AN10927

MIFARE and handling of UIDs

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Document information

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Keywords	Single Size UID, Double Size UID, 4 Byte UID, 7 Byte UID, SNR, NUID, FNUID, ONUID
Abstract	This document shows the use of UIDs in contactless smartcard systems. It indicates recommendations about the Random ID, mixed use of 4 byte and 7 byte UIDs in the same system, and it describes the options how to upgrade 4 byte UID systems to accept 7 byte UID smart cards.

Revision history

Rev	Date	Description
3.0	20110804	MIFARE Classic next generation added.
2.0	20100901	Bit order corrected (Section 3.2.2), 7 byte MF1 ICS x0 added in Table 4 (Section 3.2.5), Table 3 updated (Section 2.4)
1.0	20100519	Initial version

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1. Introduction

This document shows the use of UIDs in contactless smartcard systems. It indicates recommendations about the use of Random ID, the mixed use of 4 byte (single size) and 7 byte (double size) UIDs in the same system, and it describes the options how to upgrade 4 byte UID systems to use 7 byte UID smart cards.

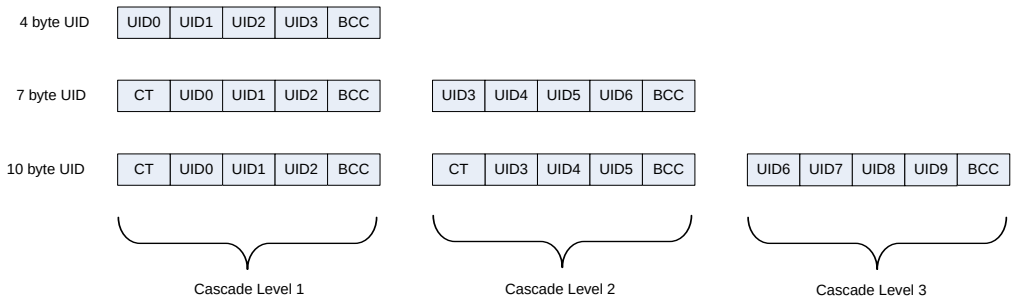
Note: A UID is not a “serial number”, but a unique identifier. There is no recommendation how to turn the array of bytes into an integer.

Note: “UID” is a common expression, defined in the ISO/IEC 14443-3. In some case the UID is even not unique (like RID or NUID, see below).

Note: The 4 byte UID is called “Single Size UID”, too. The 7 byte UID is called “Double Size UID”, too. The 10 byte UID is called “Triple Size UID”, too.

2. MIFARE and ISO/IEC 14443 UIDs

In this section the use of UIDs according to the ISO/IEC 14443 is described. Fig 1 shows the three different UID sizes defined in ISO/IEC 14443-3 as they are used during the anti-collision and selection procedure.



(1) BCC = Block Check Character, it is calculated as exclusive-or over the 4 previous bytes.

(2) CT = Cascade Tag, to indicate a following cascade level.

Fig 1. UIDs according to ISO/IEC 14443

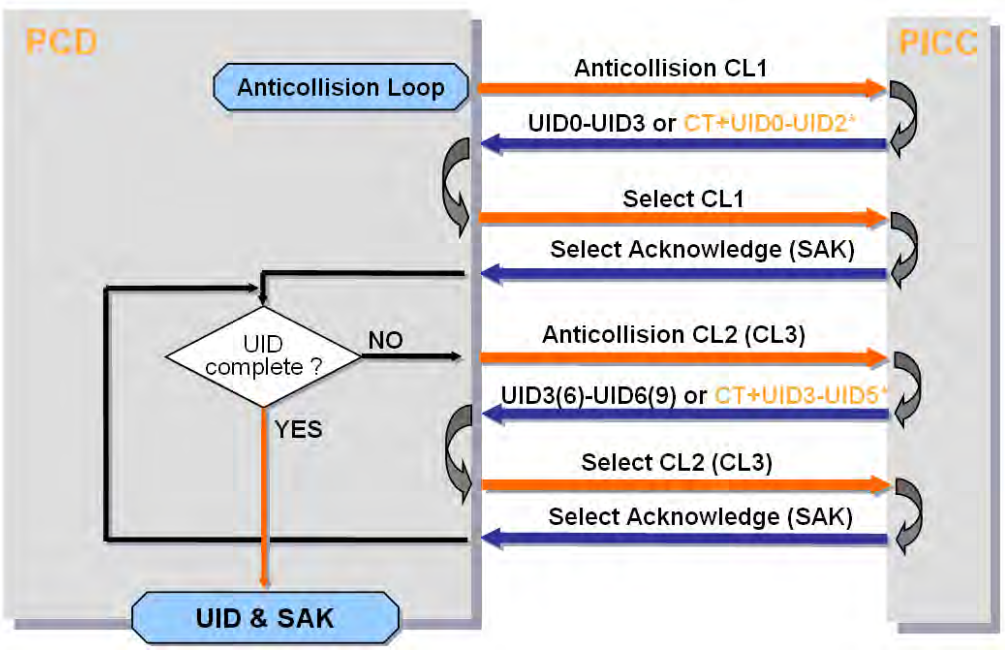
Fig 2 shows the Anticollision sequence, which is a mandatory part of the card activation sequence. It automatically selects a single PICC with 4 byte UID (= Single Size UID), 7 byte UID (= Double Size UID) or 10 byte UID (= Triple Size UID).

Cascade Level 1

In the Cascade Level 1 the PCD sends the Anticollision command CL1 (0x93) and the PICC returns

- either the 4 byte UID (UID0...UID4) and one byte BCC,
- or a Cascade Tag (CT) followed by the first 3 byte of the UID (UID0...UID2) and one byte BCC.

The CT (0x88) indicates that the UID is not yet complete, and another Cascade Level has to follow.



(3) CT = Cascade Tag

(4) CL = Cascade Level

Fig 2. Anticollision sequence

Note: The UID0 byte of a 4 byte UID must not be 0x88.

The CL1 then must be selected, using the Select command CL1 (0x93). The PICC returns its SAK CL1, which indicates

- whether the UID is complete or not, and (if so),
  - the type of card (for details refer to [1] and [2]), and
  - whether the card supports T=CL.

Cascade Level 2

If the UID is not yet complete, the PCD continues with an Anticollision CL2 command (0x95), and the PICC returns

- either the last 4 bytes of the Double Size UID (UID3...UID6) and one byte BCC,
- or a Cascade Tag (CT) followed by the next 3 bytes of the Triple Size UID (UID3...UID5) and one byte BCC.

The CT (0x88) indicates that the UID is not yet complete, and another Cascade Level has to follow.

Note: The UID3 byte of a 7 byte or 10 byte UID must not be 0x88.

The CL2 then must be selected, using the Select command CL2 (0x95). The PICC returns its SAK CL2, which indicates

- whether the UID is complete or not, and (if so),
  - the type of card (refer to [1] and [2]), and

– whether the card supports T=CL.

Cascade Level 3

If the UID is not yet complete, the PCD continues with an Anticollision CL3 command (0x97), and the PICC returns

- the last 4 bytes of the Triple Size UID (UID3...UID6) and one byte BCC.

The CL3 then must be selected, using the Select command CL3 (0x97). The PICC returns its SAK CL3, which indicates

- the type of card (refer to [1] and [2]), and
- whether the card supports T=CL.

2.1 Single Size UID

The single size UID contains 4 bytes. As shown in Table 1, the value of the UID0 byte defines how those 4 bytes shall be interpreted.

Table 1. Assignment of Single Size UIDs

POR = Power on reset

UID0 [Hex]	Definition	Range
08	RID: UID1, UID2 and UID3 are dynamically generated during or after each Power-On-Reset (POR).	appr. 16 million
x0... x7	Proprietary use (i.e. used for MIFARE)	appr. 2.1 billion
18…78, 98…E8	Proprietary use (i.e. used for MIFARE)	appr. 218 million
x9...xE	Proprietary use (i.e. used for MIFARE)	appr. 1.6 billion
xF	Fixed number, non-unique	appr. 268 million
88	Cascade Tag	-
F8	RFU	-

Note: Single Size UIDs do not have a manufacturer code.

Note: The use of Single Size UIDs (unique ones) might end soon, since the number of usable IDs is limited to approximately 3.7 billion pieces only.

2.1.1 Random ID (RID)

A single size UID with UID0 = 0x08 indicates a Random Identifier. The Random ID (RID) is dynamically generated, when the PICC powers up. Deselecting a PICC does not reset the RID, but a field reset does.

Note: RID is always limited to 4 bytes.

Note: Depending on the PICC implementation, a UID (i.e. Double Size UID) may be retrieved from the card by proprietary means after the PICC is selected with its RID.

2.1.2 Fixed but non-unique ID (FNUID)

The 4 byte UIDs with UID0 = xF_h are fixed identifiers (like unique ones), but the same UID might be used for several PICCs, so that contactless systems cannot rely on the uniqueness of such a PICC identifier. These UIDs are called FNUID in the following.

The probability to have 2 PICCs on one PCD at the same time with the same FNUID is still extremely low.

However, it might create conflicts, if the contactless system uses the UID not only for the card activation but also as a logical reference to the PICC. There is a proposal how to handle this in chapter 3.2.

2.1.3 Re-used UID (ONUID)

The very old Single Size UIDs will be re-used, which means the same UID might be used for several PICCs, so that contactless systems cannot rely on the uniqueness of such a PICC identifier. These ID are called ONUID in the following.

The probability to have 2 PICCs on one PCD at the same time with the same ONUID is still extremely low.

However, it might create conflicts, if the contactless system uses the UID not only for the card activation but also as a logical reference to the PICC. There is a proposal how to handle this in chapter 3.2.

2.2 Double Size UID

Double Size UIDs always contain a manufacturer code in the UID0. With the double size UIDs each manufacturer can theoretically use up to $2.8 * 10^{14}$ UIDs.

2.2.1 Manufacturer Code

In double and triple size UIDs the UID0 contains the manufacturer code which indicates the manufacturer of the PICC as shown in Table 2.

Table 2. Manufacturer Code

UID0 [Hex]	Definition
81 ... FE	not allowed
04	NXP Semiconductors, formerly Philips Semiconductors

2.2.2 Unique ID ranges for Double Size UIDs

Double Size UIDs always contain a manufacturer code in the UID0.

Note: Due to the content of Double Size UIDs of MIFARE products the best diversification can typically be found in the UID1 and UID2.

2.3 Triple Size UID

Triple Size UIDs always contain a manufacturer code in the UID0.

Currently there is no PICC using a triple size UID. However, according to ISO/IEC 14443 it is mandatory that every PCD supports Triple size UIDs.

2.4 UID used in MIFARE products

In the past MIFARE Classic cards were limited to 4 byte UIDs only, i.e. normally every MIFARE Classic related product has used a single size UID only. Due to the limited number of UIDs in the single size range all new MIFARE related products are supporting 7 byte UIDs.

Table 3 indicates which MIFARE product uses which UID.

Table 3. UIDs and MIFARE products

NUID = Non Unique ID, ONUID = Re-used UID, FNUID = Fixed, non-unique UID

Product	MIFARE Ultralight™ (C)	MIFARE™ Classic		MIFARE Plus™	MIFARE DESFire™ (EV1)	SmartMX™
	MF0 ICxx	MF1Syyyy	MF1SyyyyX[1]	MF1 PLUS	MF3 IC Dxx	P5 xx
Name	MIFARE Ultralight, Ultralight C	MIFARE Classic 1K/4K	MIFARE Classic 1K/4K	MIFARE Plus S, MIFARE Plus X (2K and 4K)	MIFARE DESFire, MIFARE DESFire EV1	with MIFARE Classic implementation
Single Size UID	-	-	-	-	-	x[2]
Single Size FNUID	-	-	-	-	-	x
Single Size ONUID	-	x	x	x	-	-
Double Size UID	x	-	x	x	x	x[3]
RID option	-	-	x	x[4]	x	x[3]
UID Perso Option	-	-	X	-	-	x[3]
UID needed for operation	-	x	x	x[5]	-	x[6]
UID recommended for key diversification	x	x	x	x	x	x

The Single Size FNUID or ONUID can be used like a Single Size UID – except the fact that identifier of this range will be used multiple times.

RID is optional and should be used to protect privacy. In case RID is enabled, there is a defined and confidential way to retrieve the UID for each product.

1. MIFARE Classic next generation
2. For existing masks using Singe Size UID only that have not been switched to Single Size FNUID yet
3. For MIFARE Classic implementation using the MIFARE FleX™ framework
4. MIFARE Plus support RID only in SL3.
5. In SL1 and SL2 only.
6. For the MIFARE Classic implementation.

3. UID and MIFARE Classic / MIFARE Plus

3.1 Card activation

In the past the MIFARE Classic always used a Single Size UID, some very old MIFARE readers may not have implemented the additional cascade levels according to the ISO/IEC 14443, which are required to select a Double Size UID. In such case there are the following different options to activate a card:

- Single Size NUID (FNUID or ONUID)
- RID

In any case it is strongly recommended to implement the full 4 byte, 7 byte and 10 byte UID card activation on the PCD, as required by the ISO/IEC 14443.

3.1.1 Single Size NUID

The MIFARE Plus card or MIFARE Classic card with Single Size NUID can be activated like a usual Single Size UID card.

Note: There is a very small probability that 2 cards in the PCD field have the same NUID, and therefore cannot be properly selected without the user removing one card.

Note: NUID might be an order option or an option which can be chosen during personalization of the card.

3.1.2 Double Size UID with “shortcut”

The MIFARE Classic next generation offers the feature to use the Double Size UID, but activate the card with REQA - Anticollision CL1 - Select CL1 – Read Block 0.

In such case the Read Block 0 command might return CRC and parity errors, if more than one card is selected. This conflict cannot be resolved by the reader, if it does not support CL2, but the user needs to separate a single card.

Note: The 4 bytes of the CL1 (CT + UID0...UID2) is taken as input for the MIFARE Classic authentication, if the MIFARE Classic next generation is selected with the Read Block 0.

Note: This feature is neither supported by the MIFARE Classic (MF1Syyyy) nor by the MIFARE Plus. Future versions of MIFARE Plus may include this feature.

Note: This feature is supported by the MIFARE Ultralight and MIFARE Ultralight C, too.

3.1.3 RID

Some MIFARE Classic, the MIFARE DESFire (EV1) and the MIFARE Plus offer the option to enable RID. RID is always 4 bytes only. The MIFARE Plus offers RID only in SL3.

3.2 UID in the contactless system

In some cases the reader infrastructure might be able to handle Double Size UIDs, but the (background) system can only handle 4 byte UIDs. Or vice versa, the reader infrastructure might not be able to handle Double Size UIDs, but the (background) system needs uniqueness and can handle Double Size UIDs.

In such a case there are at least 5 different options:

- Single Size NUID for card activation and for the system
- Single Size NUID for card activation, and Double Size UID for the system
- Double Size UID for card activation, and Single Size NUID for the system
- RID for card activation, and Single Size NUID for the system
- RID for card activation, and Double Size UID for the system

3.2.1 Single Size NUID for card activation and for the system

The MIFARE Plus card or MIFARE Classic card with Single Size NUID can be activated like a usual Single Size UID card.

Note: There is an extremely small probability that 2 cards in the field have the same NUID, and therefore cannot be properly selected without the user removing one card.

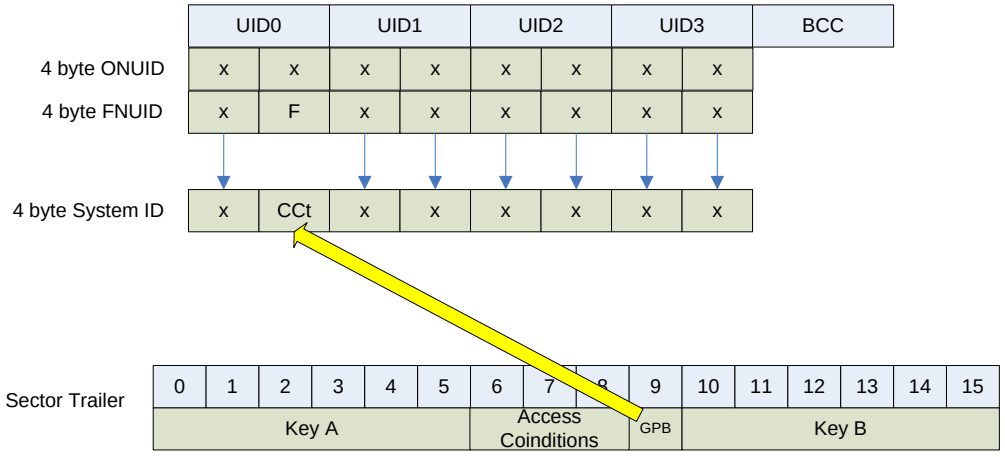
Note: NUID might be an order option or an option which can be chosen during personalization of the card.

There is a probability that the same NUID appears in the system more then once. Either the cards have to be pre-selected e.g. at issuing to avoid such collision in the system, or the system has to be able to deal with these cards in a special way.

System ID

The system could use a 4 byte **system ID** (see Fig 3), derived from the

- high nibble of the UID0 (4 bit)
- the low nibble of the GPB used as card counter (4 bit)
- the UID1, UID2 and UID3.



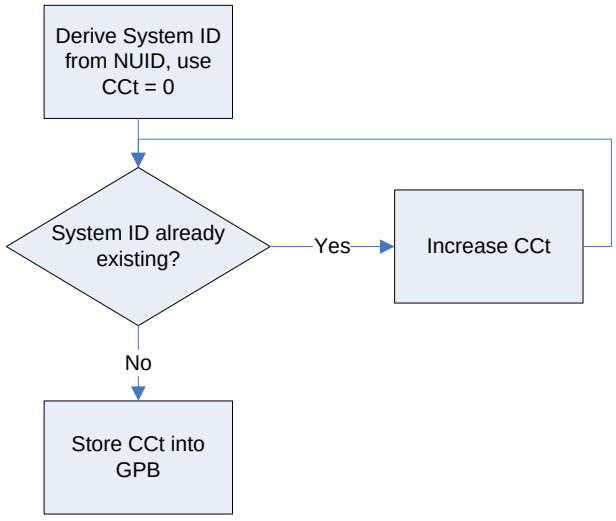
(1) CCt = CardCounter, to be stored in the GPB of an application sector

(2) GPB = General Purpose Byte (Byte 9 of a Sector Trailer)

Fig 3. How to derive a 4 byte System ID out of a NUID and GPB

This system ID must be created when the card is issued or personalized as shown in Fig 4. The GPB should be stored in a Sector Trailer that is not going to be changed later on. It could be the Sector Trailer of the first sector being used by the application.

Note: This proposal can handle up to 16 cards with the same NUID in the same system.



(1) This flow requires the personalization process to check all the existing System IDs.

Fig 4. How to create a System ID during card personalization

3.2.2 Double Size UID for card activation, but Single Size NUID for the system

After the card is activated using the Double Size UID, the following proposal can be used to derive a 4 byte NUID out of the 7 byte UID.

Derive NUID out of a Double Size UID

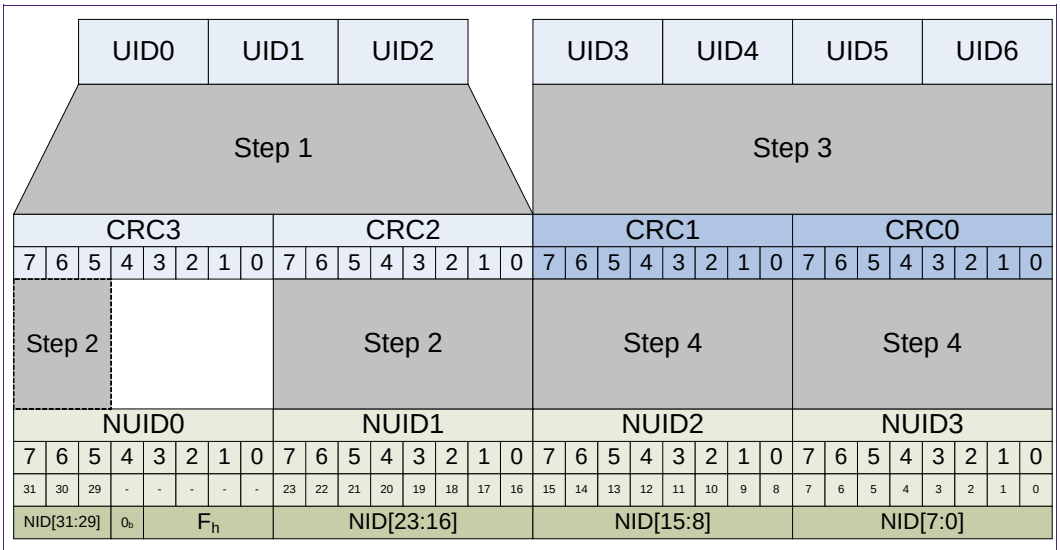
The lower nibble of UID0 must be set to F_h to indicate the non-unique range.

The bit[4] of UID0 shall be set to 0b for compliance reasons.

To generate the 27 bits of the NUID out of the 7 byte UID a CRC calculation shall be done as follows (see Fig 5):

1. Reset the CRC calculator with the standard ISO/IEC 14443 type A preset values: 6363hex.
2. Feed UID0, UID1 and UID2 into the CRC calculator.
3. Result shall be denoted as CRC[3:2]
4. Set NUID[31:29] to CRC[3][7:5] and NUID[23:16] to CRC[2][7:0]
5. Feed UID3, UID4, UID5 and UID6 into the CRC calculator (do not reset the CRC engine before!).
6. Result shall be denoted as CRC[1:0]
7. Set NUID[15:8] to CRC[1][7:0] and NUID[7:0] to CRC[0][7:0]

This mapping ensures that no bit shifting is necessary to build the final NUID from the CRC bytes.



(1) Bit [4..0] of NUID0 must be set to 01111bin.

Fig 5. How to create a single size NUID out of double size UID

This NUID can be treated like the standard NUID.

3.2.3 RID for card activation, but Single Size NUID for the system

The MIFARE card with RID can be activated like a usual Single Size UID card.

In case RID is enabled, there is a defined and confidential way to retrieve the UID, which then can be used in the (background) system.

If the UID is a Double Size UID, the proposal as shown above (see 3.2.2) can be used to derive a Single Size NUID from the Double Size UID.

3.2.4 RID for card activation, but Double Size UID for the system

The MIFARE card with RID can be activated like a usual Single Size UID card.

In case RID is enabled, there is a defined and confidential way to retrieve the UID, which then can be used in the (background) system.

3.2.5 MIFARE Classic Authentication

The MIFARE Classic card requires a 4 byte UID input for the authentication command as shown in Table 4.

Table 4. UID bytes as input for the MIFARE Classic Authentication

Table description (optional)

Product	UID	Input for Authentication	Comments
MF1Sxxxx	4 byte UID	4 byte UID (UID0...UID3)	
MF1Sxxxx	4 byte NUID	4 byte NUID (UID0...UID3)	
MF1Sxxxx	7 byte UID	CL2 bytes (UID3...UID6)	
MF1Sxxxx	7 byte UID	CL1 bytes (CT,UID0...UID2)	for shortcut activation
MF1Sxxxx	4 byte RID	4 byte RID (UID0…UID3)	
MF1 PLUS	7 byte UID	CL2 bytes (UID3...UID6)	in SL1 and SL2
MF1 PLUS	4 byte UID	4 byte UID (UID0...UID3)	in SL1 and SL2
MF1 PLUS	4 byte NUID	4 byte NUID (UID0...UID3)	in SL1 and SL2
MF1 PLUS	4 byte RID	-	not available in SL1 or SL2
P5 xxx	4 byte UID	4 byte UID (UID0...UID3)	in B1 / B4 using MIFARE OS
P5 xxx	4 byte NUID	4 byte NUID (UID0...UID3)	in B1 / B4 using MIFARE OS
P5 xxx	7 byte UID	CL2 bytes (UID3...UID6)	in B1 / B4 using MIFARE OS[7]
P5xxx	4 byte RID	4 byte RID (UID0…UID3)	in B1 / B4 using MIFARE OS[7]

3.2.6 Key diversification with MIFARE SAM

The key diversification input must not be the RID. In case of NUID, the 4 bytes NUID can be taken as input.

Refer to [3] for more details.

7 For MIFARE Classic implementation using the MIFARE FleX™ framework

4. Annex A, Overview over reader UID functionalities

The following tables indicate, how Double Size UID are supported by which reader, reader module or reader IC.

Reader Modules:

Reader	Anti-collision	WRITE	Comment
MF CM200	cascade level 2 possible, but LLL[8] has to be adapted[9]	possible, but LLL has to be adapted	The MF CM200 is not available anymore.
MF CM500	cascade level 2 possible, but LLL has to be adapted[10]	possible, but LLL has to be adapted	The MF CM500 is not available anymore.

Reader Devices:

Reader	Anti-collision	WRITE	Comment
MF RD260	only cascade level 1, no firmware update or extension possible	only COMPATIBILITY WRITE, no firmware update or extension possible	Does not support 7 Byte UID. The MF RD260 is not available anymore.
MF RD560	only cascade level 1, no firmware update or extension possible	only COMPATIBILITY WRITE, no firmware update or extension possible	Does not support 7 Byte UID. The MF RD560 is not available anymore.

Reader ICs:

Reader	Anti-collision	WRITE	Comment
MF RC171	full cascade level 2 possible, but LLL has to be adapted	possible, but LLL has to be adapted	The MF RC171 is not available anymore.
MFRC500	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	
MF RC530	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	
MF RC531	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	
CL RC632	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	
MF RC522	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	
MF RC523	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	
PN xxx	BFL contains the full cascade level 2 support	BFL contains the full 4 byte WRITE support	

[8] **L**ow **L**evel **L**ibrary

[9] example see 6.2

[10] example see 6.2

5. List of References

[1] Doc. No. 0184xx “AN10833 MIFARE Type Identification Procedure”

[2] Doc. No. 1308xx “AN10834 MIFARE ISO/IEC 14443 PICC Selection”

[3] Doc. No. 1653xx “AN10922 Symmetric key diversifications”

6. Annex B, LLL extension for RC171 and CM220/CM500

6.1 MF RC171 low level library extension: Cascade Anticollision

```
/*****************************************************************************/
int CALL_CONV MfPiccCascAnticoll (unsigned char select_code,
                                  unsigned char bcnt,
                                  unsigned char *snr)
/*****************************************************************************/
{
  int           status;
  unsigned char snr_chk = 0;
  int           i;

  if (MfAssertMode(select_code,0x93|0x95|0x97))
      return (MI_WRONG_PARAMETER_VALUE);

  MfOutp(ENABLE, _PEN | _PRE);         // CRC-disable, Parity enable
  MfOutp(MODE  , __mode);              // __mode preset
  MfOutp(BCNTS ,(unsigned char)(bcnt + 16));           // 16 + number of
bits
  MfOutp(STACON, (unsigned char)(__stacon|_AC));        // anticollision-
mode
  MfDelay50us(4);                                 // BUS-access not allowed
                                                  // for 35us
  MfOutp(DATA, select_code);           // "SELTYPE" of MIFARE1
  MfOutp(DATA, (unsigned char)(((2 + (bcnt >> 3)) << 4) | (bcnt &
0x07)));
                                                   // bytecount higher nibble
                                                   // bitcount  lower  nibble
                                                   // incl. first 2 bytes!!
  for (i = 0; i < (bcnt + 7)/8; i++)
  {
    MfOutp(DATA, snr[i] );
  }
  MfOutp(TOC, TIMEOUT_14443_3); // set timeout
  while (!((status = MfInp(STACON)) & _DV));
  MfOutp(TOC, 0);         // reset timer

  if ((status = MfInp(STACON)) & (_TE | _BE))       // any error
  {
     if (status & _TE)
       return (MI_NOTAGERR);
     if (status & _BE)
     {
       MfDelay50us(10);            // delay 500us
       return (MI_BITCOUNTERR);
     }
  }
  for (i = 0; i < 4; i++)
  {
     snr[i] = MfInp(DATA);
     snr_chk ^= snr[i];
  }
  snr_chk ^= MfInp(DATA);
  // serialnumber check
  if (snr_chk)
    return (MI_SERNRERR);
  return (MI_OK);
}
```

6.2 MF CM200 / CM500 low level library extension: Cascade Anticollison

```
/*****************************************************************************/
int CALL_CONV MfPiccCascAnticoll (unsigned char select_code,
                                  unsigned char bcnt,
                                  unsigned char *snr)
/*****************************************************************************/
{
  int           status;
  unsigned char snr_chk = 0;
  int           i;

  if (MfAssertMode(select_code,0x93|0x95|0x97))
      return (MI_WRONG_PARAMETER_VALUE);

  MfOutp(ENABLE, _PEN | _PRE);         // CRC-disable, Parity enable
  MfOutp(MODE  , __mode);              // __mode preset
  MfOutp(BCNTS ,(unsigned char)(bcnt + 16));           // 16 + number of
bits
  MfOutp(STACON, (unsigned char)(__stacon|_AC));        // anticollision-
mode
  MfDelay50us(4);                               // BUS-access not allowed
                                                // for 35us
  MfOutp(DATA, select_code);           // "SELTYPE" of MIFARE1
  MfOutp(DATA, (unsigned char)(((2 + (bcnt >> 3)) << 4) | (bcnt &
0x07)));
                                                 // bytecount higher nibble
                                                 // bitcount  lower  nibble
                                                 // incl. first 2 bytes!!
  for (i = 0; i < (bcnt + 7)/8; i++)
  {
    MfOutp(DATA, snr[i] );
  }
  MfOutp(TOC, TIMEOUT_14443_3); // set timeout
  while (!((status = MfInp(STACON)) & _DV));
  MfOutp(TOC, 0);         // reset timer

  if ((status = MfInp(STACON)) & (_TE | _BE))       // any error
  {
     if (status & _TE)
       return (MI_NOTAGERR);
     if (status & _BE)
     {
       MfDelay50us(10);            // delay 500us
       return (MI_BITCOUNTERR);
     }
  }

  for (i = 0; i < 4; i++)
  {
     snr[i] = MfInp(DATA);
     snr_chk ^= snr[i];
  }
  snr_chk ^= MfInp(DATA);
  // serialnumber check
  if (snr_chk)
    return (MI_SERNRERR);
  return (MI_OK);
}
```

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8. Contents

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