13.56MHz, ISO15693 Standard Compliant Contactless Identification Device

General Description

The EM4135 is a CMOS integrated circuit intended for use in contactless Read/Write transponders. The IC is a member of IS O 15693 standard passive Read/Write RF tags operating at 13.56MHz.

The 2.4k bit EEPROM memory contained in the chip is organized in 38 words of 64 bits, each word can be irreversibly locked. The memory contains a unique serial number (UID).
An ISO 15693 anticollision algorithm allows operating more tags in the field simultaneously. The EM4135 is completely ISO 15693 compliant since it includes all ISO15693 mandatory features.

The 64bits UID as defined in ISO15693 standard is factory programmed and locked. It includes a 6 bits chip type and a 10 bits customer code made specific on request.

The resonant capacitor value is selected by metal mask.

Applications

- Access Control
- Ticketing
- Asset management

Features

- ISO15693 Standard: Fully Compliant
- Operating Frequency: 13.56MHz ± 7KHz (ISM, world-wide licence free available)
- 2.4K bit EEPROM organised in 38 words of 64 bits
- 64-bit Unique Identifier (UID)
- Lock feature convert EEPROM words in Read Only
- Support Application Field Identifier (AFI)
- Power-check for EEPROM write operation
- Resonant capacitor integrated on chip 28pF or 95pF (selectable by mask option)
- No external supply buffer capacitor needed
- -40 to +85°C temperature range
- Very low Power consumption (no battery needed)
- Bonding pads optimised for flip-chip assembly

Typical Operating Configuration

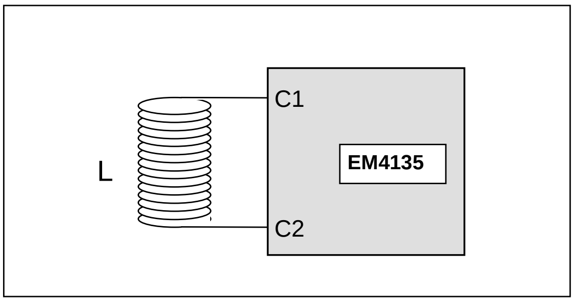


Figure 1.

Block Diagram

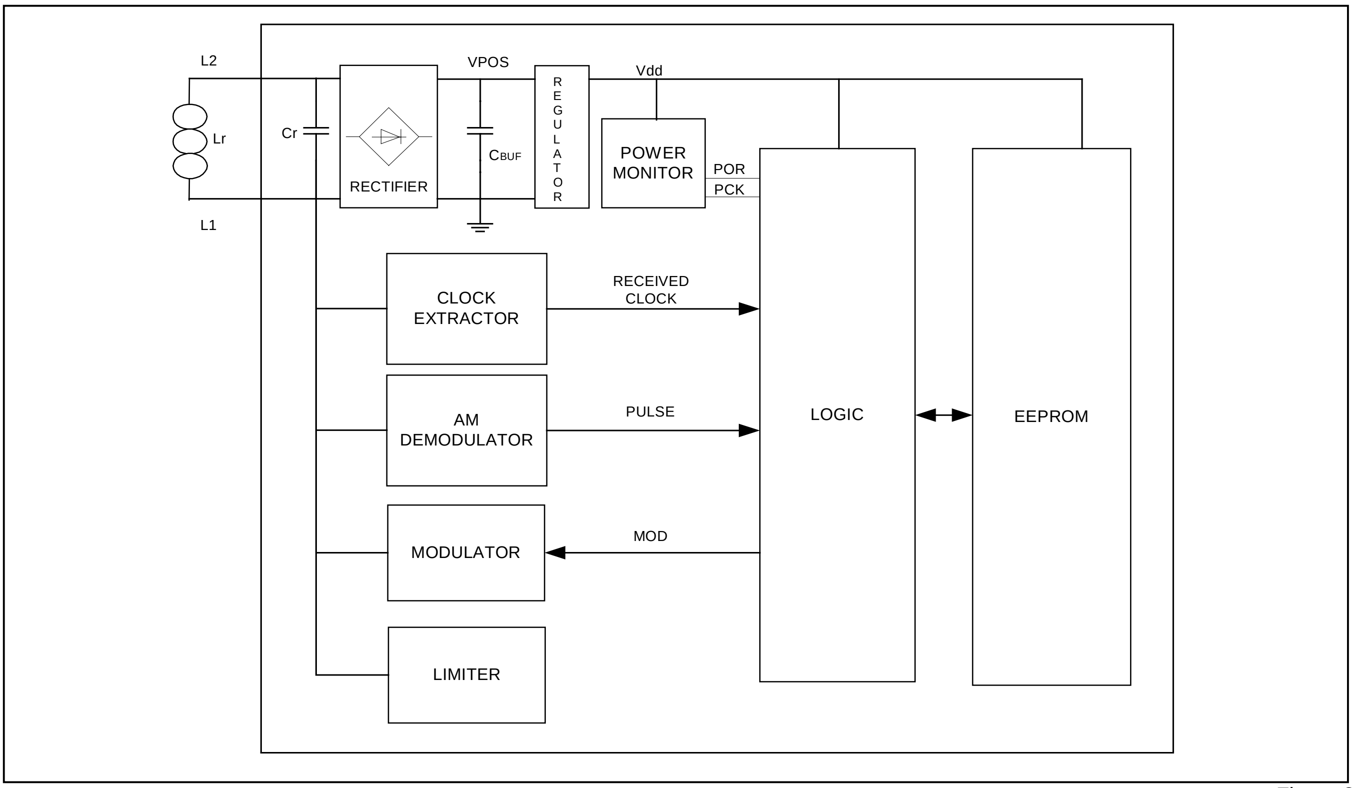


Figure 2.

Definitions, abbreviations and symbols

Terms and definitions

Downlink
Tag to reader communication link

Uplink
Reader to tag communication nlink

Modulation index
Modulation Index equal to [a-b] / [a+b] where a and b are the peak and minimum signal amplitude respectively.
Note: The Index value may be expressed as a percentage.

SubCarrier
A signal of frequency fs used to modulate the carrier of frequency fc

Byte
A byte consists of 8 bits of data designated b1 to b8, from the most significant bit (MSB, b8) to the least significant bit (LSB, b1)

Anticollision loop
Algorithm used to prepare for and handle a dialogue between a VCD and one or more VICCs from several in its energising field.

Abbreviations

AFE	Analog Front-End
AFI	Application family identifier
ASK	Amplitude shift keying
CRC	Cyclic Redundancy Check
DSFID	Data Storage Format Identifier
EOF	End of Frame
LSB	Least significant bit
MSB	Most significant bit
PPM	Pulse position modulation
RF	Radio frequency
RFU	Reserved for future use
SOF	Start of frame
VCD	Vicinity coupling device (reader)
VICC	Vicinity integrated circuit card (tag)
UID	Unique identifier

Symbols

a	Carrier amplitude without modulation
b	Carrier amplitude when modulated
fc	Frequency of operating field (carrier frequency)
fs	Frequency of subcarrier

Handling Procedures

This device has built-in protection against high static voltages or electric fields; however, anti-static precautions should be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within supply voltage range.

Electrical Specifications

Absolute maximum ratings

V_{SS} =0 V

Parameter	Symbol	Min	Max.	Unit
Supply Voltage	V_{POS}	-0.3	7	V
Voltage at any other pin except L1,L2	V_{pin}	V_{SS}-0.3	3.6	V
Storage temperature	T_{store}	-55	+125	°C
Operating temperature	T_{op}	-40	+ 85	°C
Maximum AC current induced on L1, L2	I_{coil_RMS}		30	mA

Table 1.

Stresses above these listed maximum ratings may cause permanent damage to the device. Exposure beyond specified electrical characteristics may affect reliability or cause malfunction.

Operating Conditions

V_{SS} =0 V

Parameter	Symbol	Min	Max	Unit
AC peak current induced on L1, L2 in operating conditions	I_{coilop}		10	mA
Operating temperature	T_{op}	-40	85	°C

Table 2.

Electrical Parameters

Operating conditions (unless otherwise specified):

V_{POS} = 3.0V, V_{SS} = 0V, F_{coil} = 13.56MHz Sine wave, V_{coil} = 2V_{pp}, T_{op} = 25°C

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Resonance Capacitor	C_r	f = 100 kHz, U = 100mVpp	25.2	28	30.8	pF
Resonance Capacitor	C_r	f = 100 kHz, U = 100mVpp	85.5	95	104.5	pF
Series resistance of Resonance Capacitor	R_s	f = 13.56 MHz, U = 100mVpp			5	Ω
Coil limiting voltage	V_{CLIM}	Icoil=10mA	4.5	5.5	7	V
Regulated voltage	V_{REG}	Icoil=10mA	2.6	3.0	3.4	V
EEPROM Read Voltage	V_{RD}	Read Mode	1.8			V
Supply current	I_{RD}	Circuit is in ready state			120	uA
EEPROM write voltage	V_{WR}	Write Mode for EEPROM	2.2			V
EEPROM write current	I_{WR}	Write Mode for EEPROM		30	50	uA
POR level high	V_{PORH}		2.2	2.5	2.9	V
POR level low	V_{PORL}		1.3	1.6	1.9	V
Power-Check high	V_{PWRH}		2.2	2.45	2.7	V
Power-Check low	V_{PWRL}		2.1	2.35	2.6	V
Modulator Voltage Drop, low current	$V_{modiso1}$	IL2 = 100 uA	1			V
Modulator Voltage Drop high current	$V_{modiso2}$	IL2 = 1 mA			2	V
Monoflop Timeout	T_{mono}		0.15	0.3	0.5	us
EEPROM Cycling Endurance	N_{cy}	erase all/ write all	10^5			cycle
EEPROM Retention	T_{ret}	T_{op} = 55°C after 10^5 cycles	10			year

Table 3.

Timing Characteristics

All timings are derived from the field frequency and are specified as a number of RF periods.

Parameter	Symbol	Value Single Subcarrier	Value Dual Subcarrier	Unit
Downlink data rate mode 2048/2032	**Opt 2048/2032**			
Read Bit Period	Trdb	2048	2032	RF Periods
SOF duration	Tsof	8192	8128	RF Periods
EOF duration	Teof	8192	8128	RF Periods
Read one word duration	Trdw	212992	211328	RF Periods
Write Access Time 1	Twa1	1162	1162	RF Periods
Write Access Time 3	Twa3	5764/6532 (note2)	5764/6532 (note2)	RF Periods
EEPROM Write Time	Twee	147136	147136	RF Periods
Downlink data rate mode 512/508	**Opt 512/508**			
Read Bit Period	Trdb	512	508	RF Periods
SOF duration	Tsof	2048	2032	RF Periods
EOF duration	Teof	2048	2032	RF Periods
Read one word duration	Trdw	53248	52832	RF Periods
Write Access Time 1	Twa1	1162	1162	RF Periods
Write Access Time 3	Twa3	5764/6532 (note2)	5764/6532 (note2)	RF Periods
EEPROM Write Time	Twee	147136	147136	RF Periods

Table 4.

Note 1: Twa time depends on the command, see below.
Note 2: The timings are *min/max* for Twa3

Twa1 Write Single Block command
Twa3 Lock Block command

Memory organisation
The 2.4K bit EEPROM are organised in 36 words of 64 bits. Block 0 to 11 are used for proprietary information, so they are not described.

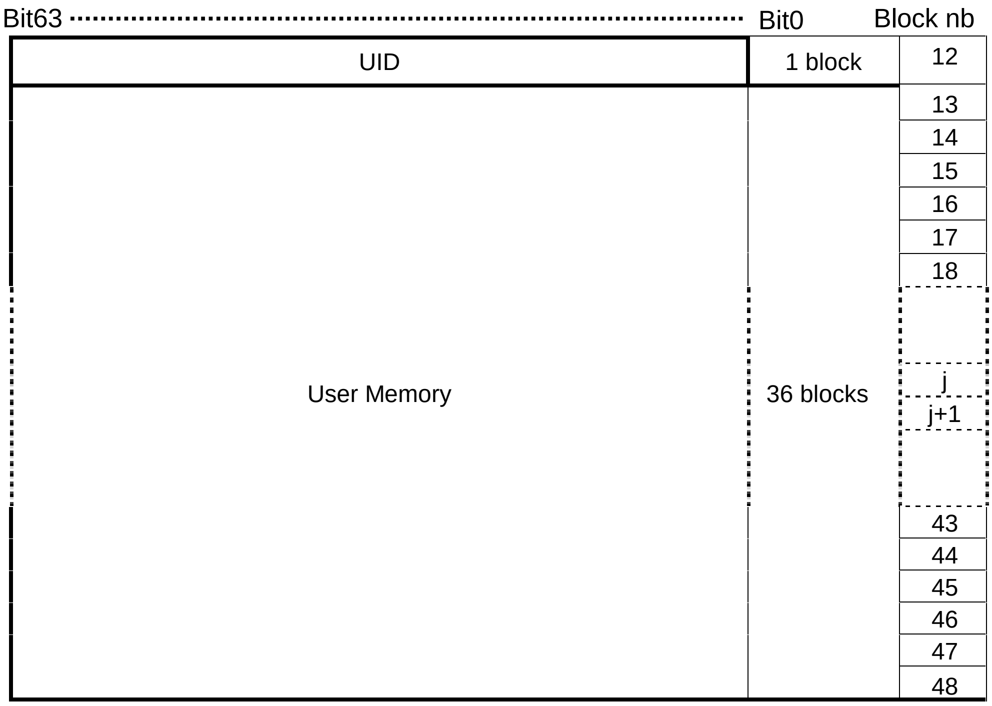


Figure 3.

Note:
- The UID value is worldwide unique serial number programmed at wafer level.

Functional Description

Initial dialogue for vicinity cards

The dialogue between the VCD and the VICC (one or more VICCs may be present at the same time) is conducted through the following consecutive operations:

- Activation of the VICC by the RF operating field of the VCD,
- VICC waits silently for a command from the VCD
- Transmission of a command by the VCD,
- Transmission of a response by the VICC.

These operations use the RF power transfer and communication signal interface specified in the following paragraphs and are performed according to the protocol defined in ISO/IEC 15693-3.

Power transfer

Power transfer to the VICC is accomplished by radio frequency via coupling antennas in the VCD and in the VICC. The RF operating field that supplies power to the VICC from the VCD is modulated for communication from the VCD to the VICC.

Frequency

The frequency fc of the RF operating field is 13,56 MHz ± 7 kHz.

Operating Field

The VCD is capable of powering any single reference VICC (defined in the test methods) at manufacturer's specified positions (within the operating volume).

The VCD does not generate a field higher than the value specified in ISO/IEC 15693-1 (alternating magnetic field) in any possible VICC position.

Test methods for determining the VCD operating field are defined in ISO/IEC 10373-7.

Communications signal interface VCD to VICC

For some parameters several modes have been defined in order to meet different international radio regulations and different application requirements.

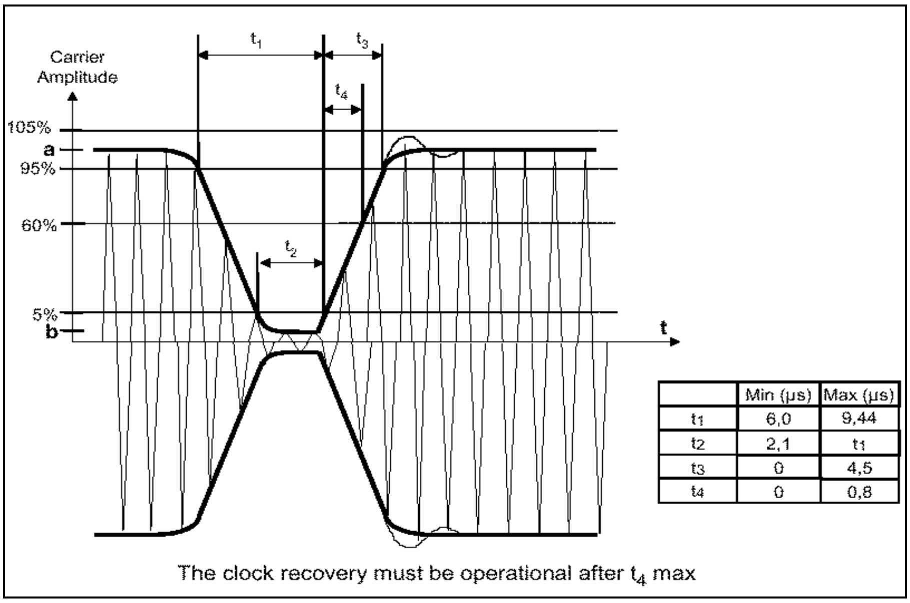
From the modes specified any data coding can be combined with any modulation.
However, combination of 1 out of 256 coding and 100% ASK modulation is not recommended as it may lead to synchronisation problems. Regulatory wise, this combination do not have any benefit. The following combination are recommended:

- 1 out of 256 + 10% ASK for FCC part 15 compliance (US)
- 1 out of 4 + 100 % ASK or 10% ASK for ETSI 300 330 compliance (Europe)

Modulation

Communications between the VCD and the VICC takes place using the modulation principle of ASK. Two modulation indexes are used: 10% and 100%. The VICC decodes both. The VCD determines which index is used.
Depending on the choice made by the VCD, a "pause" will be created as described in Figure 5 and Figure 6.

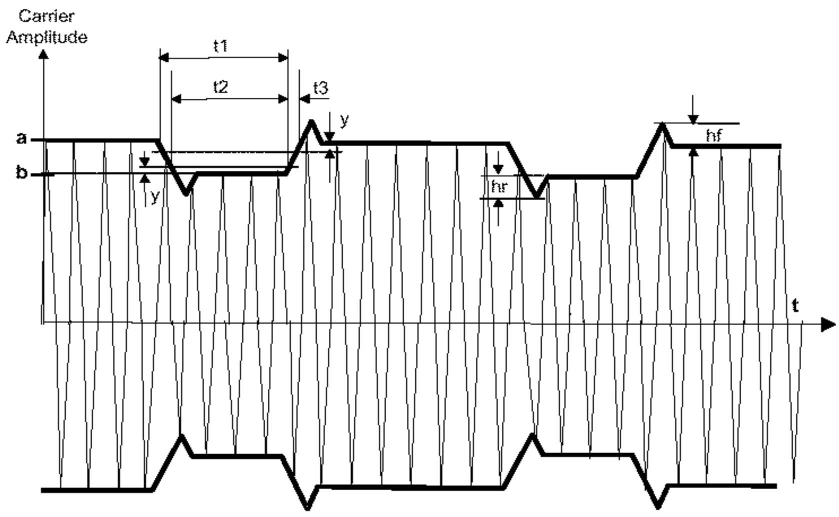
Modulation of the carrier for 100% ASK



	Min (µs)	Max (µs)
t1	6,0	9,44
t2	2,1	t1
t3	0	4,5
t4	0	0,8

Figure 5.

Modulation of the carrier for 10% ASK



	Min	Max
t1	6,0 µs	9,44 µs
t2	3,0 µs	t1
t3	0	4,5 µs
Modulation index	10%	30%

y	0,05 (a-b)
hf, hr	0,1 (a-b) max

The VICC shall be operational for any value of modulation index between10% and 30%.

Figure 6.

Data rate and Data coding
Data coding is implemented using Pulse Position Modulation.

Two data coding modes are supported by the VICC. The selection is made by the VCD and indicated to the VICC within the start of frame (SOF).

Data coding mode: 1 out of 256

The value of one single byte is represented by the position of one pause. The position of the pause on 1 of 256 successive time periods of 256/fc (~18,88 µs), determines the value of the byte. In this case the transmission of one byte takes ~4,833 ms and the resulting data rate is 1,65 kbits/s (fc /8192). The last byte of the frame is completely transmitted before the EOF is sent by the VCD.

Figure 7. illustrates this pulse position modulation technique for a data coding 1 out of 256.

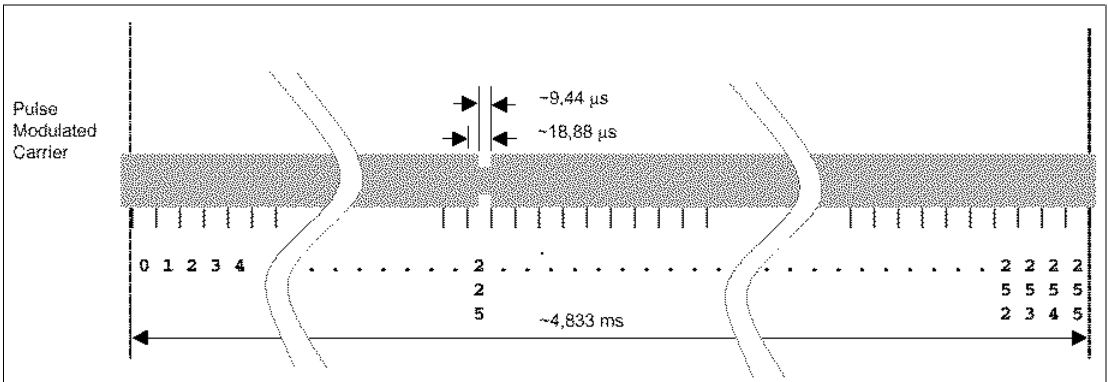


Figure 7.

In Figure 7, the VCD sent the data 'E1' = (11100001)b = (225) to the VICC.

The pause occurs during the second half of the position of the time period that determines the value, as shown in Figure 8.

Detail of one time period

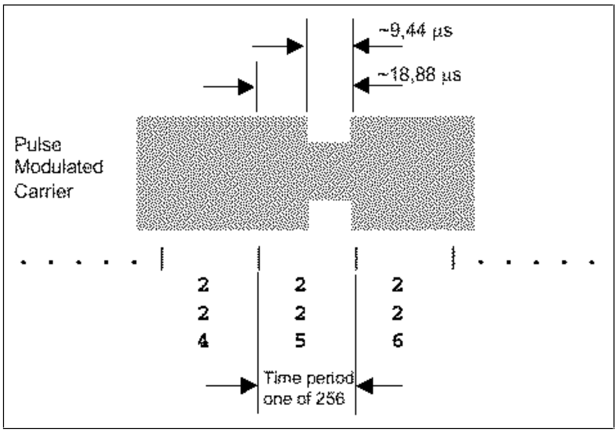


Figure 8.

Warning: In case of usage of 1/256 coding with 100% modulation index, an accurate timing is needed to ensure proper decoding.

Data coding mode: 1 out of 4

Pulse position modulation for 1 out of 4 mode can be also selected. In this case the position determines two bits at a time.

Four successive pairs of bits form a byte, where the least significant pair of bits is transmitted first. The resulting data rate is 26,48K bits/s (fc /512).

Figure 9. illustrates the 1 out of 4 pulse position technique and coding.

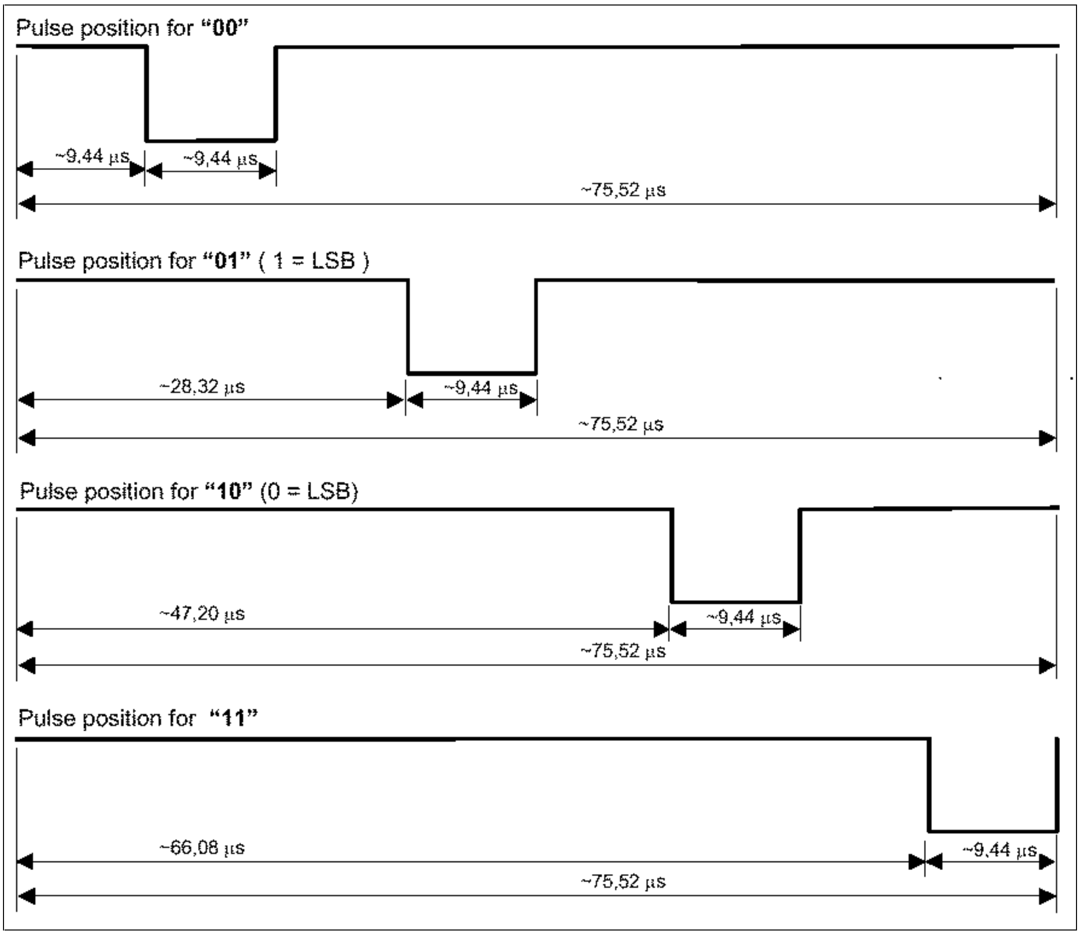


Figure 9.

For example, Figure 10. shows the transmission of 'E1' = (11100001)b = 225 by the VCD.

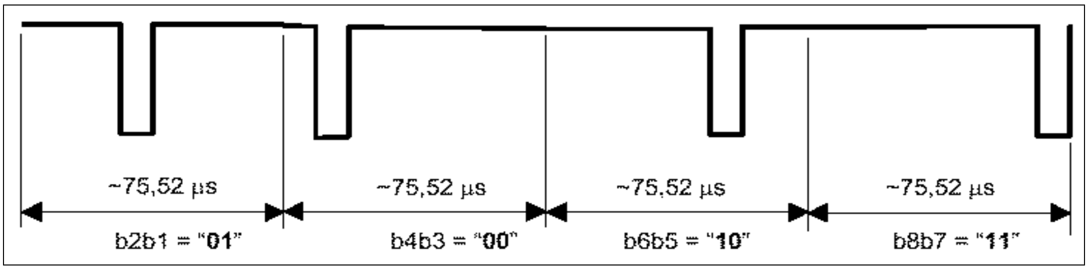


Figure 10.

VCD to VICC frames

Framing has been chosen for ease of synchronisation and independence of protocol.

Frames are delimited by a start of frame (SOF) and an end of frame (EOF) and are implemented using code violation. Unused options are reserved for future use by ISO/IEC.

The VICC is ready to receive a frame from the VCD within 300 µs after having sent a frame to the VCD.

The VICC is ready to receive a frame within 1 ms of activation by the powering field.

SOF to select 1 out of 256 code

The SOF sequence described in Figure 11 selects the 1 out of 256 Data Coding mode.

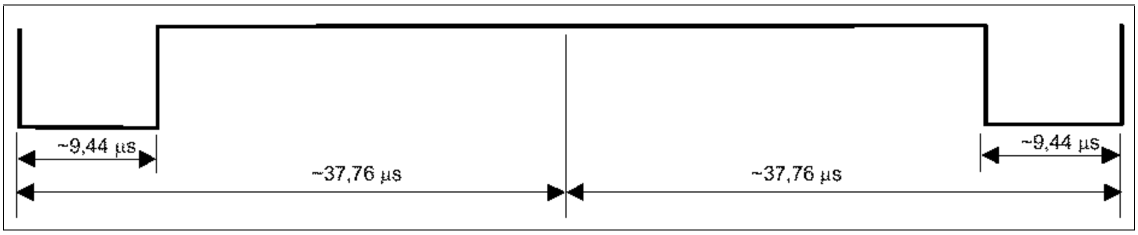


Figure 11.

SOF to select 1 out of 4 code

The SOF sequence described in Figure **12**12 selects the 1 out of 4 Data Coding mode.

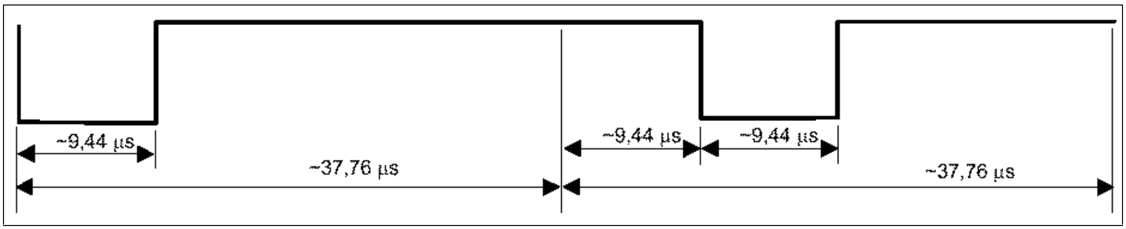


Figure 12.

EOF for either data coding mode

The EOF sequence for either coding mode is described in Figure 13.

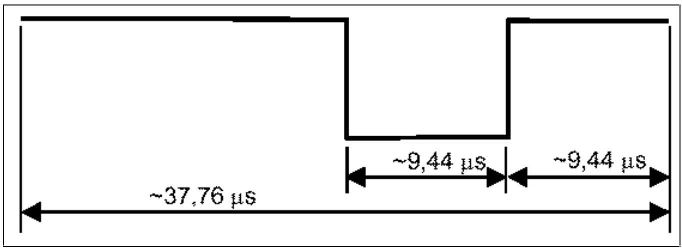


Figure 13.

Communication signal interface VICC to VCD
For some parameters, several modes have been defined in order to, allow for use in different noise environments and application requirements.

Load modulation
The VICC is capable of communication to the VCD via an inductive coupling area whereby the carrier is loaded to generate a subcarrier with frequency fs. The subcarrier is generated by switching a load in the VICC.

The load modulation amplitude is at least 10 mV when measured as described in the test methods.

Test methods for VICC load modulation are defined in International Standard ISO/IEC 10373-7.

SubCarrier
One or two subcarriers may be used as selected by the VCD using the first bit in the protocol header. The VICC supports both modes.

When one subcarrier is used, the frequency fs1 of the subcarrier load modulation is fc/32 (423,75 kHz).

When two subcarriers are used, the frequency fs1 is fc/32 (423,75 kHz), and the frequency fs2 is fc/28 (484,28 kHz).

If two subcarriers are present there is a continuous phase relationship between them.

Data rates
A low or high data rate may be used. The selection of the data rate is made by the VCD using the second bit in the protocol header as defined in Table10. The VICC supports the data rates shown in Table6.

Data Rate	Single Subcarrier	Dual Subcarrier
Low	6,62 kbits/s (fc/2048)	6,67 kbits/s (fc/2032)
High	26,48 kbits/s (fc/512)	26,69 kbits/s (fc/508)

Table 6.

Bit representation and coding
Data are encoded using Manchester coding, according to the following schemes. All timings shown refer to the high data rate from the VICC to the VCD. For the low data rate the same subcarrier frequency or frequencies are used, in this case the number of pulses and the timing is multiplied by 4.

Bit coding when using one SubCarrier
A logic 0 starts with 8 pulses of fc /32 (~423,75 kHz) followed by an unmodulated time of 256/fc (~18,88 µs), see Figure 14.

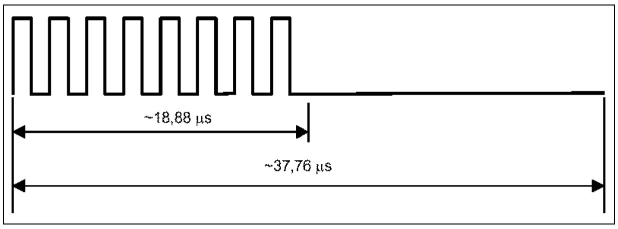


Figure 14.

A logic 1 starts with an unmodulated time of 256/fc (~18,88 µs) followed by 8 pulses of fc/32 (~423,75 kHz), see Figure 15.

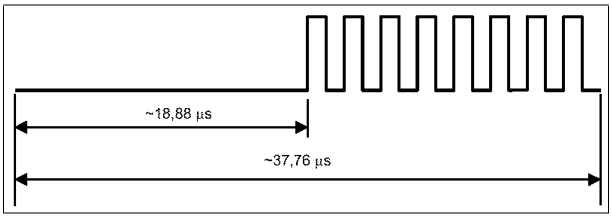


Figure 15.

Bit coding when using two SubCarriers
A logic 0 starts with 8 pulses of fc/32 (~423,75 kHz) followed by 9 pulses of fc/28 (~484,28 kHz)
See Figure 16.

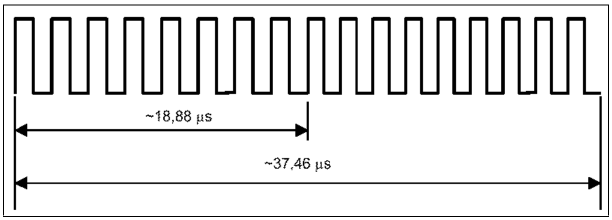


Figure 16.

A logic 1 starts with 9 pulses of fc/28 (~484,28 kHz) followed by 8 pulses of f c /32 (~423,75 kHz) see Figure 17.

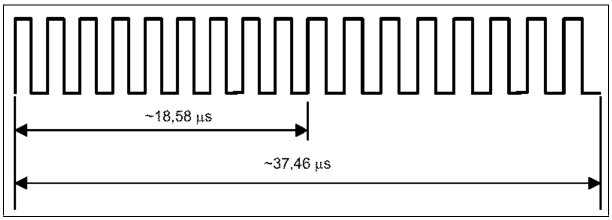


Figure 17.

SOF when using one SubCarrier
SOF comprises 3 parts:
- An unmodulated time of 768/fc (~56,64 µs).
- 24 pulses of fc/32 (~423,75 kHz).
- A logic 1 which starts with an unmodulated time of 256/fc (~18,88 µs), followed by 8 pulses of fc/32 (~423,75 kHz).

The SOF for one subcarrier is illustrated in Figure 18.

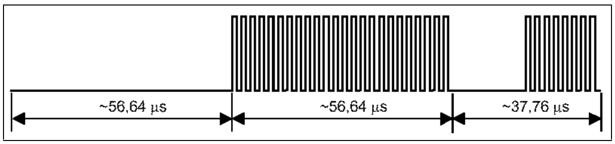


Figure 18.

SOF when using two SubCarriers
SOF comprises 3 parts:
- 27 pulses of fc/28 (~484,28 kHz).
- 24 pulses of fc/32 (~423,75 kHz).
- A logic 1 which starts with 9 pulses of fc/28 (~484,28 kHz) followed by 8 pulses of fc/32 (~423,75 kHz).

The SOF for 2 subcarriers is illustrated in Figure 19.

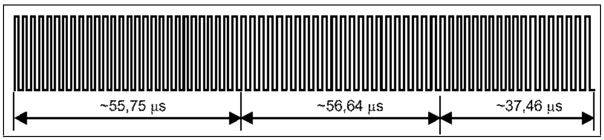


Figure 19.

EOF when using one SubCarrier

EOF comprises 3 parts:

- A logic 0 which starts with 8 pulses of fc/32 (~423,75 kHz), followed by an unmodulated time of 256/fc (~18,88 µs).
- 24 pulses of fc/32 (~423,75 kHz).
- An unmodulated time of 768/fc (~56,64 µs).

The EOF for 1 subcarrier is illustrated in Figure20.

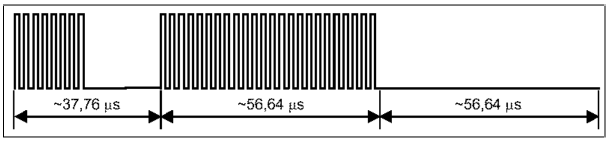


Figure 20.

EOF when using two SubCarriers

EOF comprises 3 parts:

- A logic 0 which starts with 8 pulses of fc/32 (~423,75 kHz) followed by 9 pulses of fc/28 (~484,28 kHz).
- 24 pulses of fc/32 (~423,75 kHz).
- 27 pulses of fc/28 (~484,28 kHz).

The EOF for 2 subcarriers is illustrated in Figure21.

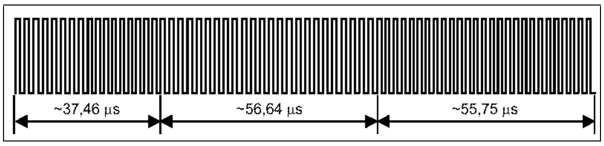


Figure 21.

Definition of data elements

Unique identifier (UID)

The VICCs are identified by a 64 bits unique identifier (UID). This is used for addressing each VICC uniquely and individually, during the anticollision loop and for one-to-one exchange between a VCD and a VICC.

The UID is set permanently by the IC manufacturer in accordance with Figure below:

UID format

MSB

63 56	55 48	47 0
'EO'	IC Mfg Code	IC manufacturer serial number

6 bit IC Id	10 bit Customer Id	32 bit Unique Serial Number

Figure 22.

The UID comprises:

- The 8 MSB bits is 'E0',
- The IC manufacturer code, on 8 bits according to ISO/IEC 7816-6:1996/Amd.1
- EM-Microelectronic is identified by code 0x16.
- A unique serial number on 48 bits assigned by the IC manufacturer.

Note: 64 bit UID is stored in EEPROM. EM IC manufacturer code is programmed with 0x16. 48 bits of IC manufacturer serial number are composed of 6 bit IC code (different for each member of EM ISO 15693 family), 10 bit Customer Id and 32 bit unique serial number.

IC Id “0x04” corresponds to EM4135.

Application family identifier (AFI)

EM4135 supports AFI feature. AFI (Application family identifier) represents the type of application targeted by the VCD and is used to extract from all the VICCs present only the VICCs meeting the required application criteria.

AFI is coded on one byte, which constitutes 2 nibbles of 4 bits each, and programming is done at wafer level.

The most significant nibble of AFI is used to code one specific or all application families, as defined in Table .

The least significant nibble of AFI is used to code one specific or all application sub-families. Sub-family codes different from 0 are proprietary.

AFI most significant nibble	AFI least significant nibble	Meaning VICCs respond from	Examples / note
‘0’	‘0’	All families and sub- families	No applicative preselection
X	'0'	All sub-families of family X	Wide applicative preselection
X	Y	Only the Yth sub-family of family X	
‘0’	Y	Proprietary sub-family Y only	
‘1'	‘0’, Y	Transport	Mass transit, Bus, Airline
'2'	‘0’, Y	Financial	IEP, Banking, Retail
'3'	‘0’, Y	Identification	Access control
'4'	‘0’, Y	Telecommunication	Public telephony, GSM
‘5’	‘0’, Y	Medical	
'6'	‘0’, Y	Multimedia	Internet services
'7'	‘0’, Y	Gaming	
'8'	‘0’, Y	Data storage	Portable files
'9'	‘0’, Y	Item management	
'A'	‘0’, Y	Express parcels	
'B'	‘0’, Y	Postal services	
'C'	‘0’, Y	Airline bags	
'D'	‘0’, Y	RFU	
'E'	‘0’, Y	RFU	
‘F’	‘0’, Y	RFU	

Table 7.

Note:

- The AFI byte can only be programmed at wafer level. It has to be specified at order.
- X = ‘1’ to ‘F’,Y=‘1’ to ‘F’.

VICC decision tree for AFI

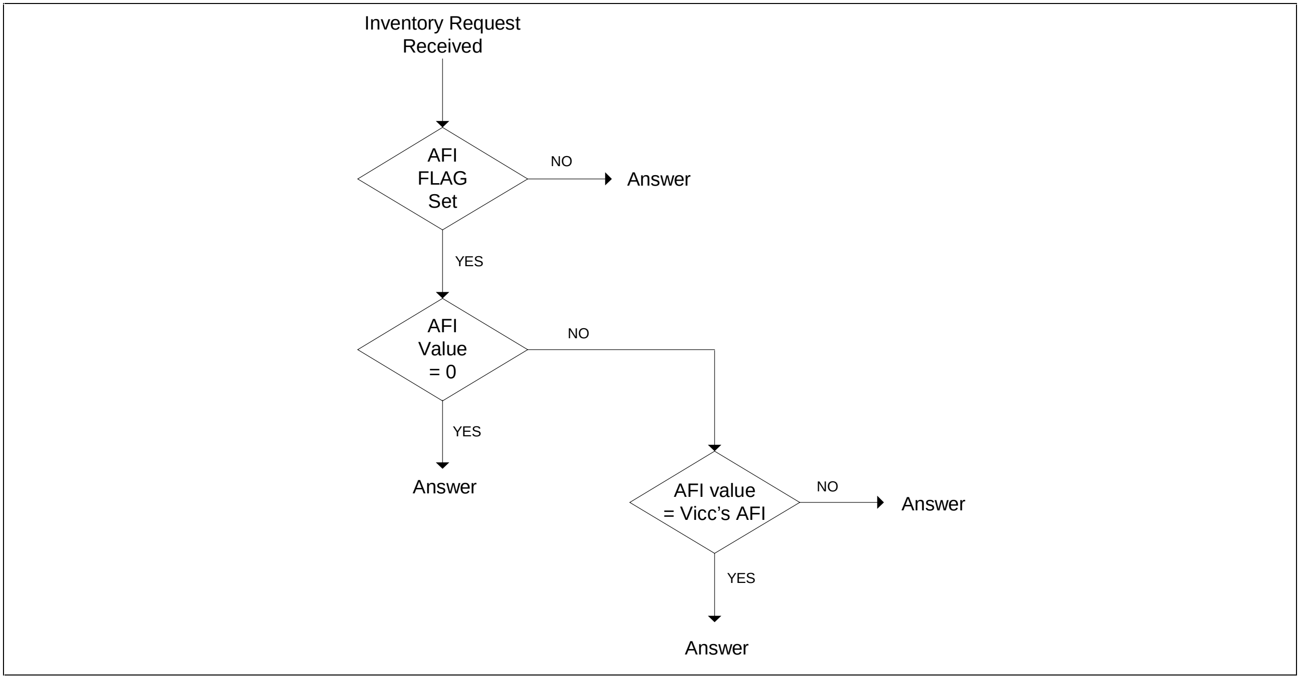


Figure 23.

Note: "Answer" means that the VICC answers to the Inventory request.

Block security status

The block security status is sent back by the VICC as a parameter in the response to a VCD request as specified in clause 10 (e.g. Read Multiple block). It is coded on one byte.

Bit	Flag name	Value	Description
b1	Lock_Flag	0	Not locked
		1	Locked
b2 to b8	RFU	0	

Figure 24.

CRC

The CRC is calculated in accordance with ISO/IEC 13239.
Information on how to calculate the CRC can be found in annex C of ISO/IEC 15693-3 document.

The initial register content is all ones: 'FFFF'.

The two bytes CRC are appended to each request and each response, within each frame, before the EOF. The CRC is calculated on all the bytes after the SOF up to but not including the CRC field.

Upon reception of a request from the VCD, the VICC verifies that the CRC value is valid. If it is invalid, it will discard the frame and will not answer (modulate).

Upon reception of a response from the VICC, it is recommended that the VCD verify that the CRC value is valid. If it is invalid, actions to be performed are left to the responsibility of the VCD designer.

The CRC is transmitted least significant byte first.

Each byte is transmitted least significant bit first.

CRC bits and bytes transmission rules

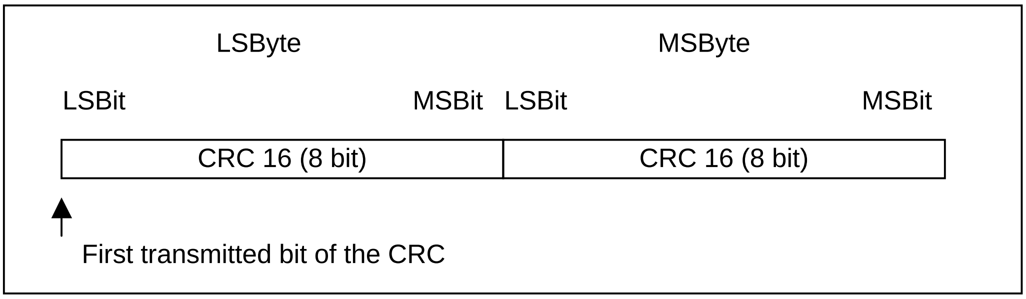


Figure 25.

Overall protocol description

Protocol Concept

The transmission protocol defines the mechanism to exchange instructions and data between the VCD and the VICC, in both directions.

It is based on the concept of "VCD Talks First".

This means that any VICC does not start transmitting (i.e. modulating according to ISO/IEC 15693-2) unless it has received and properly decoded an instruction sent by the VCD.

A) The protocol is based on an exchange of:
- a request from the VCD to the VICC
- a response from the VICC(s) to the VCD

B) Each request and each response are contained in a frame.

C) Each request consists of the following fields:
- Flags
- Command code
- Mandatory and optional parameters fields, depending on the command
- Application data fields
- CRC

D) Each response consists of the following fields:
- Flags
- Mandatory and optional parameters fields, depending on the command
- Application data fields
- CRC

E) The protocol is bit-oriented. The number of bits transmitted in a frame is a multiple of eight (8), i.e. an integer number of bytes.

F) A single-byte field is transmitted least significant bit (LSBit) first.

G) A multiple-byte field is transmitted least significant byte (LSByte) first, each byte is transmitted least significant bit (LSBit) first.

H) The setting of the Flags indicates the presence of the optional fields. When the Flag is set (to one), the field is present. When the Flag is reset (to zero), the field is absent.

I) RFU Flags are set to zero (0).

Modes

The term mode refers to the mechanism to specify in a request the set of VICC's that answers to the request.

Addressed mode

When the Address_Flag is set to 1 (addressed mode), the request contains the unique ID (UID) of the addressed VICC.

Any VICC receiving a request with the Address_Flag set to 1 compares the received unique ID (address) to its own ID.

If it matches, it executes it (if possible) and returns a response to the VCD as specified by the command description.

If it does not match, it remains silent.

Non-addressed mode

When the Address_Flag is set to 0 (non-addressed mode), the request does not contain a unique ID.

Any VICC receiving a request with the Address_Flag set to 0 executes it (if possible) and returns a response to the VCD as specified by the command description.

Select mode

When the Select_Flag is set to 1 (select mode), the request does not contain a VICC unique ID.

The VICC in the selected state receiving a request with the Select_Flag set to 1 executes it (if possible) and return a response to the VCD as specified by the command description.

Only the VICC in the selected state answers to a request having the select Flag set to 1.

Request Format

The request consists of the following fields:
- Flags
- Command code
- Parameters and data fields
- CRC

SOF	Flags	Command Code	Parameters	Data	CRC	EOF

Figure 26.

Request Flags

In a request, the field "Flags" specifies the actions to be performed by the VICC and whether corresponding fields are present or not.

It consists of eight bits.

Request Flags 1 to 4 definition

Bit	Flag name	Value	Description
b1	Sub-carrier_Flag	0	A single sub-carrier frequency is used by the VICC
		1	Two sub-carriers are used by the VICC
b2	Data_rate_Flag	0	Low data rate is used
		1	High data rate is used
b3	Inventory_Flag	0	Flags 5 to 8 meaning is according to Table
		1	Flags 5 to 8 meaning is according to Table 12
b4	Protocol Extension_Flag	0	No protocol format extension
		1	Protocol format is extended. Reserved for future use

Table 10.

Note:

- Sub-carrier_Flag refers to the VICC-to-VCD Communication Signal Interface chapter.
- Data_rate_Flag refers to the VICC-to-VCD Communication Signal Interface chapter.

Request Flags 5 to 8 definition when Inventory Flag is NOT set

Bit	Flag name	Value	Description
b5	Select_Flag	0	Request is executed by any VICC according to the setting of Address_Flag
		1	Request is executed only by VICC in selected state. The Address_Flag is set to 0 and the UID field is not be included in the request
b6	Address_Flag	0	Request is not addressed. UID field is not included. It is executed by any VICC
		1	Request is addressed. UID field is included. It is executed only by the VICC whose UID matches the UID specified in the request
b7	Option_Flag	0	Meaning is defined by the command description. It is set to 0 if not otherwise defined by the command
		1	Meaning is defined by the command description
b8	RFU	0	

Table 11.

Request Flags 5 to 8 definition when inventory Flag is set

Bit	Flag name	Value	Description
b5	AFI_Flag	0	AFI field is not present
		1	AFI field is present
b6	Nb_slots_Flag	0	16 slots
		1	1 slot
b7	Option_Flag	0	Meaning is defined by the command description. It is set to 0 if not otherwise defined by the command
		1	Meaning is defined by the command description
b8	RFU	0	

Table 12.

Response Format

The response consists of the following fields:

- Flags
- one or more parameter fields
- Data
- CRC

SOF	Flags	Parameters	Data	CRC	EOF

Figure 27.

Response Flags

Inside the response, the tag indicates how actions have been performed by the VICC and whether corresponding fields are present or not.

Response Flags 1 to 8 definition

Bit	Flag name	Value	Description
b1	Error_Flag	0	No error
		1	Error detected. Error code is in the "Error" field.
b2	RFU	0	
b3	RFU	0	
b4	Extension_Flag	0	No protocol format extension
		1	Protocol format is extended. Reserved for future use.
b5	RFU	0	
b6	RFU	0	
b7	RFU	0	
b8	RFU	0	

Table 13.

Response error code

When the Error_Flag is set by the VICC, the error code field is included and provides information about the error that occurred. Error codes are defined in Table 14.

If the VICC does not support specific error code(s) listed in Table 14, it answers with the error code '0F' ("Error with no information given").

Response error code definition

Error code	Meaning
'01'	The command is not supported, i.e. the request code is not recognised.
'02'	The command is not recognised, for example: a format error occurred.
'03'	The command option is not supported.
'0F'	Error with no information given or a specific error code is not supported.
'10'	The specified block is not available (doesn't exist).
'11'	The specified block is already locked and thus cannot be locked again.
'12'	The specified block is locked and its content cannot be changed.
'13'	The specified block was not successfully programmed.
'14'	The specified block was not successfully locked.
'A0'	Power Check failed
'A1'	Read / Write to unused Block

Table 14.

Note:

- EM4135 supports specific error

Error codes used in special situations

Error Code	Situation / VCD request
NO RESP	Select_Flag = 1 AND address_Flag = 1
01	Command opcode is not recognized
02	Wrong Flags according Table 20, except bit4 and bit8
03	Protocol Extension Flag is set
03	RFU bit 8 is set

Table 15.

VICC states
A VICC can be in one of the 4 following states:
- Power-off
- Ready
- Quiet
- Selected

The transition between these states is specified in Figure 28.

EM4135 supports mandatory power-off, ready, quiet states and selected.

Power-off state
The VICC is in the power-off state when it cannot be activated by the VCD.

Ready state
The VICC is in the Ready state when it is activated by the VCD. It processes any request where the Select Flag is not set.

Quiet state
When in the quiet state, the VICC processes any request where the Inventory_Flag is not set and where the Address_Flag is set.

Selected state

Only a VICC in the selected state processes requests having the Select_Flag set.

VICC state transition diagram

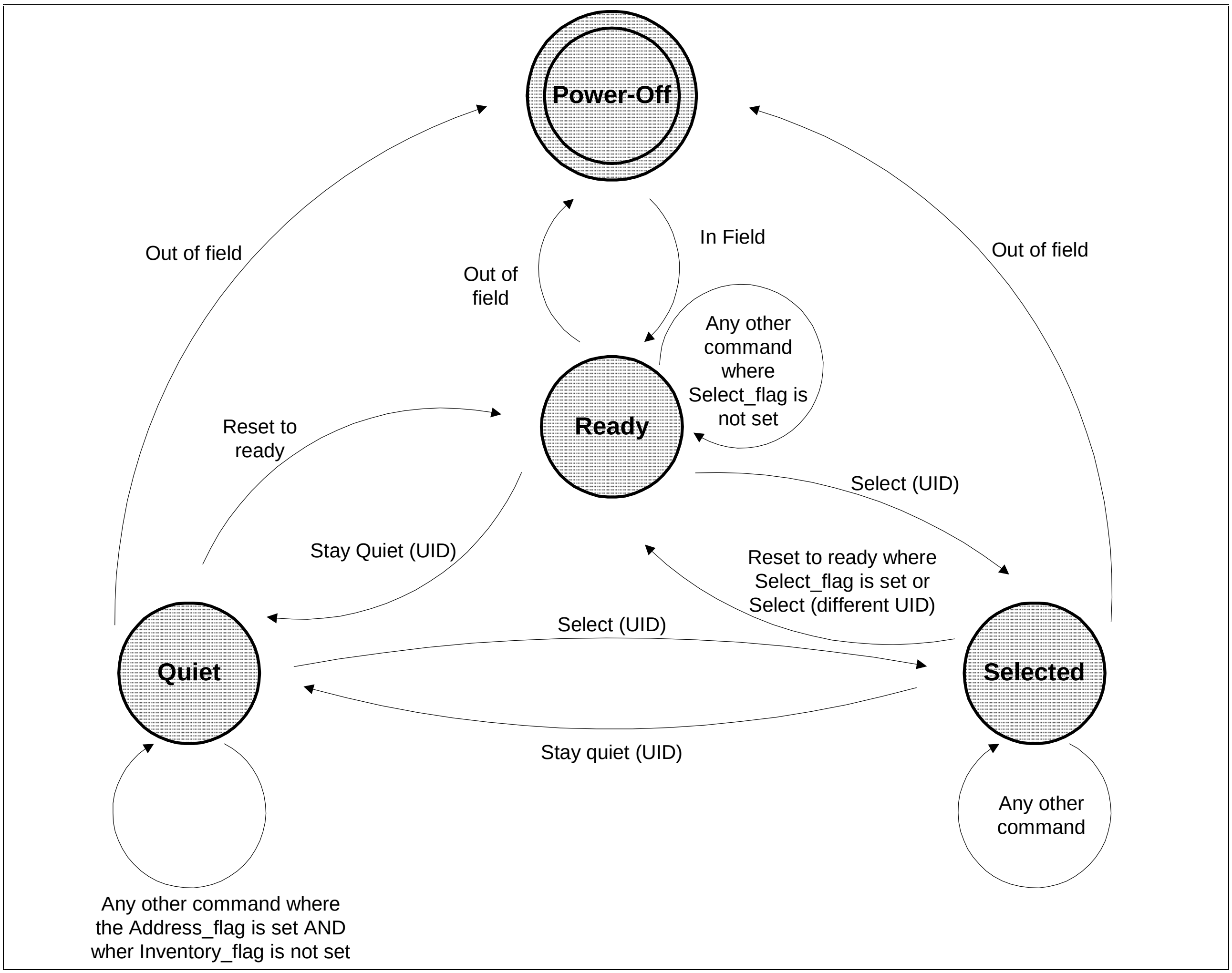


Figure 28.

Note:

- The intention of the state transition method is that only one VICC should be in the Selected state at a time.
- The VICC state transition diagram shows only valid transitions. In all other cases the current VICC state remains unchanged. When the VICC cannot process a VCD request (e.g. CRC error, etc.), it stays in its current state.

Anticollision
The purpose of the anticollision sequence is to make an inventory of the VICCs present in the VCD field by their unique UID.

The VCD is the master of the communication with one or multiple VICCs. It initiates card communication by issuing the inventory request.

The VICC sends its response in the slot determined or does not respond, according to the algorithm described in Figure 30.

Explanation of an anticollision sequence
Figure 29 summarises the main cases that can occur during a typical anticollision sequence where the number of slots is 16.

The different steps are:

A) The VCD sends an Inventory request, in a frame, terminated by an EOF. The number of slots is 16.

B) VICC 1 transmits its response in slot 0. It is the only one to do so, therefore no collision occurs and its UID is received and registered by the VCD.

C) The VCD sends an EOF, meaning to switch to the next slot.

D) In slot 1, two VICCs 2 & 3 transmits their response. This case generates a collision. The VCD detects this status and remembers that a collision was detected in slot 1.

E) The VCD sends an EOF, meaning to switch to the next slot.

F) In slot 2, no VICC transmits a response. Therefore the VCD does not detect a VICC SOF and decides to switch to the next slot by sending an EOF.

G) In slot 3, there is another collision caused by responses from VICC 4 and 5

H) The VCD then decides to send an addressed request (for instance a Read Block) to VICC 1, which UID was already correctly received.

I) All VICCs detect a SOF and exit the anticollision sequence. They process this request and since the request is addressed to VICC 1, only VICC1 transmit its response.

J) All VICCs are ready to receive another request. If it is an inventory command, the slot numbering sequence restarts from 0.

Note:
- The decision to interrupt the anticollision sequence is up to the VCD. It could have continued to send EOF's till slot 15 and then send the request to VICC 1.

Description of a possible anticollision sequence

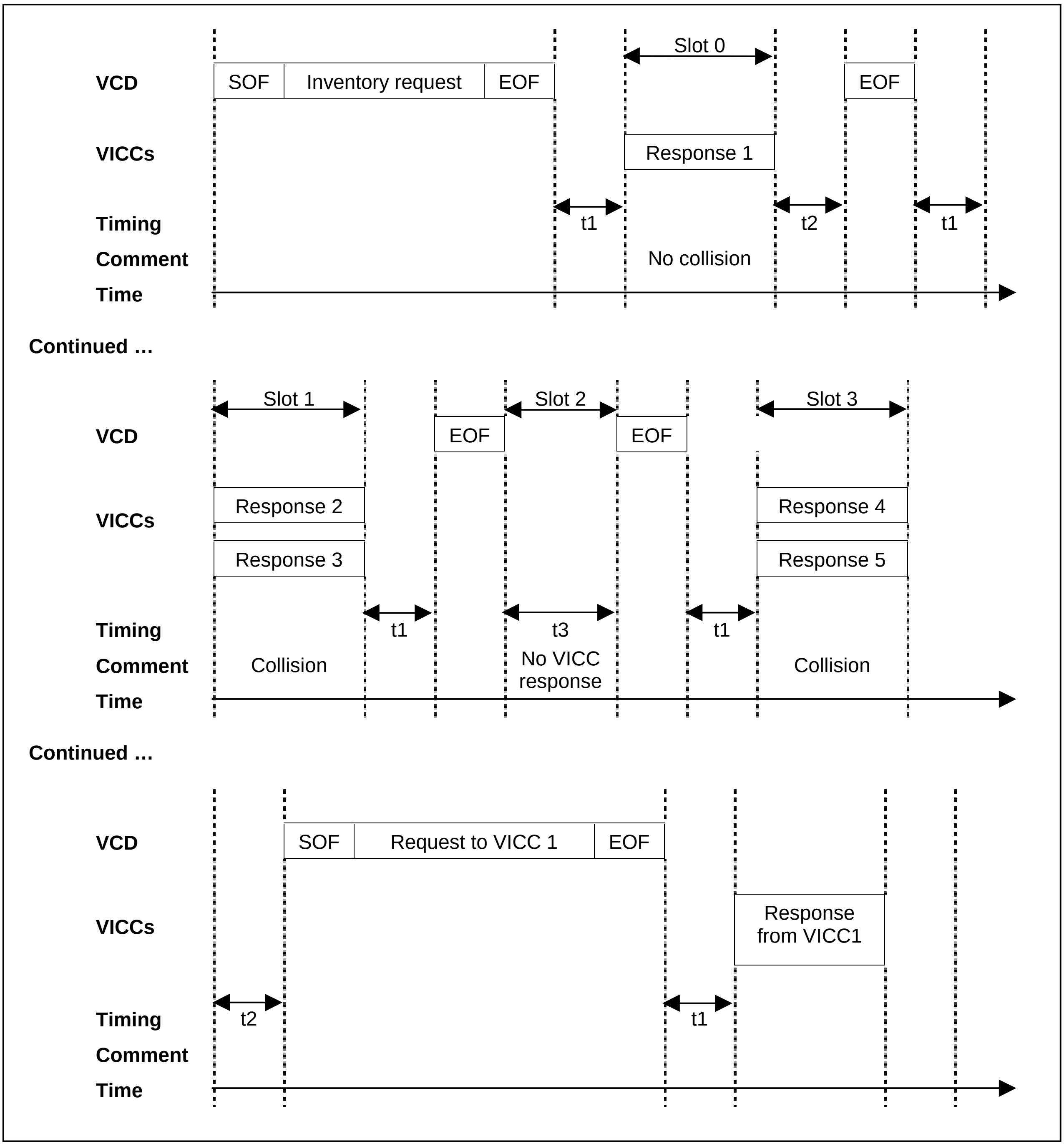


Figure 29.

Note:

- Timing t1, t2 and t3 are specified in the Timing Characteristics chapter.

Request processing by the VICC
Principle of comparison between the mask value, slot number and UID

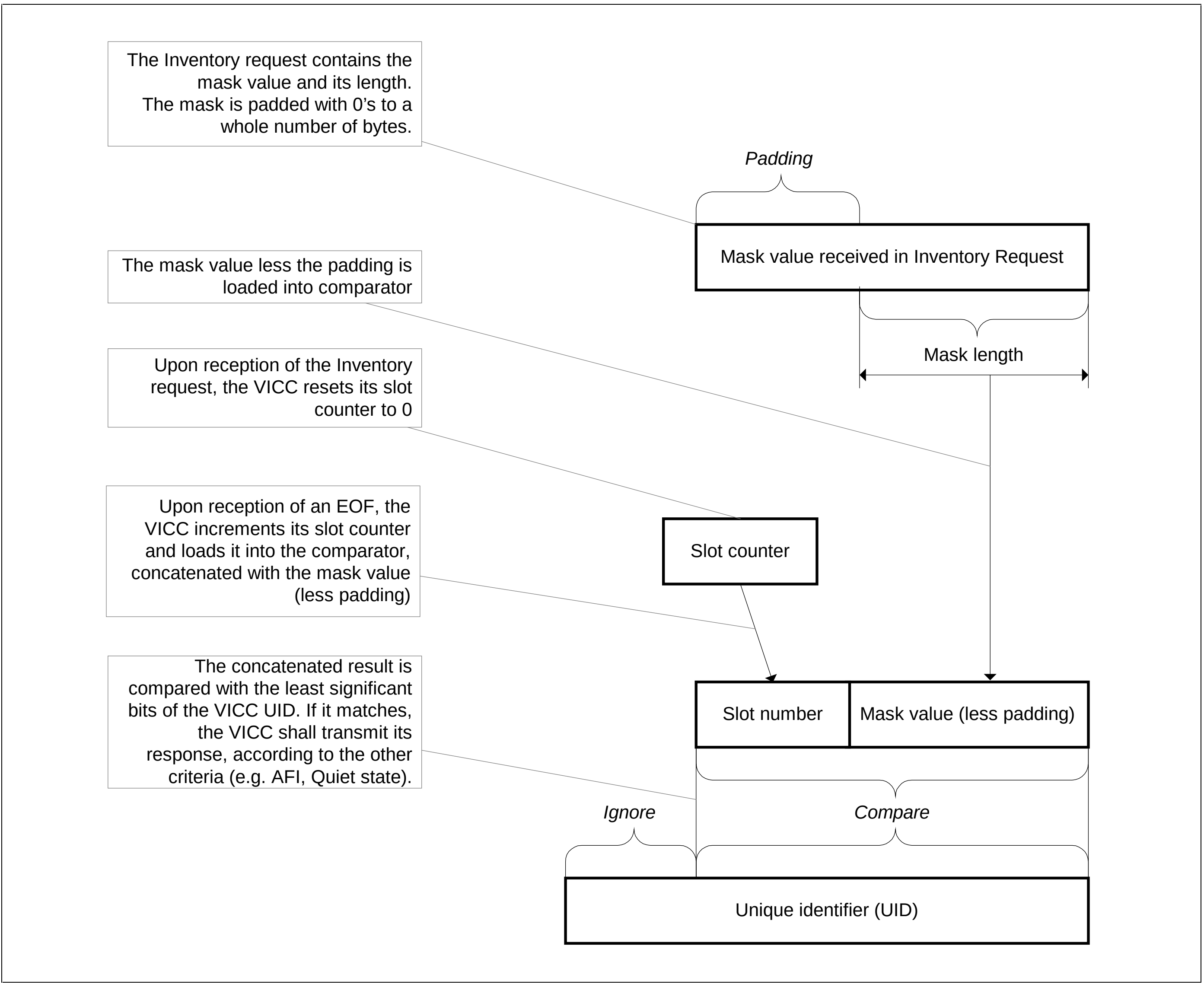


Figure 30.

Note:
- When the slot number is 1 (Nb_slots_Flag is set to 1), the comparison is made only on the mask (without padding).

Upon reception of a valid request, the VICC processes it by executing the operation sequence specified in the following text in Italics. The step sequence is also graphically represented in Figure 30.

- NbS is the total number of slots (1 or 16)
- SN is the current slot number (0 to 15)
- SN_length is set to 0 when 1 slot is used and set to 4 when 16 slots are used
- LSB (value, n) function returns the n least significant bits of value
- "&" is the concatenation operator
- Slot_Frame is either a SOF or an EOF

```
        SN= 0
        if Nb_slots_Flag then
                NbS =1 SN_length=0
                else NbS = 16 SN_length=4
        endif
label1: if LSB(UID, SN_length + Mask_length) = LSB(SN, SN_length)&LSB(Mask, Mask_length) then
                transmit response to inventory request
        endif
        wait (Slot_Frame)
        if Slot_Frame= SOF then
                Stop anticollision and decode/process request
                exit
        endif
        if SN<NbS-1 then
                SN = SN +1
                goto label1
                exit
        endif
        exit
```

Figure 31.

Request parameters
When issuing the Inventory command, the VCD sets the Nb_slots_Flag to the desired setting and add after the command field the mask length and the mask value.

The mask length indicates the number of significant bits of the mask value. It can have any value comprised between 0 and 60 when 16 slots are used and any value between 0 and 64 when 1 slot is used. LSB is transmitted first.

The mask value is contained in an integer number of bytes. LSB is transmitted first.

If the mask length is not a multiple of 8 (bits), the mask value MSB is padded with the required number of null (set to 0) bits so that the mask value is contained in an integer number of bytes.

The next field starts on the next byte boundary.

Inventory request format

SOF	Flags	Command	Optional AFI	Mask length	Mask Value	CRC 16	EOF
	8 bits	8 bits	8 bits	8 bits	0 to 8 bytes	16 bits	

Figure 32.

Example of the padding of the mask

0000	0100 1100 1111
Pad	Mask value

Figure 33.

In the example of the figure 33., the mask length is 12 bits. The mask value MSB is padded with four bits set to 0.

The AFI field is present if the AFI_Flag is set.

The pulse is generated according to the definition of the EOF.

The first slot starts immediately after the reception of the request EOF.

To switch to the next slot, the VCD sends an EOF.

Timing specifications
The VCD and the VICC comply with the following timing specifications.

VICC waiting time before transmitting its response after reception of an EOF from the VCD
When the VICC detects an EOF of a VCD request or when this EOF is in the normal sequence of a VCD request, it waits for a time t1 before starting to transmit its response or before switching to the next slot when in an inventory process.

t1 starts from the detection of the rising edge of the EOF received from the VCD.

Note:
The synchronisation on the rising edge of the VCD-to-VICC EOF is needed for ensuring the required synchronisation of the VICC responses.

Parameter	Symbol	Min.	Nom.	Max.
VICC waiting time	t1	4320/*fc* (318,6 µs)	4352/*fc* (320,9 µs)	4384/*fc* (323,3 µs)

Figure 34.

t1max does not apply for Write alike requests. Timing conditions for Write alike requests are defined in the command descriptions.

If the VICC detects a 100% carrier modulation during this time t1, it resets its t1 timer and wait for a further time t1 before starting to transmit its response to a VCD request or to switch to the next slot when in an inventory process.

VICC modulation ignore time after reception of an EOF from the VCD
When the VICC has detected an EOF of a valid VCD request or when this EOF is in the normal sequence of a VCD request, it ignores any received 10 % modulation during a time t_{mit}.

t_{mit} starts from the detection of the rising edge EOF received from the VCD.

The minimum value of t_{mit} is **t_{mit} tmin = 4384/*fc* (323,3 µs) + t_{nrt}**

Where t_{nt} is the nominal response time of a VICC. t_{nrt} is dependent on the VICC-to-VCD data rate and subcarrier modulation mode.

Note:
- The synchronisation on the rising edge of the VCD-to-VICC EOF is needed for ensuring the required synchronisation of the VICC responses.

VCD waiting time before sending a subsequent request

Remark: This chapter refers to VCD only.

A) When the VCD has received a VICC response to a previous request other than Inventory and Quiet, it waits a time t2 before sending a subsequent request. t2 starts from the time the EOF has been received from the VICC.

B) When the VCD has sent a Quiet request (which causes no VICC response), it waits a time t2 before sending a subsequent request. t2 starts from the end of the Quiet request EOF (rising edge of the EOF plus 9,44 µs).

The minimum value of t2 is **t2min = 4192/*fc* (309,2 µs).**

Note:
- This ensures that the VICCs are ready to receive this subsequent request.
- The VCD should wait at least 1 ms after it activated the powering field before sending the first request, to ensure that the VICCs are ready to receive it.

C) When the VCD has sent an Inventory request, it is in an Inventory process.

VCD waiting time before switching to the next slot during an inventory process

Remark: This chapter refers to VCD only.

An inventory process is started when the VCD sends an Inventory request.

To switch to the next slot, the VCD may send either a 10% or a 100% modulated EOF independent of the modulation index it used for transmitting its request to the VICC, after waiting a time specified in 0 and 0.

When the VCD has started to receive one or more VICC responses

Remark: This chapter refers to VCD only.

During an Inventory process, when the VCD has started to receive one or more VICC responses (i.e. it has detected a VICC SOF and/or a collision), it

- Waits for the complete reception of the VICC responses (i.e. when a VICC EOF has been received or when the VICC nominal response time t_{nrt} has elapsed),
- Waits an additional time t2
- And then sends a 10 % or 100 % modulated EOF to switch to the next slot.

t2 starts from the time the EOF has been received from the VICC (0,0).The minimum value of t2 is

t2min = 4192/*fc* (309,2 µs).

t_{nrt} is dependent on the VICC-to-VCD data rate and subcarrier modulation mode.

When the VCD has received no VICC response

Remark: This chapter refers to VCD only.

During an inventory process, when the VCD has received no VICC response, it waits a time t3 before sending a subsequent EOF to switch to the next slot.

t3 starts from the time the VCD has generated the rising edge of the last sent EOF.

A) If the VCD sends a 100% modulated EOF, the minimum value of t3 is

t3min = 4384/*fc* (323,3 µs) + t_{sof}

B) If the VCD sends a 10% modulated EOF, the minimum value of t3 is

t3min = 4384/*fc* (323,3 µs) + t_{nrt}

where:

- t_{sof} is the time duration for a VICC to transmit an SOF to the VCD.
- t_{nrt} is the nominal response time of a VICC.

t_{nrt} and t_{sof} are dependent on the VICC-to-VCD data rate and subcarrier modulation mode.

Commands

Command types

Two sets of commands are defined:

- Mandatory
- Optional

All VICCs with the same IC Manufacturer Code and same IC version number behave the same.

Command codes

Table 16 shows all implemented commands in EM4135.

Command code	Type	Function	Active Flags							
			b1	b2	b3	b4	b5	b6	b7	b8
'01'	Mandatory	Inventory	x	x	1	0	x	x	0	0
'02'	Mandatory	Stay Quiet	x	x	0	0	0	1	0	0
'21'	Optional	Write single block	x	x	0	0	x	x	x	0
'22'	Optional	Lock block	x	x	0	0	x	x	x	0
'23'	Optional	Read multiple blocks	x	x	0	0	x	x	x	0
'25'	Optional	Select	x	x	0	0	0	1	0	0
'26'	Optional	Reset to ready	x	x	0	0	x	x	0	0
'2B'	Optional	Get system information	x	x	0	0	x	x	0	0
			Sub-carrier	Data rate	Inventory	Protocol ext.	Select	Addressed	Option	RFU

Table 16.

Note:

- x means used Flag, can be 0 or 1.
- If VCD send a command with non valid Flags, VICC will answer error code '02' (command not recognised).

Mandatory commands

Command code	Type	Function	Active Flags							
			b1	b2	b3	b4	b5	b6	b7	b8
'01'	Mandatory	Inventory	x	x	1	0	x	x	0	0
'02'	Mandatory	Stay Quiet	x	x	0	0	0	1	0	0
			Sub-carrier	Data rate	Inventory	Protocol ext.	Select	Addressed	Option	RFU

Table 17.

Inventory (Command code = '01')

When receiving the Inventory request, the VICC performs the anticollision sequence.

The request contains:

- The Flags,
- The Inventory command code
- The AFI if the AFI Flag is set
- The mask length
- The mask value
- The CRC

The Inventory_Flag is set to 1.

The meaning of Flags 5 to 8 is according to Table .

Inventory request format

SOF	Flags	Inventory	Optional AFI	Mask length	Mask value	CRC 16	EOF
	8 bits	8 bits	8 bits	8 bits	0-64 bits	16 bits	

Figure 36.

The response contains:

- The DSFID
- The unique ID

If the VICC detects an error, it remains silent.

Inventory response format

SOF	Flags	DSFID	UID	CRC 16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 37.

Stay quiet (Command code = '02')

When receiving the Stay quiet command, the VICC enters the quiet state and does not send back a response. There is NO response to the Stay quiet command.

When in quiet state:

- The VICC does not process any request where Inventory_Flag is set,
- The VICC processes any addressed request

The VICC exits the quiet state when:

- Reset (power off),
- Receiving a Select request. It goes then to the selected state if supported or return an error if not supported,
- Receiving a Reset to ready request. It goes then to the Ready state.

Stay quiet request format

SOF	Flags	Stay quiet	UID	CRC 16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 38.

Request parameter:

- ❑ UID (mandatory)

The Stay Quiet command is always executed in Addressed mode (Select_Flag is set to 0 and Address_Flag is set to 1).

Optional Commands supported by EM4135

Command code	Type	Function	Active Flags							
			b1	b2	b3	b4	b5	b6	b7	b8
'21'	Optional	Write single block	x	x	0	0	x	x	x	0
'22'	Optional	Lock block	x	x	0	0	x	x	x	0
'23'	Optional	Read multiple blocks	x	x	0	0	x	x	x	0
'25'	Optional	Select	x	x	0	0	0	1	0	0
'26'	Optional	Reset to ready	x	x	0	0	x	x	0	0
'2B'	Optional	Get system information	x	x	0	0	x	x	0	0
			Sub-carrier	Data rate	Inventory	Protocol ext.	Select	Addressed	Option	RFU

Table 18.

Write single block (Command code = '21')

When receiving the Write single block command, the VICC writes the requested block with the data contained in the request and report the success of the operation in the response.

If the Option_Flag is not set, the VICC returns its response when it has completed the write operation starting after (Twa1+Twee).

If Option_Flag is set, the VICC waits for the reception of an EOF from the VCD and upon such reception returns its response. **The VCD must wait (Twa1+Twee) time before sending EOF** in order to ensure proper energy condition to VICC during EEPROM programming.

Command timing:

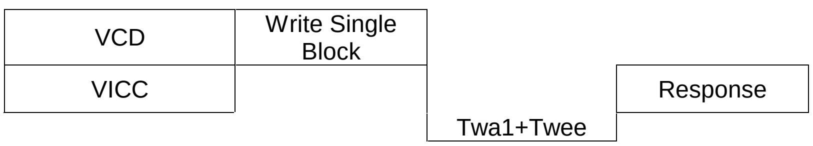


Figure 39.

Write single block request format

SOF	Flags	Write single block	UID	block number	Data	CRC 16	EOF
	8 bits	8 bits	64 bits	8 bits	64 bits	16 bits	

Figure 40.

Request parameter:

- ❑ (Optional) UID
- ❑ Block number
- ❑ Data

Write single block response format when Error_Flag is set

SOF	Flags	Error Code	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 21.

Write single block response format when Error_Flag is NOT set

SOF	Flags	CRC16	EOF
	8 bits	16 bits	

Figure 42.

Response parameter:

- Error_Flag (and Error code if Error_Flag is set)

Lock block (Command code = '22')

When receiving the Lock block command, the VICC locks permanently the requested block. Lock block command defines which memory block is locked against programming.

If the Option_Flag is not set, the VICC returns its response when it has completed the lock operation starting after (Twa3+Twee)

If Option_Flag is set, the VICC waits for the reception of an EOF from the VCD and upon such reception returns its response. **The VCD must wait (Twa3+Twee) time before sending EOF** in order to ensure proper energy condition to VICC during EEPROM programming.

Command timing:

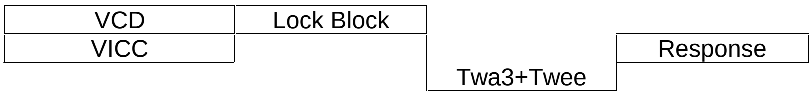


Figure 43.

Lock single block request format

SOF	Flags	Lock block	UID	block number	CRC 16	EOF
	8 bits	8 bits	64 bits	8 bits	16 bits	

Figure 44.

Request parameter:

- (Optional) UID
- Block number

Lock block response format when Error_Flag is set

SOF	Flags	Error Code	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 45.

Lock block response format when Error_Flag is NOT set

SOF	Flags	CRC16	EOF
	8 bits	16 bits	

Figure 46.

Response parameter:

- Error_Flag (and Error code if Error_Flag is set)

Read multiple blocks (Command code = '23')
When receiving the Read multiple block command, the VICC reads the requested block(s) and send back their value in the response.

If the Option_Flag is set in the request, the VICC returns the block security status, followed by the block value sequentially block by block.

If the Option_Flag is not set in the request, the VICC returns only the block value.
The blocks are numbered from '00' to 'FF' (0 to 255).

The number of blocks in the request is one less than the number of blocks that the VICC returns in its response.
EXAMPLE A value of '06' in the "Number of blocks" field requests to read 7 blocks. A value of '00' requests to read a single block.

Read multiple blocks request format

SOF	Flags	Read multiple block	UID	First block number	Number of blocks	CRC 16	EOF
	8 bits	8 bits	64 bits	8 bits	8 bits	16 bits	

Figure 47.

Request parameter:

- ❑ (Optional) UID
- ❑ First block number
- ❑ Number of blocks

Read multiple blocks response format when Error_Flag is set

SOF	Flags	Error Code	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 48.

Read multiple block response format when Error_Flag is NOT set

SOF	Flags	Block security status	Data	CRC 16	EOF
	8 bits	8 bits	64 bits	16 bits	
		Repeated as needed			

Figure 49.

Response parameter:

Error_Flag (and Error code if Error_Flag is set)

if Error_Flag is not set (the following order is respected in the VICC response)

- ❑ Block security status N (if Option_Flag is set in the request)
- ❑ Block value N
- ❑ Block security status N+1 (if Option_Flag is set in the request)
- ❑ Block value N+1
- ❑ etc.
- ❑ where N is the first requested (and returned) block.

Select (Command code = '25')
When receiving the Select command:

- ❑ If the UID is equal to its own UID, the VICC enters the selected state and sends a response.
- ❑ If it is different, the VICC returns to the Ready state and does not send a response.

The Select command is always executed in Addressed mode. (The Select_Flag is set to 0. The Address_Flag is set to 1.)

Select request format

SOF	Flags	select	UID	CRC 16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 50.

Request parameter:

- UID (mandatory)

Select response format when Error_Flag is set

SOF	Flags	Error Code	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 51.

Select block response format when Error_Flag is NOT set

SOF	Flags	CRC16	EOF
	8 bits	16 bits	

Figure 53.

Response parameter:

- Error_Flag (and Error code if Error_Flag is set)

Reset to ready (Command code = '26')

When receiving a Reset to ready command, the VICC shall return to the Ready state.

Reset to ready request format

SOF	Flags	Reset to ready	UID	CRC 16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 53.

Request parameter:

- UID (optional)

Select response format when Error_Flag is set

SOF	Flags	Error Code	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 54.

Select block response format when Error_Flag is NOT set

SOF	Flags	CRC16	EOF
	8 bits	16 bits	

Figure 55.

Response parameter:

- Error_Flag (and Error code if Error_Flag is set)

Get system information **(Command code = '2B')**
This command allows for retrieving the system information value from the VICC.

Get system information request format

SOF	Flags	Get system Info	UID	CRC 16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 56.

Request parameter:

- (Optional) UID

Get system information response when Error_Flag is set

SOF	Flags	Error Code	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 57.

Get system information response format when Error_Flag is NOT set

SOF	Flags	Info Flags	UID	AFI	VICC memory size	IC reference	CRC 16	EOF
	8 bits	8 bits	64 bits	8 bits	16 bits	8 bits	16 bits	

Figure 58.

Response parameter:

Error_Flag (and Error code if Error_Flag is set)

if Error_Flag is not set

Information Flag

UID (mandatory)

Information fields, in the order of their corresponding Flag, as defined in figure 49 and table 9, if their corresponding Flag is set.

Information Flags definition

Bit	Flag name	Value	Description
b1	DSFID	0	DSFI is not supported. DSFI field is not present
b2	AFI	1	AFI is supported. AFI field is present
b3	VICC memory size	1	Information on VICC memory size is supported. Memory size field is present
b4	IC reference	1	Information on IC reference is supported. IC reference field is present
b5	RFU	0	
b6	RFU	0	
b7	RFU	0	
b8	RFU	0	

Table 19.

VICC memory size information

16 14	13 9	8 1
RFU	Block size in bytes	Number of blocks
b000	b001000	b0110010

Table 20.

Note:

- Block size is expressed in number of bytes on 5 bits: 8 bytes for EM4135.
- Number of blocks is on 8 bits: 38 blocks for EM4135
- The three most significant bits are reserved for future use and are set to zero.
- The IC reference is on 8 bits and matches with IC Id in UID (see UID_definition).

IC reference

8	1
IC reference	
b00000101	

Table 21.

Pad Assignment

Pin	Name	I/O	Description
1	L1	ANA	Antenna terminal
2	L2	ANA	Antenna terminal
3	VPOS	Power	Positive supply voltage unregulated
4	VSS	Substrate	Negative supply voltage
5	T_SCLK	I	Test shift-clock
6	T_CLK	I	Test clock
7	T_IN	I	Test data in
8	T_EN	I	Enables chip test when high
9	T_OUT	O	Test data out

Table 22.

Chip Floorplan

Test pads 4 to 9 are located in scribe line.
Test pads 4 to 8 are common between two dies. Pads 9a and 9b are output pads, pad 9a is connected to chip A (left die), pad 9b is connected to Chip B (right die).

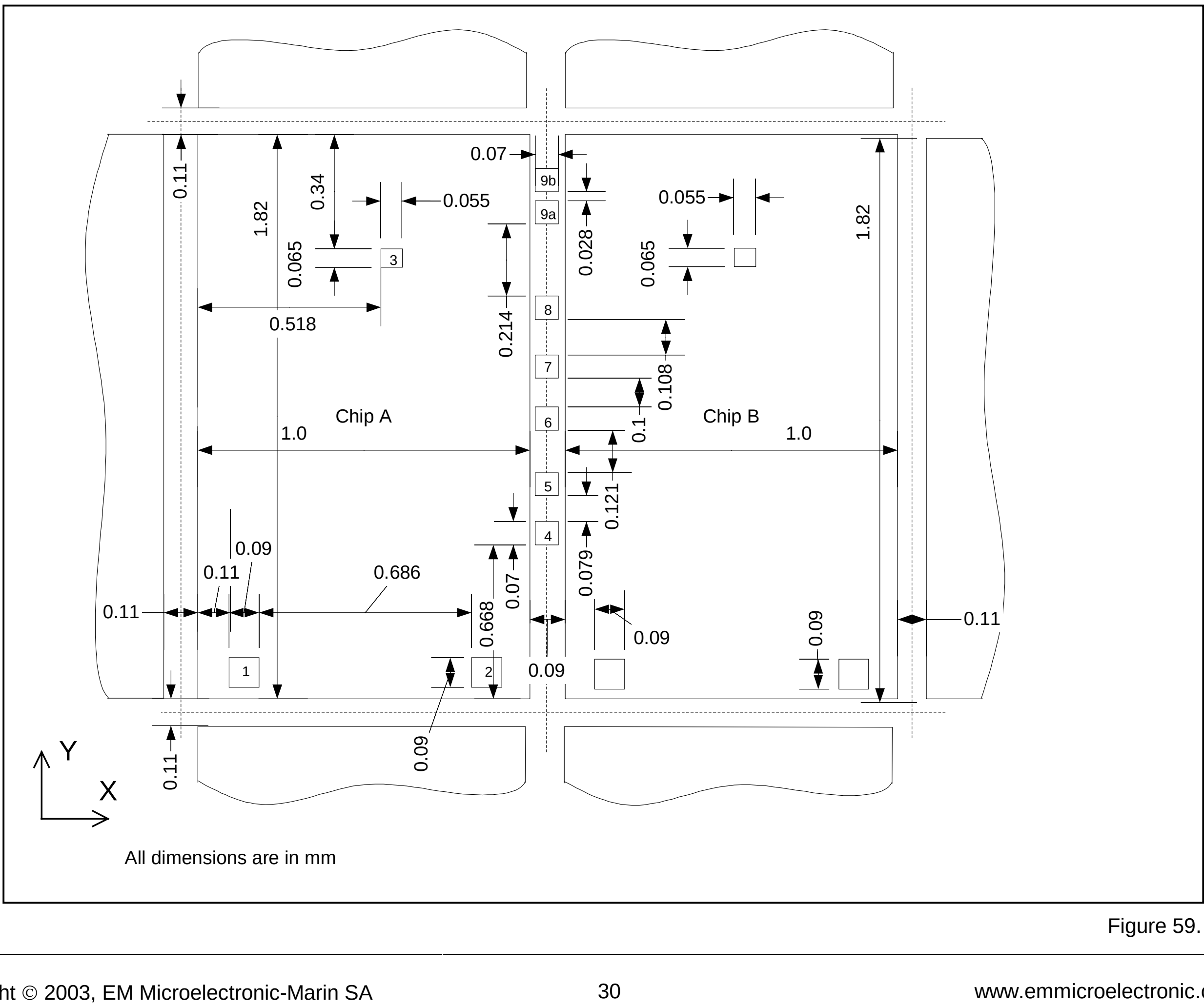


Figure 59.

Ordering Information

For wafer form delivery, please refer to EM4135 wafer specification document
For CIDPACK delivery, please to CIDPACK data sheet.

DIE Form:

EM4135 AM WW 11 - 002

Circuit Name:
EM4135

Coding:
AM= Manchester, Multi Baud Rate

Die form:
WW =Unsawn Wafer
WS = Sawn Wafer/Frame
WT = Sticky Tape

Thickness:
6 = 6 mils (152um)
7 = 7 mils (178um)
11 = 11 mils (280um)

Bumping:
" " (blank) = no bumps
E = with Gold Bumps

Customer Version:
002: resonance capacitor of 28pF
502: resonance capacitor of 95pF

Package Form:

EM4135 AM CI2LB - 002

Circuit Name:
EM4135

Coding:
AM= Manchester, Multi Baud Rate

Package/Card & Delivery Form:
CI2LB = CID Pack, 2 long pins (2.5mm), in tape
CI2LC = CID Pack, 2 long pins (2.5mm), in bulk
CB2RC = PCB Package, 2 pins, in bulk

Customer Specific Version:
002: resonance capacitor of 28pF
502: resonance capacitor of 95pF

Standard Versions:

The versions below are considered standards and should be readily available. For the other delivery form, please contact EM Microelectronic-Marin S.A. Please make sure to give complete part number when ordering.

Part Number	Resonant Capacitor	Package/Die Form	Delivery form/Bumping
EM4135AMWW11-002	28pF	Unsawn wafer, 11 mils thickness	No bump
EM4135AMWW11-502	95pF	Unsawn wafer, 11 mils thickness	No bump
EM4135AMWS11E-002	28pF	Sawn wafer, 11 mils thickness	Gold bump
EM4135AMCI2LC-002	28pF	CID package, 2pins (length 2.5mm)	bulk
EM4135AMCB2RC-002	28pF	COB package, 2pins	bulk

Table 23.