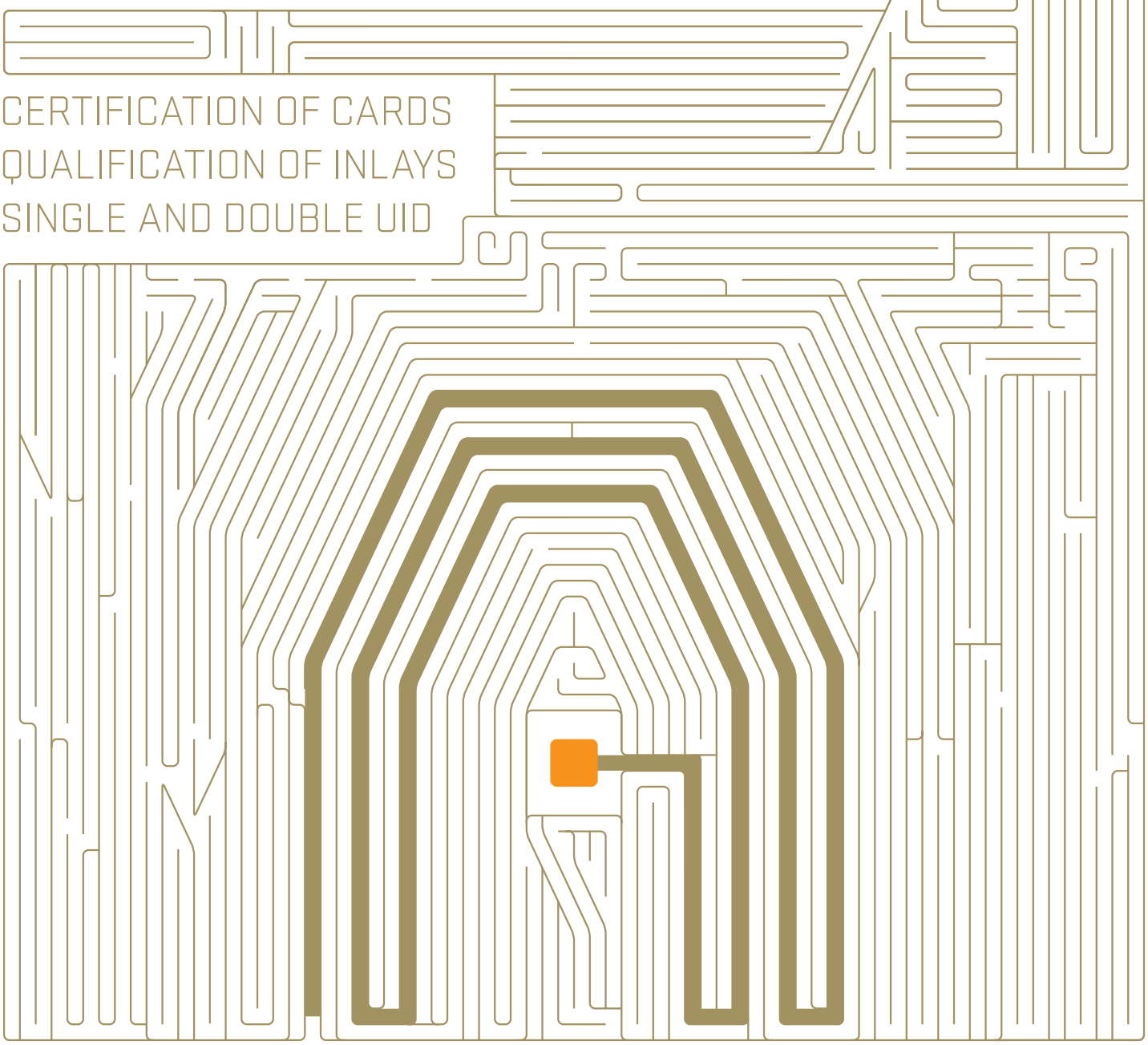
TESTPLAN FOR MIFARE™ AIR-INTERFACE COMPATIBILITY & ISO-CERTIFICATION

CERTIFICATION OF CARDS
QUALIFICATION OF INLAYS
SINGLE AND DOUBLE UID

Arsenal Testhouse GmbH
Untergoin 39
3074 Michelbach, Austria
ts@arsenal-testhouse.com
www.arsenal-testhouse.com

MiFARE Certification Institute



REVISION HISTORY

Revision	Date	Description	Author
1.0	2012/05/01	Initial Issue	T.Sumberger

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1. Introduction

This document describes procedures for testing of MIFARE™ Air-Interface Compatibility of cards. The purpose of the certification process is to ensure that any certified card of one manufacturer will be able to establish data exchange via the RF-interface with any certified terminal of any other manufacturer. To ensure compatibility a set of parameters and tests were defined, that have to be met by both cards and terminals.

MIFARE™ cards are fulfilling this test plan comply with the relevant clauses of ISO/IEC 14443 (type A) and ISO/IEC 10373-6.

Currently they can be either *Single UID* (single 32 bit UID) or *Double UID* (cascaded UID, up to level 2).

2. Terms and definitions

The following list gives a short explanation of terms and shortcuts used in this document:

Module	Chip on a carrier material without connected antenna
Inlay	Carrier, containing a chip/module with connected antenna
Card	TAG with physical dimensions according to ISO/IEC 7810
PICC	Proximity card with physical dimensions according to ISO/IEC 7810
PCD	Proximity coupling device – read/write device for PICC
DUT	Device under test
RF	Radio frequency
ASK	Amplitude shift key (modulation)
MCI	MIFARE™ Certification Institute (AIT)
EOP	End of "PAUSE"
EOC	End of communication bit
REQA	Request command (ISO/IEC 14443)
WUPA	Wakeup command (ISO/IEC 14443)
ATQA	Answer to a request (ISO/IEC 14443)
Card Identifier	Card identification number for administration
UID	Unique identification number (Serial number)
SEL	Select command (ISO/IEC 14443)
SAK	Select acknowledge (ISO/IEC 14443)
HLTA	Halt command (ISO/IEC 14443)
H	Magnetic field strength
C	Modulation coefficient
C-carrier	Carrier signal load modulation coefficient
C-upper	Upper sideband load modulation coefficient
C-lower	Lower sideband load modulation coefficient
C-min	Minimum load modulation coefficient
A	Area
FDT	Frame Delay Time (ISO/IEC 14443)

3. Certification

3.1. Test samples

Applicants seeking certification have to make available test samples of the cards in the required quantity. Test samples will be kept at MCI for reference. The applicant has to provide to MCI any information about the construction of the cards, used parts and their suppliers and subcontractors asked by MCI.

3.2. Certificate and test report

For cards having successfully passed all applicable tests of this test plan a certificate will be awarded with the MIFARETM Air-Interface Compatible logo showing if the card is single or double UID. Besides the certificate, the test report containing the individual test results is handed out to the applicant.

3.3. Compatibility notes

MIFARE™ Air-Interface Compatibility is verifying the contactless RF interface only and is therefore applicable to all types of MIFARE™ cards. This certification ensures that basic data exchange can be established between the card and the terminal over the RF-interface only. No further functionality of the card is tested.

MIFARE™ terminals certified according to the "Test plan for MIFARE™ Compatibility for Certification of Terminals and Qualification of Contactless Readers" up to version 2.1 are not verified to handle cascaded UIDs correctly.

The following table shows the compatibility matrix:

Card \ Reader	Single UID reader/terminal	Double UID reader/terminal
Single UID	yes	yes
Double UID	no	yes

3.4. Certification of cards

MIFARE™ certification is available to card manufacturers for finished cards.

Generally a card comprises of an inlay holding the chip and antenna coil, which is moulded into a plastic material, forming the card.

A *Full Certification Test* is carried out on a submitted card that, in its entity or parts of it, has not been tested for certification or qualification according to this test plan or any prior version of it.

An *Upgrade Certification Test* can be carried out if the inlay of the presented card has already been qualified according to this test plan to obtain a MIFARE™ Air-Interface Compatible certificate for the card.

A *Delta Certification Test* is intended for customers already having a MIFARE™ Air-Interface Compatible certificate for their card, but having minor changes (e.g. card material or chip module). In this case a reduced test set is applicable for re-certification of their card.

An *ISO Certification Test* is carried out, if the applied cards have no MIFARE™ Chip assembled. At this test the lower limit H_{min} is 1.5 A/m instead of 1.25 A/m.

Test sets for the individual certification tests are described in section 0.

3.5. Qualification of inlays (prelams)

This test plan introduces the concept of qualification for inlays, produced by a third party manufacturer, who can apply for qualification of an inlay without having to produce a complete card. The test set for qualification of an inlay is the same as for certification of a card (*Full Certification Test*).

By using an inlay that has been qualified according to this test plan a card manufacturer can apply for certification of his card by an *Upgrade Certification Test*.

3.6. Validity period

A MIFARE™ certificate and MIFARE™ qualification is valid for a period of two years from the day of issue as long as no changes are made to the product. If changes are necessary, information about the change has to be passed on to the MIFARE™ Certification Institute, which will decide if it is a minor or major change. For major changes a *Full Certification* is required, for minor changes a *Delta Certification* with a reduced test set is applicable.

Note: A change of chip type or coil characteristics always constitute a major change.
Exception: Exchange of the chip to another of the same type and manufacturer, but with different memory size.

3.7. Renewal of certificate

After the MIFARE™ certificate or MIFARE™ qualification has expired after two years and the product is still manufactured without change, a renewal of the certificate can be applied for within two years after the expiration. The test set for renewal is that of a *Delta Certification*.

3.8. Test sets

Test sets for the various types of certification and qualification are defined in the following tables.

3.8.1. Full Card Certification or Inlay Qualification

Test set	Number of cards	Performed tests	Testplan paragraph	Test temperature
Full Certification Inlay Qualification	1	Coil size	5.1	---
	5	Maximum field strength	5.10	50°C
	10	Resonance frequency	5.2	23°C
		Minimum operating field	5.3	0 / 23 / 50°C
		PICC Reception	5.4	0 / 23 / 50°C
		Miller decoder	5.5	0 / 23 / 50°C
		Frame delay	5.6	0 / 23 / 50°C
		Load modulation	5.7	0 / 23 / 50°C
		Functional test	5.8	23°C
		State machine test	5.9	23°C

3.8.2. Upgrade Certification

Test set	Number of cards	Performed tests	Testplan paragraph	Test temperature
Upgrade Certification	1	Inlay identification check	5.11	23°C
	3	Maximum field strength	5.10	50°C
	6	Resonance frequency Minimum operating field PICC Reception Miller decoder Frame delay Load modulation Functional test State machine test	5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9	23°C 0 / 23 / 50°C 0 / 23 / 50°C 0 / 23 / 50°C 0 / 23 / 50°C 0 / 23 / 50°C 23°C 23°C

3.8.3. Delta Certification

Test set	Number of cards	Performed tests	Testplan paragraph	Test temperature
Delta Certification	1	Coil size	5.1	---
	3	Maximum field strength	0	50°C
	6	Resonance frequency Minimum operating field PICC Reception Miller decoder Frame delay Load modulation Functional test State machine test	5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9	23°C 23°C 23°C 23°C 23°C 23°C 23°C 23°C

3.8.4. Full ISO Certification

Test set	Number of cards	Performed tests	Testplan paragraph	Test temperature
Full ISO Certification	5	Maximum field strength	0	50°C
	10	Resonance frequency Minimum operating field PICC Reception Frame delay Load modulation Functional test State machine test	5.2 5.3 5.4 5.5 5.7 5.8 5.9	23°C 0 / 23 / 50°C 0 / 23 / 50°C 0 / 23 / 50°C 0 / 23 / 50°C 23°C 23°C

3.9. Standards and related documents

Document	Title	Status	Edition/Date
ISO/IEC 14443-1	Identification cards – Contactless integrated circuit(s) cards – Proximity cards Part 1: Physical characteristics	IS	Ed. 2/2008
ISO/IEC 14443-2	Identification cards – Contactless integrated circuit(s) cards – Proximity cards Part 2: Radio frequency power and signal interface	IS	Ed. 2/2010
ISO/IEC 14443-3	Identification cards – Contactless integrated circuit(s) cards – Proximity cards Part 3: Initialisation and anticollision	IS	Ed. 2/2011
ISO/IEC 10373-6	Identification cards – Test Methods Part 6: Proximity cards	IS	Ed. 2/2011
ISO/IEC 7810	Identification cards – Physical characteristics	IS	Ed. 3/2003
MIFARE™ Application Note	Card IC Coil Design Guide	Rev 3.2	2006/07

4. Test plan for MIFARETM Air-Interface Compatibility

Compatibility testing is performed on a batch of sample cards, drawn by MCI from a manufacturer's production lot.

Tests are performed at standardised ambient temperature (23°C±3°C), as well as the upper and lower operating temperature limits (see table I).

The test plan shown in table I gives an overview of the compatibility tests. The test lot is divided into two batches, one batch is loaded with maximum field strength according to test 0 before all measurements of tests 5.2 to 5.9 are performed.

Cards are tested under controlled temperature with a conditioning time of 30 seconds. For the actual test the RF field is turned on for 1 second. Measurements are taken at the end of the on-time of the RF field.

Minimum operating field strength is H_{min} = 1.25 A/m (rms), maximum operating field strength is H_{max} = 7.5 A/m (rms).

Test / Measurement	Test	Test configuration	Test limits	Magnetic field strength	Test temperature	Measured value
Coil size	5.1		A_{active} > 11200 mm^2 A_{mean} > 2778.5 mm^2 [1])		23°C	
Resonance frequency	5.2		14.5 – 18.5 MHz		23°C	fres [MHz]
Minimum Operating field	5.3	ISO/IEC 10373-6	[2]) C = 17.96mV		0°C, 23°C, 50°C	Minimum field strength
PICC Reception	5.4	ISO/IEC 10373-6	[2]) C-sideband levels [mV peak] > $22/H^{0.5}$	H = 1.25 and 7.5 A/m	0°C, 23°C, 50°C	C-carrier and C-sideband
Miller decoder	5.5	ISO/IEC 10373-6	[2]) C-sideband levels [mV peak] > $22/H^{0.5}$	H = 1.25 and 7.5 A/m	0°C, 23°C, 50°C	C-carrier and C-sideband
Frame delay time PCD to PICC	5.6	ISO/IEC 10373-6	EOP threshold 5% ... 60%	H = 1.25 and 7.5 A/m	0°C, 23°C, 50°C	EOP threshold in %
Load modulation	5.7	ISO/IEC 10373-6	[2]) C-sideband levels [mV peak] > $22/H^{0.5}$	H = 1.25 - 3 - 4.5 - 6 – 7.5 A/m	0°C, 23°C, 50°C	C-carrier and C-sideband
Functional test	5.8			H = 1.25 A/m	23°C	ATQA, UID, SAK
State machine test	5.9			H = 1.25 A/m	23°C	Command sequence
Maximum field strength	0			H = 12.0 A/m max.	50°C	
Inlay identification check[3])	5.11		see 5.11		23°C	

Notes:

[1]) In case a coil of more than 4 turns is used, only the 4 largest windings are considered for calculation of the mean coil area.
[2]) For the magnetic field strength H < 1.5A/m the load modulation coefficients are valid as calculated for 1.5A/m
[3]) For *Upgrade Certification* only, see 3.4 and 3.8.2

Table I: Summary of compatibility tests

5. Tests and Measurements in Detail

The following chapter describes in detail the performed tests on short range and proximity cards (PICCs), their configuration, setup and limits for MIFARE™ Air-interface Compatibility certification.

5.1. Coil size

The card is screened with a high power fluorescent lamp to detect the location of the coil and the chip inside the PICC. The coil size is checked with a diaphragm with an aperture showing the mean coil area defined in the *MIFARE™ Card IC Coil Design Guide*. The active coil area is the sum of the area enclosed by each turn of the coil and the mean coil area is the active coil area divided by the number of turns. Limits for the active coil area are $A_{active} > 11200mm^2$ and for the mean coil area $A_{mean} > 2778.5\ mm^2$. For cards with coils having more than 4 turns, only the 4 largest windings are considered for the calculation of the mean coil area A_{mean}. The barycentre of the mean coil area shall be centric on the card with a maximum deviation of ±6mm from geometric card centre. (see *MIFARE™ Card IC Coil Design Guide*).

5.2. Resonance frequency

The resonance frequency of the card is measured using a RLC meter connected to the calibration coil (which is specified in ISO/IEC 10373-6 for field strength measurement). For the measurement the PICC to test is placed directly on the calibration coil to achieve close coupling. The value of the equivalent series resistor is measured for various frequencies finding out the frequency where the maximum of the equivalent series resistor is measured, which will be the resonance frequency of the card.

The measurement is performed at standard ambient temperature.

The limits for acceptance are:

	min.	max.
f_{res} in MHz	14.5	18.5

5.3. Minimum operating field

The field strength is raised and the level at which the PICC begins to operate is measured. The minimum operating field has to be below $H_{min} = 1.25$ A/m (rms value).

The operation of the PICC is documented by the measurement of the load modulation coefficients which are valid for a field strength of 1.5 A/m (carrier and sideband levels,see 5.7).

The test PCD assembly as described in ISO/IEC 10373-6 (Annex A) is used to drive the PICC under test and to measure the response of it. The basic measurement equipment is shown in figure 1.
For measurement of the magnetic field strength using the calibration coil see ISO/IEC 10373-6. The test is performed at ambient temperature as well as both minimum and maximum specified temperature. For this test a standard modulation pulse signal shall be used as shown in figure 2 with the rise and fall times defined in table II.

Test pattern	t1 [µs]	t2 [µs]	t3 [µs]	t4 [µs]
T1 MID	2.5	1.0	1.0	0.4

Table II: Timing parameters for standard modulation pulse

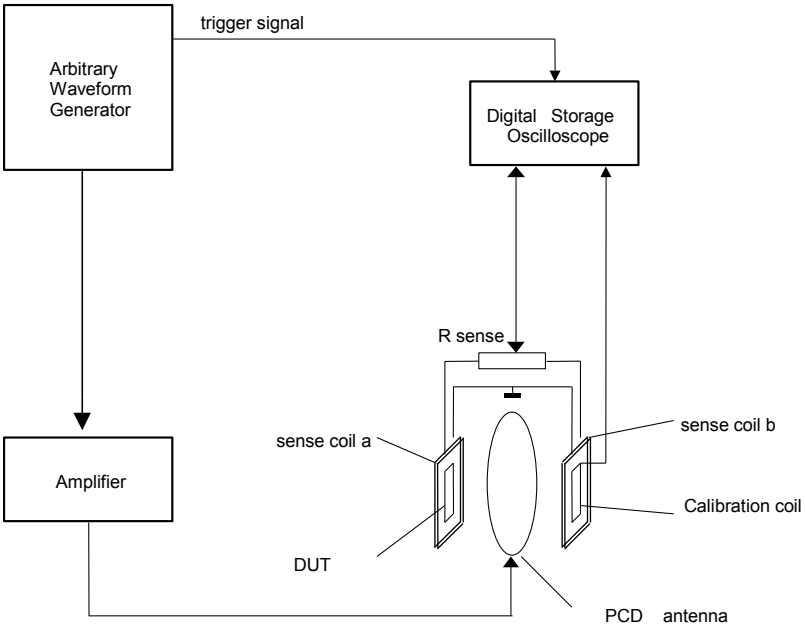

Fig. 1: Basic PICC measurement setup

5.4. PICC Reception (Acceptance of "Pause")

Communication between PCD and PICC takes place using the modulation principle of ASK with a modulation index of 100%, creating a pulse as shown in figure 4.2, called "PAUSE". This test verifies the acceptance of the pulses with various length and shape sent by the PCD.
The test setup is described in figure 1. Without a PICC in the test setup the amplifier level is adjusted until the desired field strength is reached, using the output of the calibration coil for calculating the magnetic field strength. Then the PICC is placed in the DUT position. A request (REQA) commands is sent to the PICC while checking the response on the digital storage oscilloscope. The operation of the PICC is documented by the presence of load modulation coefficients (carrier and sideband levels, see 5.7). The test is run with a set of differently shaped pulses to test worst case conditions.

The test is performed at ambient temperature as well as both minimum and maximum specified temperature (see table I). Tested field strengths are H_{min} and H_{max}.

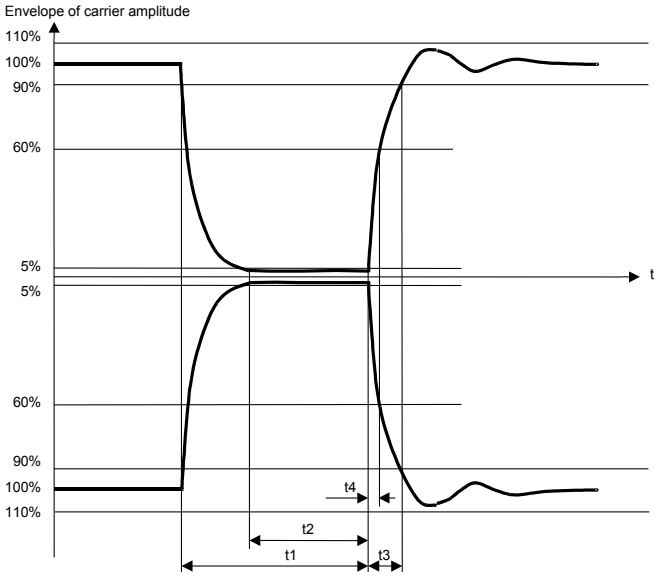

Fig. 2: Modulation pulse "PAUSE"

Test pattern	t1 [µs]	t2 [µs]	t3 [µs]	t4 [µs]
ISO Scenario 1	3.0	0.6	1.2	0.5
ISO Scenario 2 [2])	2.0	1.6	1.0	0.5
ISO Scenario 3 [2])	3.0	0.5	0.25	0.14
T1 MAX [3])	3.0	1.4	1.0	0.4
T1 MIN [3])	2.0	0.7	1.0	0.4
T2 5% [3])	3.0	1.5	1.0	0.4
HUMP [1])	3.0	1.0	1.0	0.4

Table III: Timing parameters for modulation pulses

[1]) Falling edge does not decrease monotonically but has a local maximum of 10% with a time interval of 0.5µs between the local maximum and the point of passing the 10%-level before.
[2]) Waveforms with 10% overshoot
[3]) This waveforms will be used for chip types, which were developed according to ISO 14443:2001.

5.5. Miller decoder

This test verifies the correct decoding of the pulses sent to the PICC and checks the sensitivity to tolerances of the "PAUSE" pulse with respect to its position in the bit-frame.

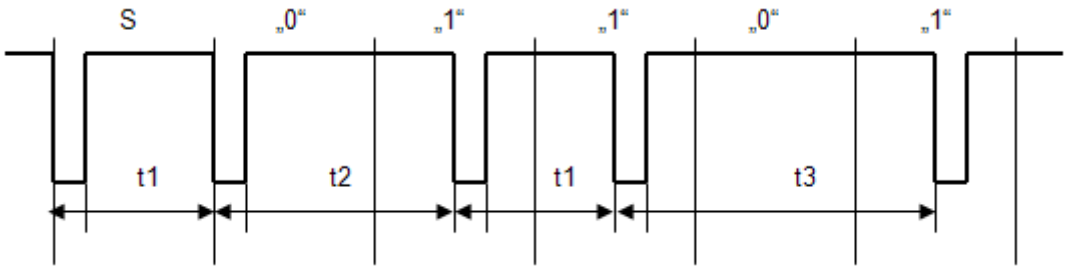

Fig. 3: Timing of pulses sent to PICC

Limits stated in table IV shall apply for MIFARE™ Certification of PICCs.

Pattern / Parameter		periods of fc = 13.56 MHz	value in µs
MILLER MIN	t1	116	8.47
	t2	180	13.14
	t3	244	17.81
MILLER MAX	t1	140	10.22
	t2	204	14.89
	t3	268	19.56

Table IV: Limits for "PAUSE" pulse timing with respect to bit-frame

The test is performed in the setup described in figure 1 using wakeup (WUPA) commands, which are sent to the PICC while checking the response on the digital storage oscilloscope. As modulation pulse a “PAUSE” with a length of 36 periods (2,65µs) is used. The test is run with a set of maximum and minimum parameters to test worst case conditions. Timing values are measured as seen in Fig. 3..

Tested field strengths are H_{min} and H_{max}. Test temperatures are ambient and both minimum and maximum (see table I).

5.6. Frame delay time PCD to PICC

The purpose of this test is to check that the card answers after an exactly defined time following the last bit sent by the reader, which is essential for the functioning of the anticollision. The test circuit is the same as for PICC Reception test. Test commands are sent to the card and the timing is measured. The first modulation bit sent by the PICC have to start exactly 1172 periods after the rising edge of the "PAUSE" of the EOC bit, if the last data bit transmitted is a logic "0", or 1236 periods after the last data bit, if it is a logic "1".

By counting the periods backwards from the first modulation bit of the PICC the "End of Pause"- (EOP-) threshold is measured using a "PAUSE"-pulse with a flat rising edge.

Limits for the EOP are 5% (minimum) and 60% (maximum) of the unmodulated carrier level measured on the calibration coil (see figure 4.1).

The test is performed in the setup described in figure 4.1 using request (REQA) commands, which are sent to the PICC while checking the response on the digital storage oscilloscope.

Tested field strengths are H_{min} and H_{max}. Test temperatures are ambient and both minimum and maximum (see table I).

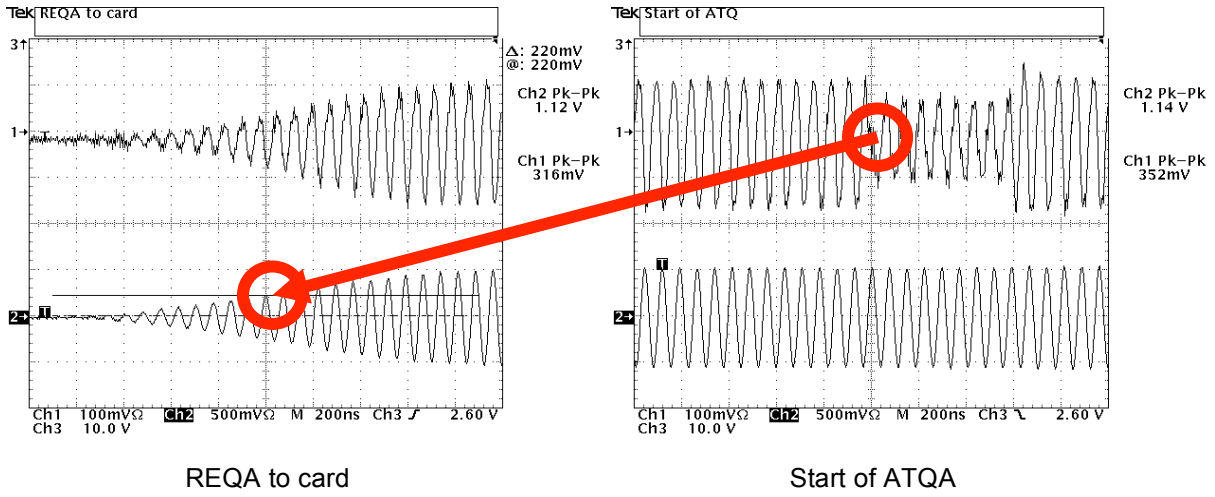

Fig. 4: Frame delay time measurement

5.7. Load modulation

The test circuit defined in ISO/IEC10373-6 with the setup of figure 1 is used. A request (REQA) command is repeatedly sent to the PICC while checking the response on the digital storage oscilloscope. The magnetic field strength is set to the defined levels of 1.25 A/m, 3 A/m, 4.5A/m, 6 A/m and 7.5 A/m by measurement through the calibration coil. The standard timing of modulation pulse “PAUSE” defined in figure 2 and table II shall be used. Stored data in the digital oscilloscope is read out and processed by a computer. Carrier and sideband levels are calculated by a discrete Fourier transformation as defined in ISO/IEC 10373-6. The calculated load modulation amplitude shall be at least $C = 22/H^{0.5}$ (mVpeak), where H is the magnetic field strength in A/m (rms). For the magnetic field strength H < 1.5A/m the load modulation coefficients are valid as calculated for 1.5A/m.

Test temperatures are ambient and both minimum and maximum (see table I).

5.8. Functional test

A computer controlled test setup incorporating a reader module is used to test the basic functionality of the PICC. This tests check that the PICC answers correctly to a request (REQA) command with a answer to request (ATQA) and performs a full sequence anticollision loop as defined in ISO/IEC 14443-3. Then reading of the serial number (UID) and selecting of the PICC is tested. Finally a check of the acknowledge (SAK) sent by the PICC according to the definitions made in ISO/IEC 14443-3 is done. For PICCs with double UID the byte 'uid[0]' shall specify the IC-manufacturer as given in the Registration Sheet.

Tested field strength is $H_{min.}$ Test temperature is ambient (see table I).

5.9. State machine test

A computer controlled test setup incorporating a reader module is used to test the correct sequence of commands according to the definitions made in ISO/IEC 14443-3 and a typical anticollision loop on two cards.

Tested field strength is $H_{min.}$ Test temperature is ambient (see table I).

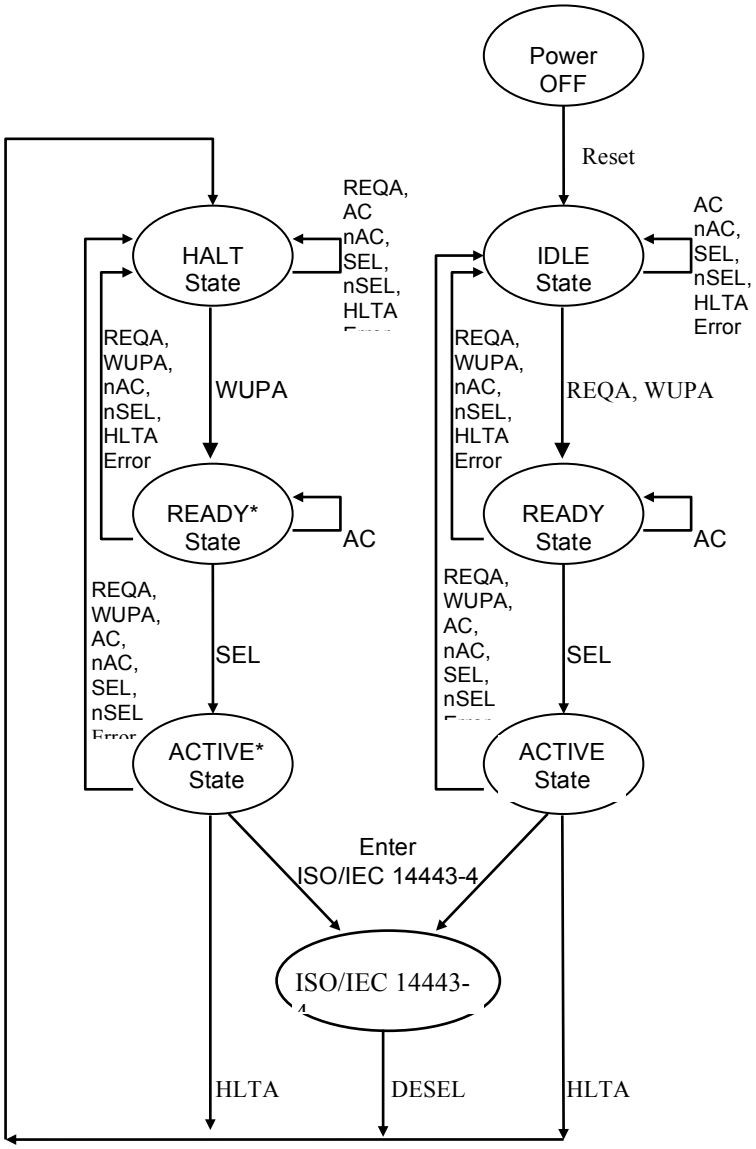

Fig. 5: State machine diagram

5.10. Maximum field strength

The tested cards are exposed to a magnetic field strength of 12A/m for 25s followed by an off-state for 5s repeated twice at the carrier frequency (13.56MHz). This results in average field strength levels of 10A/m for an averaging period of 30s according to the definitions made in ISO/IEC 14443-1.

Ambient temperature is 50°C, total duration of exposure is one minute.

After the exposure the full test programme will be performed and the results have to be within the specified limits.

5.11. Inlay identification check

This test is only applicable for a MIFARE™ *Upgrade Certification*. In this case it is necessary to prove that the inlay of the submitted card is the same as qualified earlier by a MIFARE™ *Inlay Qualification.*

The inlay identification check comprises a test of visual and electrical parameters, defined in the following table:

Test group	Tests	Testplan paragraph	Max. deviation from qualified inlay
Visual	Coil size and layout	5.1	±0.5mm in either axis
	Coil type and material		same type and material
	Module		same module
Electrical	Resonance frequency	5.2	±300 kHz
	Minimum operating field	5.3	±0.1 A/m
	Load modulation	5.7	±5mV

All tests are carried out at 23°C only.