RFID circuit with read/write functions

(Functionally compatible to MF0 IC U1X.Philips)

General description

The IZ2822 RFID circuit with read/write functions is purposed for usage in contactless plastic cards.

Application areas: transference supervisory control system, antitheft systems, access control systems in buildings, restricted areas, burglar alarm, registration & identification systems in transportation & technological processes.

External coil is connected to create contactless identifier mark. Build-in radio channel receive signal induced in antenna. This signal is used by power supply unit to generate supply voltage & by control unit to separate clocking signal.

Main features

- 512 bit (16 pages x 4 bytes) EEPROM ;
- 100,000 memory program/erase cycles;
- Temperature range from minus 40 to plus 85 °C;
- ESD protection up to 2000 V;
- Latch current not less than 100 mA for 25 °C temperature;
- Contactless data & power supply transfer;
- Operating field frequency 13,56 MHz;
- Data transfer rate – 106 kbit/s;
- Build-in resonance capacitry 42,5 pF $\leq C_R \leq$ 57,5 pF;
- Anticollision function support, permit to process few identifier marks in receiving zone at the same time;
- Data exchange meet international standards ISO 14443-2, ISO 14443-3, type A;
- Internal DC voltage limitation to prevent identifier mark fail in power electromagnetic field.;
- Internal circuit clocking by means of separation of clock pulses from external electromagnetic field;
- data storage without power supply (non-volantive memory);
- sector organization of memory with possibility of writing protection of each sector

Tab.1 Contact pad description

Contact pad number	Symbol	Function
01	COIL1	Coil connetion I/O
02	COIL2	Coil connetion I/O
03	U_{CC}	Power supply
04	DATA	Data output (testing)
05	GND	Common
Note – Contact pads U_{CC}, GND, DATA are purposed only fo testing during IC manufacturing and are not used by customer		

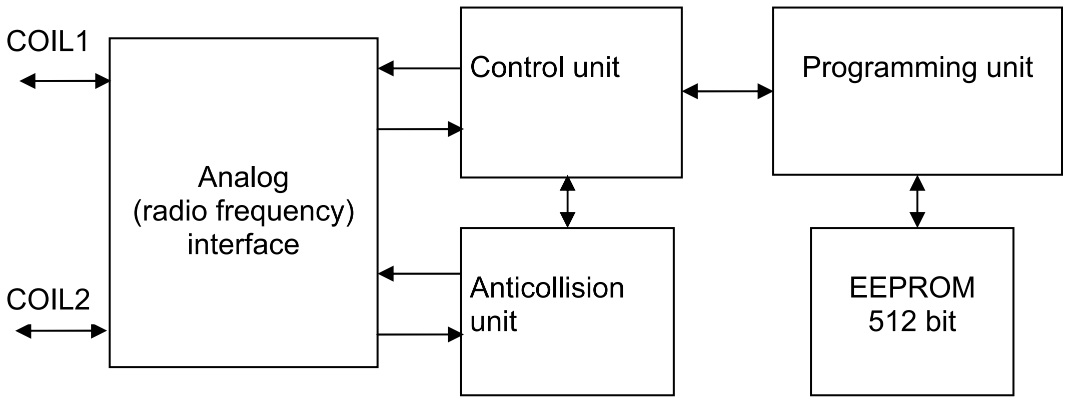


Fig.1 – Block diagram

Tab.2 Recommended operation modes

Symbol	Parameter	Value		Unit
		min	max	
U_{CC}	Power supply voltage	3,0	-	V
U_{COIL}	External coil alternating voltage – pins COIL1, COIL2	3,0	-	V
I_{COIL}	External coil current – pins COIL1, COIL2	-	30	mA
f_{COIL}	Operating frequency	12,93	14,30	MHz
U_{ST}	Internal stabilizer voltage - for I_{COIL}=30 mA	-	6,0	V

Tab. 3 Maximum ratings

Symbol	Parameter	Value		Unit
		min	max	
I_{COIL}	External coil current – pins COIL1, COIL2	-	100	mA

Tab. 4 – Electric parameters

Symbol	Parameter	Mode of testing	Value		Ambient tempera-ture, °C	Unit
			min	max		
I_{CC}	Consumption current	U_{CC}= 3,0 V U_{IH} =U_{CC}	-	97 100	25±10 85 -40	uA

Functional description

The chip consists of the 512 bit EEPROM, the analog (RF) interface and the control unit. Energy and data are transferred via an antenna, which consists of a coil with a few turns directly connected to the chip. No further external capacity is necessary as resonanse capacity is build inside chip

RF interface provide power supply voltage, generate reset signal, after power is switched on, separate clocking pulses, perform modulation of transmission and demodulation of received signal.

Digital control unit provide connection between different units responsible on anticollision function, command interpreter, EEPROM access control.

EEPROM: 512 bits are organized in 16 pages with 4 bytes each. 80 bits are reserved for serial number

(UID) storage. 16 bits are used for the read-only locking mechanism. 32 bits are available as OTP(one time programmable) area. 384 bits are user data read/write memory.

The commands are initiated by the reader and controlled by the command interpreter which handles the internal states of the chip and generates the appropriate responses.

Memory structure

The 512 bit EEPROM memory is organised in 16 pages with 4 bytes each.

In the erased state the EEPROM cells are read as a logical “0”, in the written state as a logical “1”

Byte number	0	1	2	3	Page
Serial number	SN0	SN1	SN2	BCC0	0
Serial number	SN3	SN4	SN5	SN6	1
Internal / LOCK	BCC1	Internal	LOCK 0	LOCK 1	2
OTP	OTP 0	OTP 1	OTP 2	OTP 3	3
Data (Read/Write)	DATA 0	DATA 1	DATA 2	DATA 3	4
Data (Read/Write)	DATA 4	DATA 5	DATA 6	DATA 7	5
Data (Read/Write)	DATA 8	DATA 9	DATA 10	DATA 11	6
Data (Read/Write)	DATA 12	DATA 13	DATA 14	DATA 15	7
Data (Read/Write)	DATA 16	DATA 17	DATA 18	DATA 19	8
Data (Read/Write)	DATA 20	DATA 21	DATA 22	DATA 23	9
Data (Read/Write)	DATA 24	DATA 25	DATA 26	DATA 27	10
Data (Read/Write)	DATA 28	DATA 29	DATA 30	DATA 31	11
Data (Read/Write)	DATA 32	DATA 33	DATA 34	DATA 35	12
Data (Read/Write)	DATA 36	DATA 37	DATA 38	DATA 39	13
Data (Read/Write)	DATA 40	DATA 41	DATA 42	DATA 43	14
Data (Read/Write)	DATA 44	DATA 45	DATA 46	DATA 47	15

Note - User area is indicated by bold line

Fig. 2 – EEPROM map

Instruction set

State diagram ***Typical transmission time***

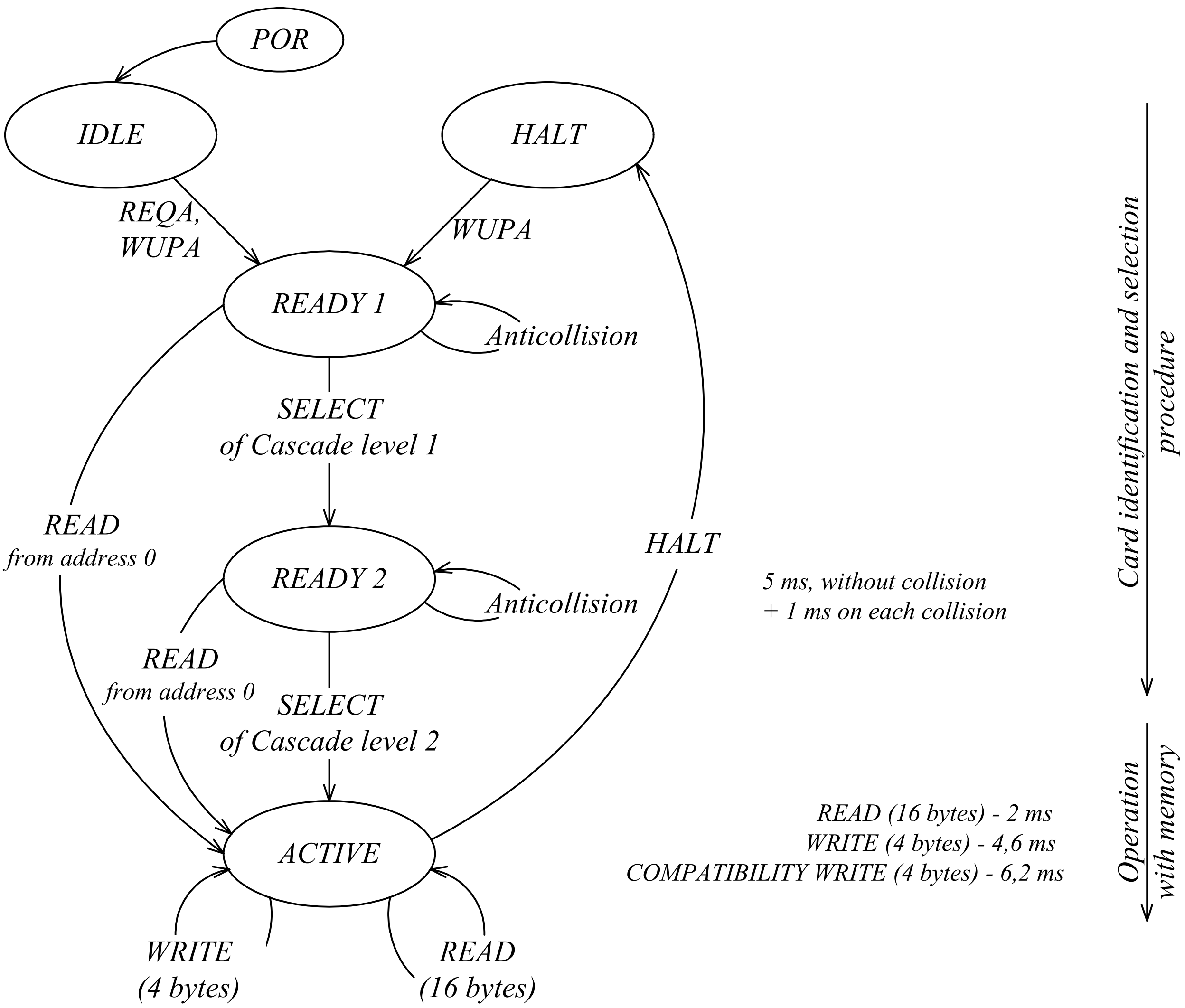


Fig. 3– Chip instruction set

Idle state

After Power On Reset (POR) the card (chip) jumps into the Idle state. With a card request (REQA) or a all card requst (WUPA) commands sent from the reader card (chip) it leaves this state. Any other data or commands received in this state is interpreted as an error and the card continues waiting in the Idle state.

After a correctly executed HALT command, card jumps into the Halt state, which can be left via a WUPA command.

Ready state 1 (READY1)

In this state the card supports the reader in resolving the first part of its UID (3 bytes) with the anticollision commands (ANTICOLLISION) or card select command (SELECT) of cascade level 1. This state is left correctly after one of two commands:

With the SELECT command of cascade level 1 the reader brings the card into ready state 2 (READY 2) where the second part of the UID has to be resolved.

With the READ (from address 0) command the complete anticollision mechanism may be skipped and the card jumps directly into the active state ACTIVE.

If more than one card is in the field of the reader, a read from address 0 will cause a collision because of the different serial numbers, but all cards will be selected.

Any other data received in ready state 1 (READY 1) state is interpreted as an error and the card jumps back to its waiting state (IDLE or HALT, depending on it's previous state).

Ready state 2 (READY2)

In this state, which is similar to state Readyl, the card supports the reader in resolving the second part of its UID (4 bytes) with the ANTICOLLISION command of cascade level *2.* This state is usually left with the SELECT command of cascade level *2.*

Alternatively, state Ready2 may be skipped via a READ (from address 0) command as described in state Readyl.

If more than one card is in the field of the PCD, a read from address 0 will cause a collision because of the different serial numbers, but all cards will be selected! The response of the card to the SELECT of cascade level 2 command is the SAK (Select Acknowledge) byte. According to ISO/IEC14443 this byte indicates whether the anticollision cascade procedure is finished. In addition it defines for the MIFARE architecture platform the type of the selected device. Now the card is uniquely selected and only this device will continue communication with the reader even if other contactless devices are in the field of the reader. Any other data received in this state is interpreted as an error and the card jumps back to its waiting state (IDLE or HALT, depending on it's previous state).

Active state (ACTIVE)

In the Active state either a READ (16 bytes) or a WRITE (4 bytes) command may be performed. The correct way to leave this state is to send a HALT command. Any other data received in this state is interpreted as an error and the card jumps back to its waiting state (IDLE or HALT, depending on it's previous state).

Halt state (HALT)

Besides the Idle state the Halt state constitutes the second waiting state implemented in the card. A card that has already been processed can be set into this state via the HALT command. This state helps the reader in the anticollision phase to distinguish between already processed cards and cards that have not been selected yet. The only way to get the card out of this state is the WUPA command.

Any other data received in this state is interpreted as an error and the card remains in this state.
If not inspected command was not received command interpreter restore card to Idle state from any state exepting Halt state. In case the Halt state card continue to be in this state.

Data transmission protocol

Data exchange protocol between reader and the card meet to the standard for contactless smart cards ISO/IEC 14443 type A.

Reader-card data transmission

Data transfer rate during initialization and anticollision is

f = 13,56 MHz/128 ≈ 106 kbit/s.

One bit data transfer duration is t = 128/13,56 MHz ≈ 9,44 us

Data transmission from the reader to a card occurs to use of a principle of 100 % of amplitude modulation of.

The amplitude of carrier frequency should decrease monotonously up to size, smaller than 5 % from its initial value.

There are three sequences determined for coding sequence of transmitted bits:

- Sequence X – The "pause" follows from the bit transfer start through 64 periods of carrier frequency;
- Sequence Y - Modulation is absent for all duration a bit (128 periods of carrier frequency);
- Sequence Z - The "pause" should be in the beginning a bit .

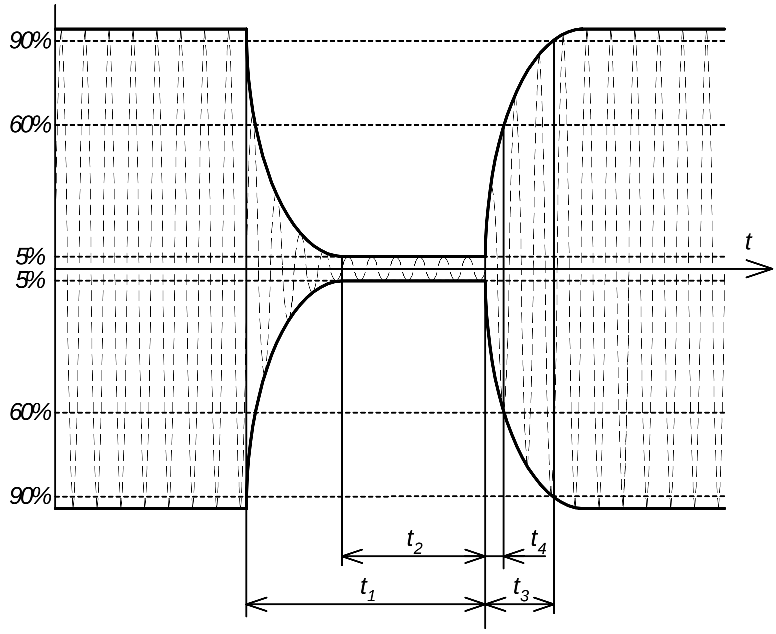


Fig.4 Parameters of carrier frequency envelope

Table 5 - Parameters of carrier frequency envelope

Symbol	Condition	Value		Unit
		Min	Max	
t_1	-	2,0	3,0	us
t_2	$t_1 \geq 2,5$	0,5	t_2	us
	$t_1 \leq 2,5$	0,7		
t_3	-	0	1,5	us
t_4	-	0	0,4	us

The given sequences are used for coding the following information:

- Logic "1" - sequence X;
- Logic "0" - sequence Y with following two exceptions:
  a) If two and it is more consecutive going a bit - "0" sequence Z should be used for transfer of the second and following "0";

b) If the first bit after start of the data frame is "0" sequence Z should be used for representation of it a bit;

- Start of transfer - sequence Z;
- The end of transfer - logic "0" follows with sequence Y;
- There is no information - at least, two sequences Y.

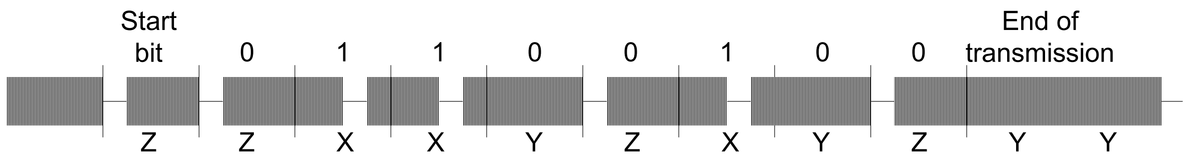


Fig. 5-Representation of coding of bits for data transmission transfer from the reader to a card (Miller modified coding)

Data transmission from a card to the reader

A bit of the data transfer rate during initialization and anticollisions is
f = 13,56 MHz / 128 ≈ 106 kbit/s.
One bit data transfer duration is
t = 128/13,56 MHz ≈ 9,44 мкс.

Data transmission is perfomed by modulation of carrier frequency, due to inductive connection between the aerial of the reader and the aerial of a card. Frequency of modulation (subcarrier frequency) f_s should be equal f_s = 13,56 MHz / 16 ≈ 847 kHz.

Hence, duration of one bit of the data is equivalent to 8 periods of subcarrier frequency.

Subcarrier frequency f_s is modulated with use of amplitude modulation for coding the transmitted data.

Bits are coded by the Manchester code with the following definitions:

- Sequence D - carrier frequency is modulated by subcarrier frequency for first half (50 %) duration of a bit;

- Sequence E - carrier frequency is modulated by subcarrier frequency for for second half (50 %) duration of a bit;

- Sequence F - carrier frequency is not modulated by subcarrier frequency for duration of one bit.

The transmitted data are coded by the following sequences:

- Logic "1" it is coded by sequence D;
- Logic "0" it is coded by sequence E;
- Start of transfer is coded by sequence D;
- The end of transfer is coded by sequence F;
- Absence of the information is coded by subcarrier frequency absence

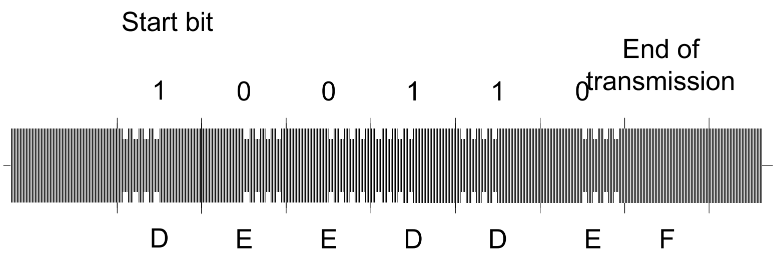


Fig. 6 Coding of a bit for data transmission from a card to the reader

Requirements to the command response time of a card

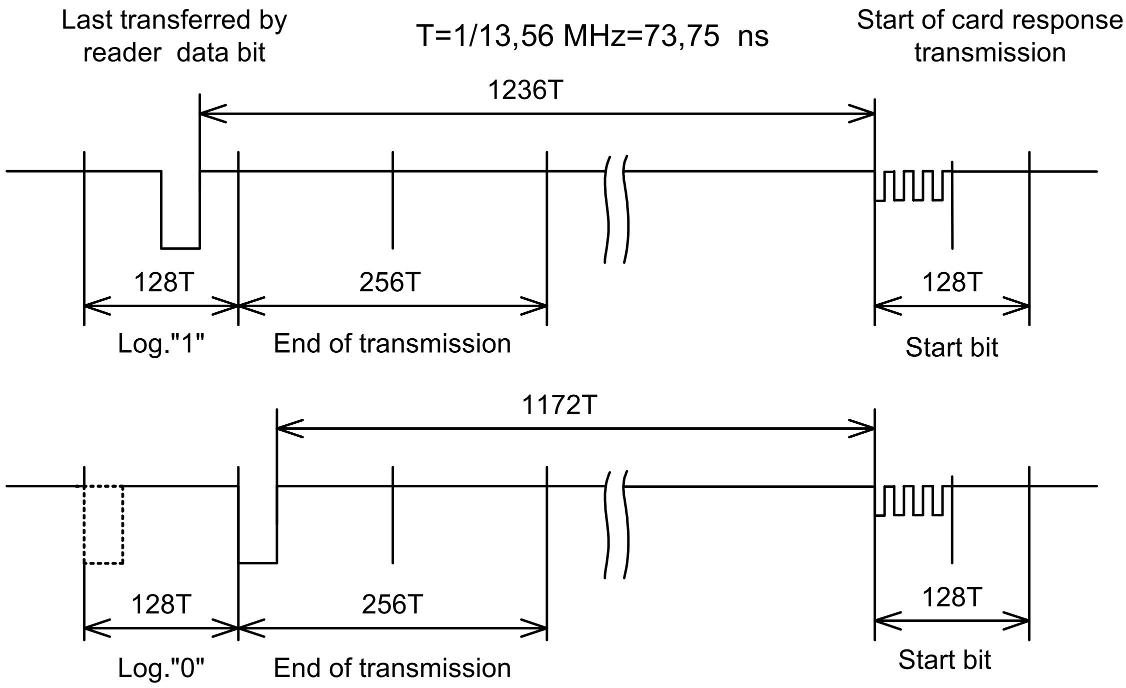


Figure 7 - Responce of a card

The given time diagram applied for the following commands:
- REQA – request of a card;
- WUPA - request of all cards;
- ANTICOLLISION - an anticollision;
- SELECT – card select.

Command set

REQA and WUPA card request commands

All reader commands and card responses are transmitted inside data frames.

REQA and WUPA card request commands are used for initialization initialization of transfer and will consist of following sequences:

- Start bit of transfer (S), always logical "1";
- 7^{th} data bit - the instruction code, a low bit is transmitted first (hexadecimal instruction code REQA - 0x26, WUPA commands - 0x52);
- End of transmission (E).

By transfer of REQA and WUPA commands the parity bit is not transmitted.

Table 6 –Card request command format REQA

Start bit	Command code bits 0x26 (REQA)							End of transmission
	0	1	2	3	4	5	6	
S	0	1	1	0	0	1	0	E

On receiving of REQA and WUPA request commands the card should give out request response ATQA consisting of two bytes (a standard frame) on which the reader determines the type of a card. Respose code is 0x0004.

Standard frame

All commands of the reader, except REQA and WUPA card request commands, all responses of a card to these commands are transmitted in the identical format called as a standard frame.

Standard frames are used for data exchange and will consist of the following sequence:

- Start bit of transfer (S), always logical “1”;

- n × (8 data bits + P parity check bit (odd)), where n ≥ 1. The low bit of everyone data byte is transmitted first. Each byte of data follows with odd bit of parity check;

- End of transmission (E).

Table 7 - the Format of a standard frame

<table>
<tr><td rowspan="2">Start bit</td><td colspan="26">Data transmission: n × (8 data bits + parity check bit (add))</td><td rowspan="2">Parity</td><td rowspan="2">End of transmis-sion</td></tr>
<tr><td colspan="8">1st byte
bit number</td><td>Parity</td><td colspan="8">2nd byte
bit number</td><td></td><td colspan="8">nth byte
bit number</td></tr>
<tr><td>S</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>P</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>P</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>P</td><td>E</td></tr>
</table>

The command of anticollision ANTICOLLISION

The command is used to determine the unique number of a card from which the reader will continue operation at a simultaneous determination in a field of the reader of several cards. The unique number of a card (UID) will consist from 4 bytes and control byte BCC, scaled as bit-by-bit XOR of all these bytes. 4 bytes UID and control byte BCC are in the zero block of zero sector of memory of a card. The zero block is accessible to a customer only on reading, the block can be written at a stage of testing of the circuit on a wafer.

The principle of performance the bit, received by the reader from a card, lays in a basis of the command of anticollision ANTICOLLISION. I we have several cards in magnetic field of the reader simultaneously cards respond on the command of an anticollision by the UID-codes. As each card has, unique UID different from others in some bit by transfer UID there will be an imposing "1" on "0", i.e. modulation will take place for all duration of bit that is a non-standard situation. The reader will determine this situation as a collision and on particular algorithm, the bit is admissible in a place of imposing, will establish value of bit equal "1" and the repeated command of anticollision ANTICOLLISION will transmit part UID ended in this bit, and only those cards for which part UID transferred by the reader coincides, should answer with the rest of the UID.

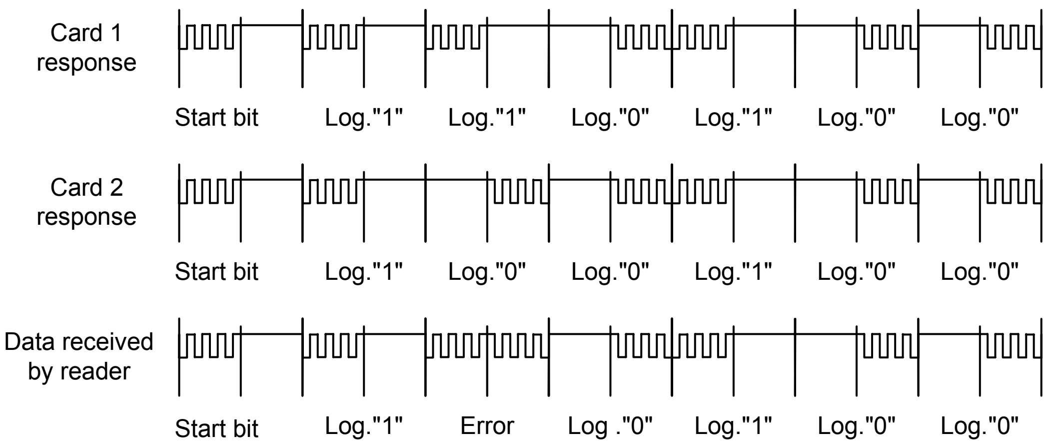


Fig. 8 - Determination of a collision

The reader will know the number of the unique map from which will continue further operation after few cycles of an anticollision. If there is only one card in a field of the reader, than, having received UID of this card, the reader sends command of card selection (SELECT).

The command of anticollision ANTICOLLISION uses standard frames with data length 7 bytes which is fragmented to two parts, the first part for transfer from the reader to a card and the second part for transfer from a card to the reader.

Thus there are two cases:

- A case of the complete byte;
- A case of byte fragmentation.

The instruction code 0x93 (same as well as for selection command of a map) is in the first part the first byte, the second byte NVB will define number of bytes (taking into account the command) and number the bit, transmitted the reader.

In the first part - the first byte is the instruction code 0x93, the second byte 0x25 will define quantity of bytes (2 bytes) and bits (5 bits) transmitted by the reader. The part 2 contains rest of UID by which the card should respond, thus on fragmented byte (3 bits) the parity bit is not inspected by the reader.

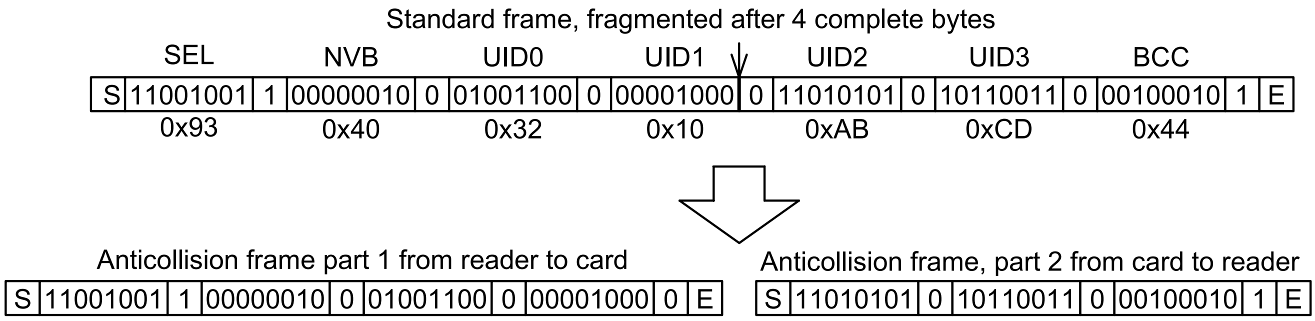


Fig.9 - Bit architecture and anticollision frame transfer (case of complete byte)

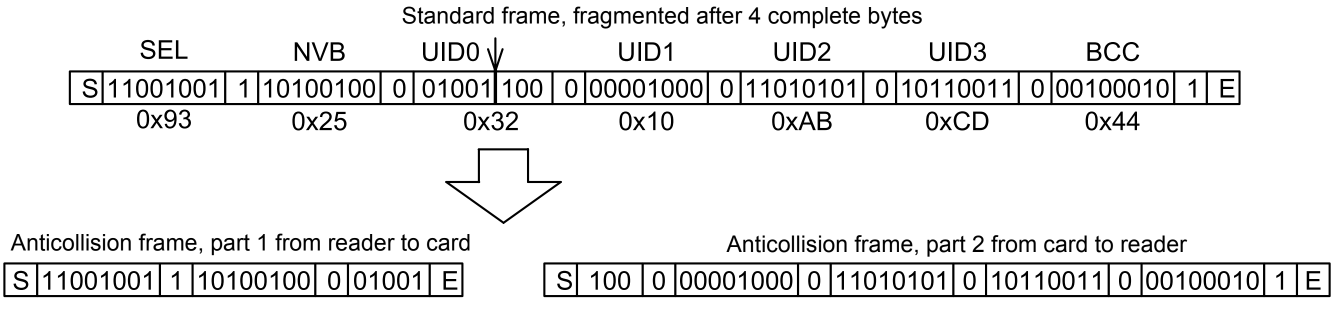


Fig.10 Bit architecture and anticollision frame transfer (case of fragmented byte)

Card select command

The reader sends card select command after complete UID of the card is detemined by the command of anticollision (ANTICOLLISION).

The command has the same code, as well as ANTICOLLISION (0x93), the second byte is equal 0x70, i.e. the reader sends 7 complete bytes (byte of the instruction code, NVB byte, UID 4 bytes and BCC byte).

The command is ended by two bytes of cyclic redundant code CRC (a generating polynomial $x^{16} + x^{12} + x^{5} + 1$), scaled on 7 previous bytes.

On receiving of card select command (at the complete matching by card UID, BCC, a parity bit and CRC a code), the card should respond SAK - selection acknowledgment code (0x08) SAK is transmitted in standard frame, following with two CRC bytes.

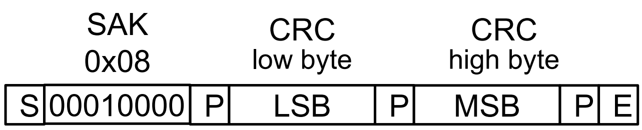


Fig. 11 - Card response on card select command

Stop command

Stop command HALT consist of 4 bytes (two bytes of instruction code and two bytes of a CRC-code) and is transmitted in a standard frame.

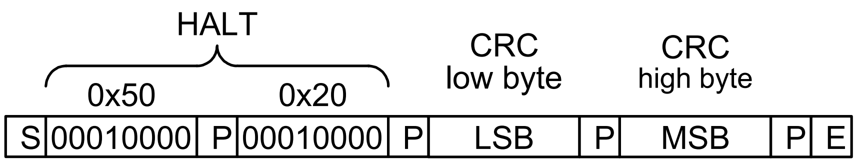


Fig. 12 Stop command HALT

On receiving stop command HALT the card jump in idle mode and does not react to all other commands, except request command for all cards WUPA.

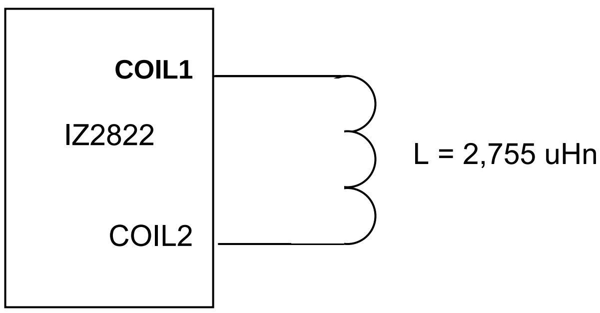
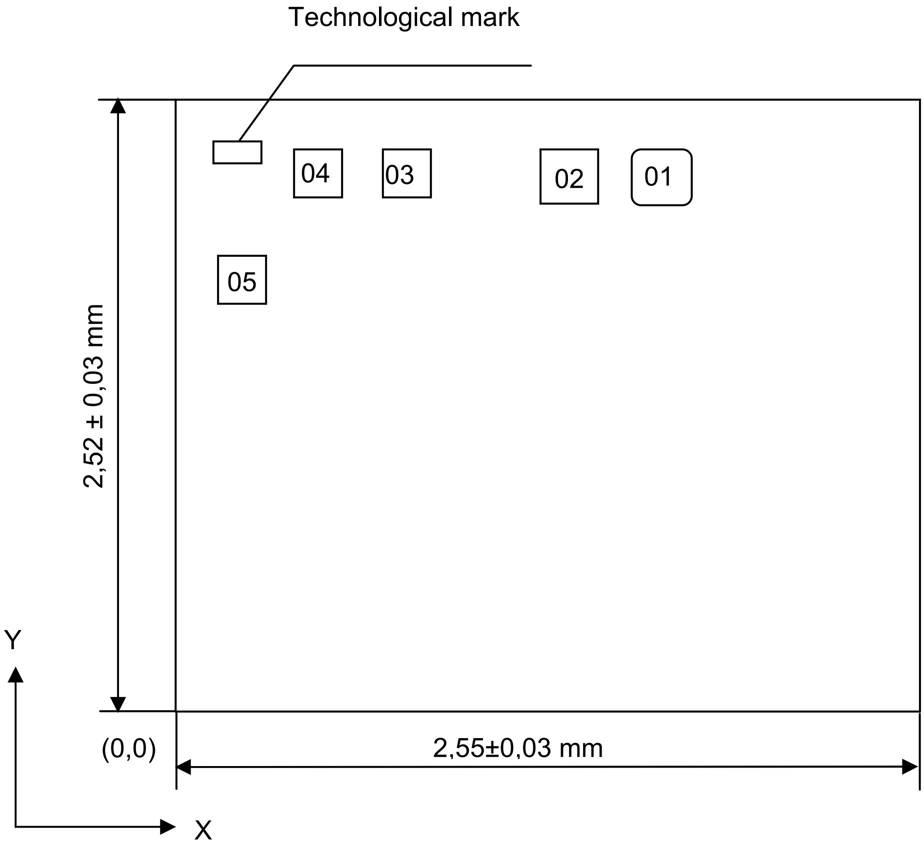


Fig.13 Recommended application diagramm

Contact pad location diagramm

ICs is shipped in chip form with fixed orientation (sticked on film)
Weight of ICs not less than 0,027 g.



Chip depth 0,18±0,01 mm.
Coordinates of technological mark, mm: x=0,221, y=2,329.

Fig. 14 – Contact pad layout

Table 8 – Contact pads location & dimensions

Contact pad number	Symbol	Pad size mm	Coordinates (ref. to left bottom corner), mm	
			X	Y
01	COIL1	0,112x0,112	1,4254	2,2660
02	COIL2	0,112x0,112	1,1524	2,2660
03	U_{CC}	0,092x0,092	0,6712	2,2860
04	DATA	0,092x0,092	0,4541	2,2860
05	GND	0,092x0,092	0,1560	2,1167