a power save mode. The RF power is turned off. This means that all tags that might be in the field will also be powered down. If successful it returns GN8 (“Good Night”). The reader will not accept any commands except reset (RST) until a Wake Up Command (WAK) is received. Standby has no parameters. Standby saves the antenna state. After wake it will be active or inactive like before. During Standby it is inactive anyway.

Instruction:

```
STB<CR>
```

Response, if successful:

```
GN8<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.5. Wake Up (WAK)

The wake up command ends the power save mode. Reader will restore its last state prior to the standby. If successful it returns GMO (“Good Morning”). Wake up has no parameters.

Instruction:

```
WAK<CR>
```

Response, if successful:

```
GMO<CR>, DNS<CR> (if not in Standby-Mode)
```

Possible Error Response:

```
UPA<CR>
```

3.6. Read Input Pin (RIP)

This command is used to read the current state of an input pin. It takes one parameter, which is the two-digit, hex-coded, zero-based number of the input pin to be read. The possible parameter range is 00 to 01.

If successful, it returns either HI! or LOW depending on whether the input pin is high or low. Not supported by every reader (NOS error).

Instruction:

`RIP<SPACE>Pin_No<CR>`

e.g. (to read the first input pin): RIP 00<CR>

Response, if successful:

`HI!<CR>` for High-State

`LOW<CR>` for Low-State

Possible Error Response:

`NOR<CR>, EHX<CR>, UPA<CR>, NOS<CR>`

3.7. Write Output Pin (WOP)

This command is used to set the state of an output pin either to high or to low. It takes two parameters. The first parameter is the two-digit, hex-coded, zero-based number of the output pin to be written to. The second parameter is either "HI" or "LOW" to set the according pin to high or low respectively. The possible parameter range is 00 to 03. Not supported by every reader (NOS error).

Instruction:

`WOP<SPACE>Pin_No<SPACE>PIN_Setting<CR>`

e.g. Set pin 0 high: `WOP<SPACE>00<SPACE>HI<CR>`

e.g. Set pin 0 low: `WOP<SPACE>00<SPACE>LOW<CR>`

Response, if successful:

`OK!<CR>`

Possible Error Response:

`NOR<CR>, EHX<CR>, UPA<CR>, NOS<CR>`

3.8. Cyclic Redundancy Check On (CON)

This commands turns on the Cyclic Redundancy Check (CRC) of the computer-to-reader communication. This is used to detect transmission errors between the reader and the computer. In general this feature is not necessary except in scenarios where you have lots of noise on the communication bus (e.g. when using USB communication in the vicinity of electric motors) or you encounter any other problems with communication errors.

If this feature is activated (default is off), the reader firmware expects a CRC16 (4 hex numbers) between all commands to the reader and the respective <CR>. Between the command and the CRC there is a space character which is included in the CRC calculation. All answers from the reader will also be extended accordingly. The CRC used uses the 8408 polynomial, starting value is 0xFFFF. This command will work with or without the (optional) CRC.

If successful the command returns OK! plus the according CRC of "OK! ".

Appendix 1 shows a function in C/C++ to calculate the correct CRC16.

Instruction:

```
CON<CR>
```

or:

```
CON 819E<CR>, con 2EC5<CR>
```

Response, if successful:

```
OK! 9356<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.9. Cyclic Redundancy Check Off (COF)

This command turns off the Cyclic Redundancy Check (CRC) of the computer-to-reader communication. This is the default setting. This command will work with or without the (optional) CRC.

If successful it returns OK!.

Instruction:

```
COF<CR>, or COF 4F5E<CR>, or cof E005<CR>
```

Response, if successful:

```
OK!<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.10. End of Frame Mode (EOF)

This command turns on the End of Frame Delimiter (EOF). This means that after every complete message (frame) the last CR will be followed by an additional line feed (LF, 0x0A). This allows the user to build simpler parsers since it is clear when no to expect any further message from the reader. The EOF returns on the end of any Instruction (<CR>) indifferent to actions done or answer and on any CNR mode answer. CNR INV itself gives no EOF answer of its own. It comes with the first Inventory. Please keep in mind: In case of a watchdog reset you get a SRT errorcode after the reset. This SRT is without the EOF because of the reset!

If successful it returns OK!.

Instruction:

```
EOF<CR>
```

Response, if successful:

```
OK!<CR><LF>
```

Possible Error Response:

```
UPA<CR>
```

3.11. No End of Frame Mode (NOF)

This command turns off the End of Frame Delimiter (NOF). Now all messages from the reader are only signaled by a CR at the end.

Instruction:

```
NEF<CR>
```

Response, if successful:

```
OK!<CR>   (no <LF>)
```

Possible Error Response:

```
UPA<CR>
```

3.12. Save Static Key (SSK)

The reader has a persistent memory which is able to save up to 24 keys for the MIFARE protocol Crypto1 unit. The static keys in the memory of the chip are not readable and are directly used by the Crypto1 unit of the reader. They will not be transmitted over the air interface.

Note: The sector no. is zero based

Instruction:

SSK<SPACE>[Loc]<SPACE>[Key]<CR>

Parameter	Description
Loc	Location where the key will be saved (0<=Loc<=23)
Key	6 Bytes ASCII-String (12 chars), LSB first

Table 2: Save Static Key parameter description

Response, if successful:

OK!<CR>

Examples:

Save the key 112233445566h in sector 0

SSK<SPACE>0<SPACE>112233445566<CR>

Save the key FFFFFFFFFFFFh in sector 23

SSK<SPACE>23<SPACE>FFFFFFFFFFFF<CR>

Possible Error Response:

UPA<CR> Unknown parameter

EDX<CR> Other characters than 0-9

EHX<CR> Key-Parameter is missing or other characters than 0-9 and A-F

WDL<CR> Key is not 6 bytes long

NOR<CR> Location given is higher than 23

3.13. Save Temporary Key (STK)

This command saves one key in the reader temporarily until a power down or a reset occurs. The only parameter is the Key to save, which is a 6 Byte ASCII String (12 Chars).

Instruction:

STK<SPACE>[Key]<CR>

Response, if successful:

OK!<CR>

Examples:

Save the key 112233445566h

STK<SPACE>112233445566<CR>

Possible error codes:

UPA<CR> Unknown parameter

EHX<CR> Key-Parameter is missing or other characters than 0-9 and A-F

WDL<CR> Key is not 6 bytes long

3.14. Set Key to Use (SKU)

The key which will be used to authenticate a chip resp. a block of a chip using MIFARE technology has to be selected with this command before using the standard authentification command (AUT). If the direct mode from the authentication command is used, this command is not necessary. The key can either be the temporary key or the static key.

Instruction:

SKU<SPACE>{Type}<SPACE>[Loc]<CR>

Parameter	Description
Type	The type of the key: TEMP chooses the temporary key STAT chooses one of the static keys by Loc
Loc	Use this parameter only with STAT-Parameter! Specifies the zero based location of the static key. See SSK command.

Table 3: Set Key to Use parameter description

Response, if successful:

OK!<CR>

Examples:

Use the temporary key

SKU<SPACE>TEMP<CR>

Use the static key in location 2

SKU<SPACE>STAT<SPACE>2<CR>

Possible error codes:

UPA<CR> Unknown parameter

EDX<CR> Location parameter missing or other characters than 0-9 given

NOR<CR> Location given is higher than 23

KNS<CR> Key Not Set (if temporary key is selected, but not set before)

3.15. Verbose Level (VBL)

Most metraTec modules send a lot of data to the host about different states, error responses or other data. While this is useful to understand exactly what the reader is doing, in some situations you only want a response from the reader when something important is happening. The VBL command gives you the possibility to set the amount of data coming from the reader to the level you need.

Instruction:

VBL<SPACE>[Mode in Decimal]<CR>

Modes:

0: Only send necessary data

1: Send all data (default)

2: Additionally give human readable tag type in SEL answer

Possible error codes:

UPA<CR> Unknown parameter

EDX<CR> Mode-Parameter is missing or other characters than 0-9 given

NOR<CR> Mode > 2

The following responses form the reader are suppresed in VBL Mode 0:

IVF<SPACE>XX<CR>

SAK<CR>

ATQA<CR>

Error Codes will still be sent in VBL Mode 0!

3.16. Set RF Signal (SRF)

This allows to control the the RF signal of the reader. Possible use is for resetting a card not properly responding by switching off the RF field, controlling read range by setting the output power or reducing the current consumption by decreasing the RF power transmitted by the reader. Power cycling or a firmware reset will restore the default values (full output power and RF on).

Instruction:

SRF<SPACE>Parameter<SPACE>(Time)<CR>

Modes:

OFF: This switches the RF signal off. All cards in the field are resetted. Current consumption goes down. Sending an INV command will turn the RF signal back on automatically. This is the state after start up.

ON: Turns the RF signal on manually.

TIM: Turns the RF signal off for the specified amount of time (in ms) and back on this can be used to reset cards with one command. Maximal value is 200ms. No instruction can be used while waiting for restart.

ROP: Sets the RF signal to the reduce output power level (100mW). This can be used to reduce the current consumption of the reader. It also reduces the read range.

FOP: Sets the RF signal back to full output power (350mW). Increases current consumption and read range. This is the default state.

Response, if successful:

OK!<CR>

Possible error codes:

UPA<CR>	Unknown parameter
NOR<CR>	Number out of Range (Tim with more than 200 ms)
EDX<CR>	Decimal error (TIM number with wrong format)
CRT<CR>	CR Timeout. New Command while in TIM waiting state

3.17. Set Card Mode (MOD)

This command switches the usable PICC commands, the used parameters and the executing of PICC commands. The MOD parameter to set depends on the used card type and security level (in case of a card using MIFARE Plus technology). Default is MIFARE Classic technology so the reader commands at startup are used as in previous releases. MIFARE Plus SL2 technology is not supported by now.

Instruction:

```
MOD<SPACE>Parameter<CR>
```

Modes:

MFC: MIFARE Classic protocol. This is the default mode and is used for MIFARE 1K / 4K Implementation and MIFARE Ultralight technology.

MP0: MIFARE Plus SL0: Commands WRP and COP supported. Used to set keys on a new PICC and to switch to SL1 (compatibility mode).

MPA: MIFARE Plus SL1 AES mode. Used to AES authenticate to a MIFARE Plus SL1 PICC. This may be used to check if a card is in SL1

MPC: MIFARE Plus SL1 Classic compatibility mode. Used just like MFC

MPI: MIFARE Plus SL1 Iso14443-4 mode. Used to activate Iso14443-4 with RATS and switch to SL3

MP3: MIFARE Plus SL3. Uses RATS command and AUT uses AES keys

Response, if successful:

```
OK!<CR>
```

Possible error codes:

`UPA<CR>` Unknown parameter

4. General ISO 14443A Commands

This list gives an overview of the existing commands that can be used with any transponder that is based on ISO14443A, including all protocols using MIFARE technology. Any commands that are specific to a certain type of MIFARE protocol can be found in the next chapter.

Command	Name	Description
INV	Inventory	Returns all UIDs from tags in read range
SEL	Select tag	Selects a tag
RDT	Read data	Get data from tag
WDT	Write data	Write Data to a tag
RATS	Request answer to select	Used to transition PICC from Iso14443-3 mode (after SEL) to Iso14443-4-mode needed for MIFARE Plus protocol

Table 4: *Overview of general ISO 14443A commands*

4.1. Inventory (INV)

This command returns all UIDs from ISO/IEC 14443-1 to 3 compatible transponder, which are in the read range of the reader. Only single and double UIDs are supported (all types of ISO14443A known today). The length of the response can either be 4 bytes (single) or 7 bytes (double). Triple UIDs will be supported as soon as there are tags with this kind of UID.

Instruction:

```
INV<CR>
```

Response, if successful:

The UIDs, separated by a carriage return:

```
UID1<CR>
```

```
UID2<CR>
```

...

The end is marked by the line:

```
IVF<SPACE>[Count]
```
(Count is the number of transponders found)

Example:

```
INV<CR>
```

Response:

C22E5732<CR>

328DA79C<CR>

IVF 02<CR>

Additional parameter: ONT (Only New Tags)

If you add the parameter ONT to the INV command only new tags will be reported.

Instruction:

INV<SPACE>ONT<CR>

Possible error codes:

UPA<CR>	Unknown parameter

4.2. Select Tag (SEL)

Before you can exchange data with a chip that uses MIFARE technology, the transponder has to be activated (or „selected" in the ISO14443 language). There are two different modes to select a card. Manual Transponder Select (MTS), which needs the UID of the transponder (normally via a previous INV command) or Automatic Transponder Select (ATS) which takes an UID saved by the last INV command. Only transponders with single or double UIDs are supported.

ATS and MTS mode return different informations!

Instruction:

SEL<SPACE>MTS<SPACE>[UID]<CR>

SEL<SPACE>ATS<CR>

Use the MTS mode to select a special card where the UID is known (usually by doing an INV before or because just one tag is used).

Use the ATS mode to fast select one tag or to cyclically select all tags. The tags need to be inventoried before.

Examples:

Select automatically (ATS)

SEL<SPACE>ATS<CR>

Select a MIFARE Classic 1K Card (single UID)

SEL<SPACE>MTS<SPACE> AC410094<CR>

Select a MIFARE Ultralight Card (double UID)

SEL<SPACE>MTS<SPACE> 047F77D18A0280<CR>

Response, if successful:

for ATS

[Human readable tag type (if VBL 2 mode)] for example "Mifare Classic 1/2K<CR>"

[ATQA]<CR> see Appendix for the ATQA codes of different chip versions

[SAK]<CR> see Appendix for the SAK codes of different chip versions. SAK length is 1 byte for short UIDs (4Bytes), 2 bytes for double length UID (7 bytes) and 3 bytes for triple length UIDs (10 bytes)

[UID]<CR>

for MTS

[Human readable tag type (if VBL 2 mode)] for example "Mifare Classic 1/2K<CR>"

[SAK]<CR> see Appendix for the SAK codes of different chip versions. SAK length is 1 byte for short UIDs (4Bytes), 2 bytes for double length UID (7 bytes) and 3 bytes for triple length UIDs (10 bytes)

Response example:

0400<CR>

08<CR>

AC410094<CR>

Possible error codes:

UPA<CR> Unknown parameter

TNR<CR> Tag not responding

EHX<CR> The string cannot be interpreted as a valid UID or includes non hex characters (only with MTS parameter)

NTI<CR> No Tag Inventoried. Only with ATS. Last inventory found no tags (or no inventory at all after last reset)

4.3. Read Data from Tag (RDT)

The read data command is used to retrieve the data stored in a transponder. Normally it returns 16 bytes. For compatibility to other ISO/IEC 14443-1 to 4 transponder than one using MIFARE Classic protocol, it has a direct read mode, marked with the first parameter "DRT". In this mode the second parameter is the custom command.

Additionally, this command supports the ability to read multiple blocks with one command, i.e. parameter "ALL" for all blocks of a sector, or "CNT" for a variable block count. If MIFARE Classic technology is used, the block has to be authenticated first (see the AUT command in the next chapter). The ALL command returns all blocks from a sector. If MIFAREn Classic 4K implementationis used, parameter "All" is set and the authenticated block no. is higher than 127 it returns 16 blocks. For Custom-Read-Commands the length of a response is maximal 64 bytes.

The block no. is given decimal! The Data is coded hexadecimal!

Instruction:

Read single Block:

```
RDT<SPACE>[Block No.]<CR>
```

Read all blocks:

```
RDT<SPACE>ALL<CR>
```

Read variable number of blocks from block No.:

```
RDT<SPACE>CNT<SPACE>[Block No.]< SPACE>[No. of Blocks]<CR>
```

Direct Read:

```
RDT<SPACE>DRT<SPACE>[CMD] <SPACE>[Block No.]<CR>
```

Parameter	Description
Block No.	Read-Start-Block, respectively Block to read (absolute), one decimal byte
No. of Blocks	Number of blocks to read beginning at Block No., one decimal byte Has to be bigger then 0
ALL	Read-all-parameter, marked that all blocks from sector should be read, only MIFARE Classic 1K and 4K implementation
CNT	Read-Count-parameter, marked that a variable number of blocks beginning at Block No. should be read
DRT	Direct-Read-Parameter, if a Transponder needs another command than 30h
CMD	Custom Read Command, one hexadecimal byte

Table 5: Read command parameter description

Response, if successful:

Number of lines is equal to the number of read blocks. If “DRT” is not set each line is 16 Bytes (32 ASCII chars, hexadecimal) long.

i.e. for one read block:

`00112233445566778899AABBCCDDEEFF<CR>`

Examples:

Read all Blocks from sector

`RDT<SPACE>ALL<CR>`

Read block number 11d

`RDT<SPACE>11<CR>`

Read 2 Blocks beginning at block 0

`RDT<SPACE>CNT<SPACE>0<SPACE>2<CR>`

Read 14 Blocks beginning at block 129<CR>

`RDT<SPACE>CNT<SPACE>129<SPACE>14<CR>`

Possible error codes:

`UPA<CR>`	Unknown parameter
`EDX<CR>`	A decimal parameter includes non decimal characters
`BNA<CR> or BAE<CR>`	Block not authenticated (any more)
`NMA<CR>`	No chip using MIFARE Classic 1K or 4K implementation authenticated (only ALL-Mode)
`NOR<CR>`	Number of blocks to Read is 0 or bigger than 16
`TNR<CR>`	Tag not responding. Most time chip was deselected after an error or while leaving the field. Use SEL (select) before reading again.

4.4. Write Data to Tag (WDT)

The write data command normally stores 16 bytes of data into a block (data or trailer block). For compatibility to other ISO/IEC 14443-1 to 4 transponder than with MIFARE Classic technology, the command also has a direct write mode, marked with the first parameter “DRT”. The number of bytes will not be checked in this mode and it depends on the second parameter (Data).

To write to cards using MIFARE Ultralight(which only have four bytes per block) the first parameter becomes “W4”. This parameter writes 4 bytes to the card.

The selected block has to be writable for this command to work.

ATTENTION

If you write wrong data to the trailer block of a sector (the fourth block of every sector, e.g. block 3, 7, 11, etc.), the sector may become locked forever or be even unreadable afterwards. We recommend to use the STM command to change the information in the trailer blocks and don't write data to it directly (although it is possible).

Instructions:

Write 16 Bytes:

```
WDT<SPACE>[Data]<SPACE>[Block No.]<CR>
```

Write 4 Bytes:

```
WDT<SPACE>W4<SPACE>[Data]<SPACE>[Block No.]<CR>
```

Write directly:

```
WDT<SPACE>DRT<SPACE>[CMD]<SPACE>[Data]<SPACE>[Block No.]<CR>
```

Parameter	Description
Data	Hexadecimal ASCII-String which represents the data. The length depends on whether “DRT” or “W4” is set. If W4 is set the length is 8 ASCII characters (4 bytes). If nothing is set, then it is 32 ASCII characters (16 bytes).
W4	Write 4 bytes (for MIFARE Ultralight protocol)
DRT	If set: the direct mode will be used
CMD	Only with “DRT”, transponder specific write command (see datasheet)
Block No.	Absolute zero based block no. which should be written

Table 6: Write command parameter description

Response, if successful:

```
OK!<CR>
```

Examples:

Write 16 bytes to block 18d

```
WDT<SPACE>00112233445566778899AABBCCDDEEFF<SPACE>18<CR>
```

Possible error codes:

UPA<CR>	Unknown parameter
EHX<CR>	The string cannot be interpreted as valid data or contains non hex characters
BAE<CR> or BNA<CR>	Block not authenticated (any more)
NMA<CR> (only ALL-Mode)	No chip using MIFARE Classic 1K or 4K implementation authenticated
WDL<CR> normal mode)	The hex string does not have the correct length (i.e. 16 bytes in
TNR<CR>	Tag not responding. Most time chip was deselected after an error or while leaving the field. Use SEL and AUT before writing again.

4.5. Contineous Read (CNR)

To allow the repeated / continuous execution of commands, the "CNR" prefix was implemented in the firmware. Only INV can be used with CNR by now. This is a very powerful mechanism for unassisted inventory operations where the reader is initialized at the beginning and then repeats the command over and over. When in CNR mode the reader does not accept any commands except RST (reset) and BRK (break).

Instruction:

```
CNR<SPACE>INV<SPACE>(ONT)<SPACE>(BAR)<CR>
```

Example: Read all tag IDs repeatedly until stopped

Instruction:

```
CNR<SPACE>INV<CR>
```

Response (exemplary, with two tags in the field):

```
078E3BB0<CR>
078E3BB7<CR>
IVF 02<CR>
078E3BB0<CR>
078E3BB7<CR>
```

```
IVF 02<CR>

078E3BB0<CR>

078E3BB7<CR>

IVF 02<CR>

...
```

Optional Parameter: ONT (Only New Tags)

Using this parameter, the reader will only report new tag ids to the host so you don't have to filter for already known tags. As long as a card/transponder stays in the field (and is powered) it will not respond a second time.

Optional Parameter: BAR (Break At Read)

To automatically break with the first inventory run that finds at least one tag use the BAR parameter. This saves having to use BRK when after finding a tag.

Example: Wait silently for a tag to enter the field, report its ID and then stop. For this to be silent, VBL should be set to 0 (see Verbosity Level).

```
CNR INV BAR<CR>
```

Response when a tag enters the field like with normal inventory plus additional Break Acknowledge to confirm the continuous mode has been left.

```
078E3BB7<CR>

IVF 01<CR>

BRA<CR>
```

4.6. Break (BRK)

To end the continuous mode entered into by the "CNR" prefix, the break command can be sent. This will lead to the complete execution of the current command iteration and will then lead to a "BRA" (break acknowledged) response. The command needs no parameter and returns no error codes.

Instruction:

```
BRK<CR>
```

Response:

```
BRA<CR>
```

Possible Error Response:

```
UPA<CR>
```

4.7. RAS (RATS Request answer to Select)

This command switches a selected tag (Iso14443-3 mode) to an Iso14443-4 mode used for MIFARE Plus technology. The command is supported in modes MP3 and MPI.

Instruction:

```
RAS<CR>
```

Response:

```
<ATS><CR>     ATS like defined in Iso14443-4
```

Possible Error Response:

```
UPA<CR>, TNR<CR>
```

5. MIFARE Protocol Commands

This section describes commands only to be used with chips using MIFARE Classic (1K or 4K implementation), MIFARE Ultralight or MIFARE Plus technology.

Command	Name	Description
AUT	Authentication	Authenticates a sector by giving one absolute block
GAB	Get Access Bits	Return the access bits from a selected block, or sector
STM	Sector Trailer Manipulation	Set new access bits and/or keys
VAL	Value Block Operations	Interface to the MIFARE value operations, like initialization, increment, decrement, restore
WRP	Write Perso	MIFARE Plus SL0 command used to set keys and other parameters
COP	Commit Perso	MIFARE Plus SL0 command used to switch to SL1

Table 7: Overview of MIFARE specific commands

5.1. Authentication (AUT)

The card with MIFARE protocol has to be selected before this command works. If the Direct Mode is not used, the SKU command has to be performed before.

In order to read or write data from or to chips using MIFARE Classic protocol, the respective memory block has to be previously authenticated with a key. The key can either be selected by using the SKU command (set key to use) or can be directly given as a parameter when using the direct (DRT) parameter (direct mode). The AUT command authenticates all the blocks in the sector you chose with Block No., i.e. authenticating Block 5 will authenticate Blocks 4 to 7 (the entire sector 1).

In order to authenticate with MIFARE Plus AES keys (16 Byte) are used.

NOTE

The ***standard password*** for transponders using MIFARE Classic is FF FF FF FF FF FF (six bytes). For MIFARE Plus the default key is FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF (16 bytes)

Instruction:

```
AUT<SPACE>DRT<SPACE>[Key]<SPACE>{Type}<SPACE>[Block No.]<CR>
```

Command	Description
DRT	Parameter to mark the direct mode and the next parameter is the key
Key	The key to use, 6 Byte ASCII string (12 chars) on MIFARE Classic, 16 Bytes (32 Chars) on MIFARE Plus
Type	Authenticate with key A or B (see …). Only on MIFARE Classic. MIFARE Plus codes it as part of Block No.
Block No.	Block which will be authenticate. Decimal coding in MIFARE Classic mode (as it only addresses the data blocks) and Hex in MIFARE Plus (as it codes block addressing)

Table 8: Overview of parameters of the AUT command

Response, if successful:

```
OK!<CR>
```

Examples:

Direct authentication block 8 (sector 2) with key type B and key 0xFFFFFFFFFFFF (MIFARE Classic)

```
AUT<SPACE>DRT<SPACE>FFFFFFFFFFFF<SPACE>B<SPACE>8<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter
`BIH<CR>` implementation)	Block no. is too high (i.e. bigger than 63 at MIFARE Classic 1K
`ATE<CR>`	Authentication Error (i.e. wrong key)
`NKS<CR>`	No Key Select, select a temporary or a static key (use STK or SSK)
`CNS<CR>`	Card is Not Selected
`TNR<CR>` while	Tag not responding. Most time chip was deselected after an error or leaving the field. Use SEL (select) before autenticating again.

5.2. Get Access Bit (GAB)

This function returns the access bits from cards using MIFARE Classic 1K and 4K implementation. The function is able to return the access bits from one block, or all blocks from an authenticated sector. The access bits must be readable for this command.

If MIFARE Classic 4K implementation is used and the authenticated block no. is higher than 127, the first three lines represent the first 15 Blocks (each line 5 blocks) and the fourth line the trailer.

Instruction:

GAB<SPACE>[Block No.]<CR>

Response, if successful:

State of C1, C2 and C3

C1<SPACE>C2<SPACE>C3<CR>

Examples:

Block 5 is authenticated and only the access bits from block 5 are required

GAB<SPACE>5<CR>

Response:

0 0 1<CR> (this equals block mode 4, the standard mode)

Block 13 (sector 3) is authenticated and all blocks of this sector should be returned

GAB<SPACE>ALL<CR>

Response:

0 1 0<CR> (Block 12 in Block Mode 2)

0 0 1<CR> (Block 13 in Block Mode 4)

0 1 1<CR> (Block 14 in Block Mode 5)

1 1 0<CR> (Block 15 in Access-Mode 3)

Block 145 (sector 33) is authenticated and all blocks of this sector should be read

GAB<SPACE>ALL<CR>

Response:

0 1 0<CR> (Block 144-148 in Block Mode 2)

0 0 1<CR> (Block 149-153 in Block Mode 4)

0 1 1<CR> (Block 154-159 in Block Mode 5)

1 1 0<CR> (Block 160 in Access-Mode 3)

Possible error codes:

UPA<CR>	Unknown parameter
NMA<CR>	No chip using MIFARE Classic 1K or 4K implementation authenticated
BAE<CR> or BNA<CR>	Block not authenticated (any more)
TNR<CR>	Tag not responding (Tag is no longer in read range)
EDX<CR>	A decimal parameter cannot be interpreted as a decimal value

5.3. Sector Trailer Manipulation (STM)

This function simplifies the usage of the protocol MIFARE Classic access conditions and key writing. With this command you can change the access bits and don't have to write to the trailer blocks directly which should reduce errors resulting in destroyed transponders. As described in the Appendix, the sector trailer contains information about keys, block-mode and Access-Modes. Use this command to set these access bits and/or keys.

There are different ways to manipulate data in the sector trailer by using these modes:

- Set key and Access Bits (SKA)
- Set Keys Only (SKO)
- Direct over write-data command (only advanced user! Included for upward compatibility to new MIFARE technologies, e.g. MIFARE Plus.)

5.3.1. Set Key and Access Bits (SKA)

Use this parameter to set both the access keys and the access bits of a specific sector. To change this information, both the access bits and keys have to be writable and the sector authenticated with the correct key. The access bits will be automatically written to the correct bits of the trailer of the given block no.

The meaning of the access bits given by the parameters C1, C2 and C3 depend on the given block no. parameter.:

- If the block no. is a sector trailer block the access bits C1, C2, C3 are interpreted as bits for access mode.
- If the block no. is not the sector trailer but a data block the access bits C1, C2, C3 are interpreted as bits for block mode.

After using this command a re-authentication will be necessary

Instruction:

```
STM<SPACE>SKA<SPACE>[Block No]<SPACE>[C1]<SPACE>[C2]<SPACE>
[C3]<SPACE>[KeyA]<SPACE>[KeyB]<CR>
```

Parameter	Description
Block No.	The data block to modify, in decimal notation
C1, C2, C3	BCD-Coded Mode, 0 or 1
KeyA	MIFARE authentication key A; 6 Bytes hexadecimal coded ASCII-string (12 chars)
KeyB	MIFARE authentication key B; 6 Bytes hexadecimal coded ASCII-string (12 chars)

Table 9: SKA mode parameter description

Response, if successful:

```
OK!<CR>
```

Examples:

Write Key A (665544332211), Key B (112233445566) and block mode 3 (1 1 0) for block 2

```
STM<SPACE>SKA<SPACE>2<SPACE>1<SPACE>1<SPACE>0<SPACE>6655443322
<SPACE>

112233445566<CR>
```

Write Key A (000000000000), Key B (FFFFFFFFFFFF) and access mode 3 (1 0 1) for block 3

```
STM<SPACE>SKA<SPACE>2<SPACE>1<SPACE>0<SPACE>1<SPACE>0000000000
00<SPACE>

FFFFFFFFFFFF <CR>
```

Possible error codes:

```
UPA<CR>          Unknown parameter

BAE<CR> or BNA<CR>  Block not authenticated

BNC<CR>          Parameter C1, C2 or C3 missing

AKW<CR>          Access bits or Keys not Writable

UKB<CR>          Use Key B for authentication  (in Access-Mode 5 and 6)

UKA<CR>          Use Key A for authentication (in Access-Mode 0 and 4)

TNR<CR>          Tag not responding (Tag is no longer in read range)

NMA<CR>          No chip with MIFARE Classic 1K or 4K implementation authenticated
```

5.3.2. Set Key Only (SKO)

Use this command to change only the key of a specific sector. The sector trailer has to be in Access-Mode 6, 1 (authenticated with key B) or 4, 0 (authenticated with key A) for this command to work.

Instruction:

```
STM<SPACE>SKO<SPACE>[Block No.]<SPACE>[KeyA]<SPACE>[KeyB]<CR>
```

Parameter	Description
Block No.	The data block to modify, in decimal notation
KeyA	MIFARE authentication key A; 6 Bytes hexadecimal coded ASCII-string (16 chars)
KeyB	MIFARE authentication key B; 6 Bytes hexadecimal coded ASCII-string (16 chars)

Table 10: SKO mode parameter description

Response, if successful:

```
OK!<CR>
```

Examples:

Sector 5 which contains block 20 get the keys 112233445566 (key A) and 665544332211 (key B)

```
STM<SPACE>SKO<SPACE>20<SPACE>112233445566<SPACE>665544332211<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter
`BAE<CR>`	An unauthenticated block is chosen
`KNC<CR>`	Keys not changeable
`UKA<CR>`	Use Key A for authentication
`UKB<CR>`	Use Key B for authentication
`BNR<CR>`	Block not readable, i.e. wrong key, see Block –and Access Mode
`BNA<CR>`	Block not authenticated, Block No. is not in authenticated sector
`NMA<CR>`	No chip with MIFARE Classic 1K or 4K implementation authenticated

5.4. Value block Operation (VAL)

This command is used to use the integrated value block operations of the MIFARE Classic protocol. A value block is able to save a signed 4 byte value and one address byte (i.e. own block address). The value is saved LSB first, i.e. 00000035h written as parameter looks like 35000000h. The value can be manipulated by four different ways (always depending on access bits). It is usually used to store information on credit values for e-payment or e-ticketing situations.

There are five different modes for this command:

- Initialization – the first step to use the next operations (sets a initial value/address)
- Increment - adds a value (given as parameter) to the value present in a chosen block (inputblock) and writes the result to the outputblock. (Mode 3)
- Decrement - subtracts a value (given as parameter) to the value present in a chosen block (inputblock) and writes the result to the outputblock. (Mode 3, 4)
- Direct Write - writes 4 value bytes and one address byte direct to the Block (Mode 3)
- Restore - Writes the Date from the outputblock to the inputblock. (Mode 3, 4)

5.4.1. Initialization of a value block (INIT)

In order to use the Increment, Decrement and Restore function, the data block has to be configured as a value block (Block Mode 3) or in transport configuration (Block Mode 0). This function initializes the MIFARE Classic data block to the correct format. In this way an initial value and an initial address has to be given (see Backup Configuration in chapter … for details of the address). If the initialization is done, the block mode can changed to 4 via the STM command. The block has to be writable, in block mode 0 or 3. When authenticated with key B and key B is readable, the block is not read/writable.

Instruction:

```
VAL<SPACE>INIT<SPACE>[Value]<SPACE>[Block No.]
(<SPACE>[Address]<CR>)
```

Parameter	Description
Value	Signed and always positive 4 byte, hexadecimal Value
Block No.	The data block to modify, in decimal, i.e. for MIFARE Classic 1K 0..63, for MIFARE Classic 4K 0..255
Address	Initial address, one decimal byte. Optional

Table 11: Init mode parameter description

Response, if successful:

OK!<CR>

Examples:

The Block Mode is set to mode 3 by another way. The initial value should be 2000h. The block to configure is block number. 4.

VAL<SPACE>INIT<SPACE>00002000<SPACE>04<CR>

The Access bits are changeable and the block number 5 should become a value block with write and increment rights. The initial value should be 2020h.

VAL<SPACE>INIT<SPACE>SAB<SPACE>WI<SPACE>00002020<SPACE>05<CR>

Now the block becomes Mode 4. The value is only a dummy.

VAL<SPACE>INIT<SPACE>SAB<SPACE>00202000<SPACE>05<CR>

Possible error codes:

UPA<CR>	Unknown Parameter
NMA<CR>	No chip with MIFARE Classic 1K or 4K implementation authenticated
WDL<CR>	Initial value is not 6 bytes long
EDX<CR>	In/Output block or value missing, or other character than '0' to '9'
EHX<CR>	The initial value is missing, or other characters the 0.. 9 and A .. F
KBR<CR>	Key B is readable
BNW<CR>	Block-Not-Writable: authenticated with key A, but not in block mode 0
BME<CR>	Block Mode Error, not 0 or 3 (not writeable with value block function)
NDB<CR>	The chosen Block is no Data Block
BAE<CR> or BNA<CR>	Block not authenticated (any more)
TNR<CR>	Tag not responding

5.4.2. Increment (INC) and Decrement (Dec)

As described at begin of this chapter, this function adds or decrements a value to a value present in the inputblock. Finally the result of this operation will be saved in the outputblock.

Conditions:

- Data block has to be configured to Block Mode 0 or 3 for increment

- Data block has to be configured to Block Mode 0, 3 or 4 for decrement
- Outputblock and inputblock have to be in the same sector

If input/output blocks are different blocks, use the restore command, else the increment/decrement function works only one time (the results are always the same)

Instruction:

```
VAL<SPACE>{MODE}<SPACE>[Value]<SPACE>[Inputblock]
<SPACE>[Outputblock]<CR>
```

Parameter	Description
MOD	Selected either increment (INC) or decrement (DEC)
VALUE	unsigned hexadecimal value (summand/subtrahend)
Inputblock	1 decimal Byte, i.e. 0 to 63 for MIFARE Classic 1K, or 0 to 255 for MIFARE Classic 4K, but not trailer
Outputblock	1 decimal Byte, i.e. 0 to 63 for MIFARE Classic 1K, or 0 to 255 for MIFARE Classic 4K, but not trailer

Table 12: INC and DEC mode parameter description

Response, if successful:

```
[VALUE]<CR>          4 bytes long result of the operation
```

Examples:

Increment the value from block 32d by 10d and write the result to block 32d

```
VAL<SPACE>INC<SPACE>10<SPACE>32<SPACE>32<CR>
```

Decrement the value from block 32d by 10d and write the result to block 32d

```
VAL<SPACE>DEC<SPACE>10<SPACE>32<SPACE>32<CR>
```

Increment the value from block 32d by 20d and write the result to block 33d

```
VAL<SPACE>INC<SPACE>20<SPACE>32<SPACE>33<CR>
```

Possible error codes:

`UPA<CR>` Unknown Parameter

`TNR<CR>` Tag no response, i.e. value block not incrementable

`EDX<CR>` In/Output block or value missing, or other character than '0' to '9'

NDB<CR>	The chosen block is no data block but a trailer
NMA<CR>	No chip with MIFARE Classic 1K or 4K implementation authenticated
ONE<CR>	Operation not Executed, Result smaller/bigger than ±2,147,483,647
VNI<CR>	The Value block is not in the right format, use INIT command

5.4.3. Restore

This command is used for powerful backups. If the input –and outputblock are not the same, this command restores the result written in the outputblock to the inputblock. The outputblock has to be in the correct value block format for this command to work. The outputblock remains unchanged by this operation.

Restore works like copying Outputblock to Inputblock!

Instruction:

```
VAL<SPACE>REST<SPACE>[Outputblock]<SPACE>[Inputblock]<CR>
```

Response, if successful:

```
OK!<CR>
```

Examples:

The result of an operation is saved in block 29d and should restore to 28d

```
VAL<SPACE>REST<SPACE>29<SPACE>28
```

Possible error codes:

UPA<CR>	Unknown Parameter
TNR<CR>	Tag no response, i.e. value block not incrementable
EDX<CR>	In/Output block or value missing, or other character than '0' to '9'
NDB<CR>	The chosen block is no data block but a trailer
NMA<CR>	No chip with MIFARE Classic 1K or 4K implementation authenticated
BNA<CR>	In- or Output block is not authenticated
VNI<CR>	The Value block is not in the right format, use INIT command first

5.5. Write Perso (WRP)

This command can only be used in MOD MP0 as it is only supported by cards with MIFARE Plus SL0. It writes a 16 Bytes data block to the send block address. This is used to initialize keys. This command needs to be used before using COP because at least 3 keys need to be set before changing the PICC to SL1. For the key blocks and for the mandatory keys see Appendix 4.

The PICC needs to be in selected mode (SEL command used).

Instruction:

```
WRP<SPACE><16 Bytes Data><SPACE><2 Bytes Block number<CR>
```

Response if successful:

```
OK!<CR>
```

Possible Error Response:

UPA<CR>, WDL<CR>, TNR<CR>

5.6. Commit Perso (COP)

This command can only be used in MOD MP0 as it is only supported by cards with MIFARE Plus SL0. The command changes the PICC from SL0 to SL1. This command should only be executed after setting at least the mandatory keys using COP.

The PICC needs to be in selected mode (SEL command used).

Instruction:

```
COP<CR>
```

Response if successful:

```
OK!<CR>
```

Possible Error Response:

UPA<CR>, WDL<CR>, TNR<CR>, COS<CR>

6. Appendix

Appendix 1: CRC Calculation

```
// this function calculates a CRC16 over a unsigned char Array with, LSB first
// @Param1 (DataBuf): An Array, which contains the Data for Calculation
// @Param2 (SizeOfDataBuf): length of the Data Buffer (DataBuf)
// @Param3 (Polynom): Value of the Generatorpolynom, 0x8408 is recommended
// @Param4 (Initial_Value):  load value for CRC16, 0xFFFF is recommended for
//                           host to reader communication
// return: calculated CRC16

unsigned short GetCrc(              unsigned char *DataBuf,
                                    unsigned char SizeOfDataBuf,
                                    unsigned short Polynom,
                                    unsigned short Initial_Value)
{
        unsigned short Crc16;
        unsigned char Byte_Counter, Bit_Counter;

        Crc16 = Initial_Value;
        for (Byte_Counter=0; Byte_Counter < SizeOfDataBuf; Byte_Counter++)
        {
                Crc16^=DataBuf[Byte_Counter];
                for (Bit_Counter=0; Bit_Counter<8; j++)
                {
                        if (( Crc16 & 0x0001)==0) Crc16>>=1;
                        else Crc16=(Crc16>>1)^Polynom;
                }
        }
         return (Crc16);
}
```

Appendix 2: Error Codes:

Error Code	Description
EDX	Error Decimal value Expected, or is missing
EHX	Error Hexadecimal value Expected, or is missing
IOS	Input and Outputblock are not in the same Sector
TNR	Tag Not Responding
UPA	Unknown Parameter
NMA	No chip with MIFARE Classic technology Authenticated
WDL	Wrong Data Length
NDB	No Data Block
KBR	Key B is Readable
ONE	Operation Not Executed
BME	Block Mode Error, not 0 or 3 (not writeable with value block function)

BNW	Block Not Writable
BAE	Block Access Error
BNA	Block Not Authenticated
AKW	Access bits or Keys not Writable
UKB	Use Key B for authentication
UKA	Use Key A for authentication
KNC	Key(s) not changeable
BIH	Block Is too high (i.e. bigger than 63 at MIFARE Classic 1K)
ATE	Authentication Error (i.e. wrong key)
NKS	No Key Select, select a temporary or a static key
CNS	Card is Not Selected
NB0	Number of Blocks to Read is 0
NTI	No Tag Inventoried
TMD	To Many Data (i.e. Uart input buffer overflow)
COS	Conditions Not Satisfied

Table 13: Overview of error codes

Appendix 3: General Information on MIFARE Classic Systems

Since transponders with MIFARE technology have serveral specialties esp. with regard to the access system used, this paragraph is meant to give a quick overview of these topics. For more information please refer to the respective datasheets of the transponders you are using. You can get these directly from NXP after signing an NDA via their website.

Memory Organisation for MIFARE Classic Protocol

The memory of chips using MIFARE Classic technology is organized in sectors composed of several numbers of data blocks and one trailer. Chips with MIFARE Classic 1K implementation contain 16 sectors of 3 data blocks and one (the fourth) trailer (Table 14). For the lower 32 sector of chips with MIFARE Classic 4K implementation the same applies. The higher 8 sectors are composed of 15 data blocks and one (the 16th) trailer block(Table 15). All blocks are read-/writable only if the corresponding sector was successfully authenticated.

The Trailer Block:

The trailer contains two secret keys (A and B) to authenticate the corresponding sector and information about access rights (the access bits). The trailer block is always the last block of a sector. This means that each sector can have its own keys for giving write or read access.

Data blocks:

The data blocks contain 16 read-/writable bytes except block 0 in sector 0, which is a read-only manufacturer block. All other blocks can be configured as normal read/write blocks or as value blocks.

15	3	63	Sector Trailer (Key A, access bits, Key B)
15	2	62	Data
15	1	61	Data
15	0	60	Data
…	…	…	…
0	3	3	Sector Trailer (Key A, access bits, Key B)
0	2	2	Data
0	1	1	Data
0	0	0	Data

Table 14: Memory organization of the chip with MIFARE Classic 1K implementation (16 sectors á 4 blocks á 16 bytes (Sector 0 in Block 0 is the manufacturer block)

32 to 39	15	Sector Trailer (Key A, Access, Key B)
32 to 39	14	Data
32 to 39	…	…
32 to 39	0	Data
0 to 31	3	Sector Trailer (Key A, Access, Key B)
0 to 31	2	Data
0 to 31	1	Data
0 to 31	0	Data

Table 15: Memory organization of the chip with MIFARE Classic 4K implementation (Sector 0 to 31: 4 blocks á 16 bytes (Sector 0 in Block 0 is the manufacture block); Sector 31 to 39: 16 blocks á 16 bytes)

At authentication and all read/write processes the zero base absolute block number must given. This is calculated with following equation:

for MIFARE Classic 1K or 4K and absolute block Nr < 128: Block Nr = Sector*4 + Block in Sector

for MIFARE Classic 4K and absolute block Nr > 128: Block Nr = Sector*16 + 128 + Block in Sector

where Block No. is the absolute zero based block number (0..63 for MIFARE Classic 1K, or 0..255 for MIFARE Classic 4K) and Block in Sector is the position of the block in the sector (0..3 for MIFARE Classic 1K & 4K (<128) , or 0..15 MIFARE Classic 4K (>128))

Access Rights

All cards using MIFARE technology have a fine grained access rights system. Each sector can be secured using two different keys (Key A and Key B). Using access bits, you can give read or write access to one or both of the keys for each block. You can use Key A in your customer application which is only able to read the data, but use Key B in your internal application to initialize the cards with full write access.

To identify the access rights for a sector there are three bits, called access bits C1, C2 and C3. With these three bits eight different modes are possible with these access bits. C1 is the LSB.

Example:

C1	C2	C3	Mode
1	1	0	3

There are four access rights per sector (one for each three data blocks and one trailer block), so each block at MIFARE Classic 1K and the lower 32 blocks at MIFARE Classic 4K has its own three access bits. At the higher 8 sectors of MIFARE Classic 4K five blocks shares one mode.

So depending on whether you set the access bits of a data block or of a trailer block (the fourth block of each sector) these bits change their meaning.

When writing the access bits of a data block you can define the following things for this block (this setting is called „block mode“).

- Is the data block readable/writeable and by which key (Key A or Key B or both)
- Is it a value block or a read/write block
- Is the block locked (not read/writable)

Read	*Write*	*Increment*	*Decrement, Restore*		*C1 C2 C3*	
A|B	A|B[1]	A|B[1]	A|B[1]	transport configuration	0 0 0	0
A|B	NEV	NEV	NEV	Read/write Block	0 1 0	2
A|B	B[1]	NEV	NEV	Read/write Block	1 0 0	1
A|B	B[1]	B[1]	A|B[1]	Value Block	1 1 0	3
A|B	NEV	NEV	A|B[1]	Value Block	0 0 1	4
B	B[1]	NEV	NEV	Read/write Block	0 1 1	6
B	NEV	NEV	NEV	Read/write Block	1 0 1	5
NEV	NEV	NEV	NEV	Read/write Block	1 1 1	7

Table 16: Access Bit meaning in „Block-mode"

[1] if Key B may be read in the corresponding Sector Trailer it cannot serve for authentication.

Consequences: If the reader tries to authenticate any block of a sector with key B using grey marked access conditions, the card will refuse any subsequent memory access after authentication.

Block Mode 0: This is the transport configuration (delivery state). In this mode the block is readable and all data manipulating commands are enabled.

But who is allowed to change the Block Mode itself? The sector trailer has its own access bits, where exactly this and some other details are configured. The set of access right stored in the trailer block is called „Access Mode". Here you can configure whether Key A, Key B or the access bits are read/writeable.

Access Bits		Key A		Key B					
read	write	read	write	read	write	C1	C2	C3	
A	NEV	NEV	A	A	A	0	0	0	0
A|B	NEV	NEV	B	NEV	B	1	0	0	1
A	NEV	NEV	NEV	A	NEV	0	1	0	2
A|B	NEV	NEV	NEV	NEV	NEV	1	1	0	3
A	A	NEV	A	A	A	0	0	1	4
A|B	B	NEV	NEV	NEV	NEV	1	0	1	5
A|B	B	NEV	B	NEV	B	0	1	1	6
A|B	NEV	NEV	NEV	NEV	NEV	1	1	1	7

Table 17: Access-Modes (NEV = Never)

Example:

Access-Mode 4: This is the transport configuration (delivery state). In this mode the access bits can only be read or written when using key A for authentication. The same applies to Key B. Key A can only be written.

Appendix 4: Overview MIFARE Plus technology S SL3:

a) Check and change Security level (all for one card in field, without answers):

SL0: Default level of MIFARE Plus PICC

Check: MOD MP0

INV

SEL ATS

WRP [KEY] 0000

Change(to SL1):

WRP [KEY] 9000

WRP [KEY] 9001

WRP [KEY] 9002 (only for MIFARE Plus X, SL2 Change key)

WRP [KEY] 9003

WRP [KEY] [Other Key you want to set, they may not be changeable in SL3]

….

WRP [KEY] [Other Key you want to set]

COP

SL1:

Check: MOD MPA

INV

SEL ATS

AUT DRT [KEY] 9004

Change (to SL3):

MOD MPI

INV

SEL ATS

RAS

AUT DRT [KEY] 9003

SL3:

Check(could also be SL2 if its a MIFARE Plus X):

MOD MP3

INV

SEL ATS

RAS

AUT FRT DRT [KEY] 9000

b)Block addresses:

Block Name		
MIFARE Data/Value blocks:	00 00 to 00 7F	MIFARE Plus (2K/4K) (Sector 0-31)
KeyA even, KeyB odd block	00 80 to 00 FF	only MIFARE Plus 4K (Sector 32-39)
Installation Identifier	B0 01	(for Virtual Card (VC))
ATS Information	B0 02	ATS
Field Configuration Block	B0 03	Defines if Random ID is used in SL3

Keys:		
AES Sector Keys	40 00 bis 40 3f	for MIFARE Plus 2K (4 blocks/sector)
	40 40 bis 40 4f	for MIFARE Plus 4K (15 blocks/sector)
Orginality Key	80 00	Set by NXP. If known this can be used to check if the card is from NXP
Card Master Key	90 00	Change of Card Configuration key, Installation Identifier, ATS, itself

Card Configuration Key	90 01	Änderung von Field Configuration Block, VC-Keys, itself
Level 2 Switch Key:	90 02	Key to switch to level 2 (only MIFARE Plus X)
Level 3 Switch Key:	90 03	Key to switch to level 3
SL1 Card Authentication Key	90 04	Additional AES Authentifizierung für SL1
Select VC Key	A0 00	key to calculate MAC in Select VC
VC Polling ENC Key	A0 80	Select VC Polling ENC Key
VC Polling MAC Key	A0 81	Select VC Polling MAC Key

Appendix 5: Overview of Tag Properties

Tag-type	SAK (Level 1/Level 2)	ATQA	UID Length
MIFARE CLassic 1K	08h/ XX	0400h	4 Bytes
MIFARE Classic 4K	18h/ XX	0200h	4 Bytes
MIFARE DESFire	24h/20h	4403h	7 Bytes
MIFAREUltralight	04h/00h	4400h	7 Bytes

Table 18: Different characteristics of chips using MIFARE technology

7. Version Control

Version	*Change*	*by*	*Date*
1.0	created	KD	11.03.2009
1.1	BAR command added	KD	10.07.2009
1.2	SRF command added	KD	16.12.2009
1.3	EOF/NEF added	KD	28.01.2010
2.0	CNR Mode only with INV CNR can only be stopped by BRK / RST SEL ATS does not work without INV before EOF works together with CRC RSN command added can accept more than one packet (total of 127Bytes input buffer).	MK	24.03.2010
2.1	Added first MIFARE Plus Commands, additional will follow soon WRP COP MOD Changes on AUT depending on MOD parameter	MK	28.06.2013
2.2	Changes to match MIFARE(R) naming conventions	CS	January 2014
2.3	Added VBL 2	MK	25.02.2015

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