RFID Transponder LSI: Babyface2

(MB89R111)

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1 GENERAL DESCRIPTION 4

2 AIR INTERFACE 4

2.1 INITIAL DIALOGUE BETWEEN TRANSPONDER AND READER/WRITER 4
2.2 POWER TRANSFER 4
2.3 SIGNAL INTERFACE ALTERNATION 5
2.4 COMMUNICATION SIGNAL INTERFACE 5
2.4.1 Communication from Reader/Writer to Transponder 5
2.4.2 Communication from Transponder to Reader/Writer 6
2.5 COMMUNICATION RANGE 8
2.6 OTHER CONSIDERATIONS ON AIR INTERFACE 8

3 CHARACTER AND FRAME TIMING 9

3.1 CHARACTER TRANSMISSION FORMAT 9
3.2 CHARACTER SPACING 9
3.3 FRAME DELIMITERS 9
3.4 SOF (START OF FRAME) 10
3.5 EOF (END OF FRAME) 10
3.6 TIMING OF TRANSPONDER RESPONSE AFTER READER/WRITER DATA TRANSMISSION 10
3.7 TIMING OF READER/WRITER COMMAND AFTER TRANSPONDER'S DATA TRANSMISSION 11
3.8 CRC 11

4 ANTICOLLISION ALGORITHM 12

4.1 PRINCIPLE OF ANTICOLLISION 12
4.2 ALGORITHM OF ANTICOLLISION 12

5 STATE DIAGRAM 13

6 INTERNAL MEMORY (FRAM) CONFIGURATION 14

6.1 MEMORY MAP 14
6.2 RELIABILITY OF FRAM 15
6.3 FRAM DATA PROTECTION FROM DROP IN SUPPLY VOLTAGE DURING ACCESSING FRAM AND UNINTENTIONAL POWER SHUTDOWN 15

7 COMMAND 17

8 TARGET ELECTRICAL CHARACTERISTICS 26

9 MOUNTING CONDITIONS 27

10 BLOCK DIAGRAM **30**

11 PAD LAYOUT **31**

12 WAFER SHIPPING SPECIFICATION **32**

12.1 WAFER CONDITIONS 32
12.2 NUMBER OF DIES PER WAFER 32
12.3 SCRIBE LINE WIDTH 32
12.4 DIE STEPPING WIDTH 32
12.5 PAD SIZE 32
12.6 WIRE BONDING OR STUD BUMP 33
12.7 INK MARK 33

13 WAFER DELIVERY SPECIFICATION **33**

1 General Description

The "Babyface2" contactless RFID (Radio Frequency Identification) transponder IC is especially designed to meet the requirements for factory automation, transportation ticketing and comparable applications. The described specifications are primarily based on the ISO/IEC 14443 standard as well as the Japanese regulations of RF radiation. Any of specifications shall be reconsidered according to customer requests and technical requirements/restrictions.

2 Air Interface

2.1 Initial Dialogue between Transponder and Reader/Writer

The initial dialogue between transponder and reader/writer is conducted according to the "reader/writer talk first" operation.

(1) The reader/writer activates the transponder by applying RF operating field.

(2) The transponder waits for a command from the reader/writer without transmitting any response.

(3) The reader/writer transmits a command to the transponder.

Note: The transponder cannot accept any commands in maximum 1.5ms after being activated. The reader/writer shall transmit a command after this time period.

(4) The transponder operates following the command transmitted from the reader/writer and then transmits a response to the reader/writer.

2.2 Power Transfer

(1) RF operating field frequency, fc: 13.56MHz±6.78kHz

(2) The minimum unmodulated operating field, Hmin: 0.5A/m

Note: It is estimated that one transponder can communicate.

(3) The maximum unmodulated operating field, Hmax: 7.5A/m

Note: It is estimated that 2 or 3 transponders are existed, and the resonance frequency of transponders are tuned higher value than 13.56MHz.

(4) The minimum OFF time of RF power: more than 100us

The following specification is associated with a reader/writer, which generates the operating magnetic field described above.

(1) The maximum reader/writer input power: 1W

(2) The maximum reader/writer antenna gain: -30dB (50ohm)

(3) The maximum variation of the reader/writer power: +20%, -80%

The reader/writer generates a field of at least Hmin and not exceeding Hmax in the operating volume. In the real operational environment, the interference between reader/writer and the transponders may happen, the antenna characteristics and the transmission voltage of reader/writer, and the antenna characteristics of the transponders need to be optimized according to the environment. In addition, the magnitude of the electric

field must be less than 500uV/m at the distance of 3m from the reader/writer antenna for the frequency range except for 13.56MHz±7kHz.

2.3 Signal Interface Alternation

In the ISO/IEC standard (14443), the reader/writer is supposed to alternate two signal interfaces, Type A and Type B (adopted in this specification). The choice of this alternation is left open to customers (reader/writer manufacturers). Be careful at the time of setting the reader/writer as only the Type B interface is supposed to be operated in "Babyface2".

2.4 Communication Signal Interface

2.4.1 Communication from Reader/Writer to Transponder

(1) Data Rate fb: 105.9375kbps(fc/128) or 211.875kbps(fc/64). The data rate can be selected by programming the operation control bit in FRAM during test sequence of this product and this controlled bit cannot be reprogrammed during operation.

(2) Required Frequency Band: fb*7

(3) Type of Modulation: ASK

(4) Modulation Index m (target): 8% - 14%

Modulation index (m) is defined as m=(a - b)/(a + b) in Figure 2-1, where (a) and (b) are peak and minimum magnetic field amplitude transmitted from a reader/writer, respectively. The rising and falling edges of the modulation shall be monotonic and less than 2usec for fb=105.9375kbps or 1usec for fb=211.875kbps.

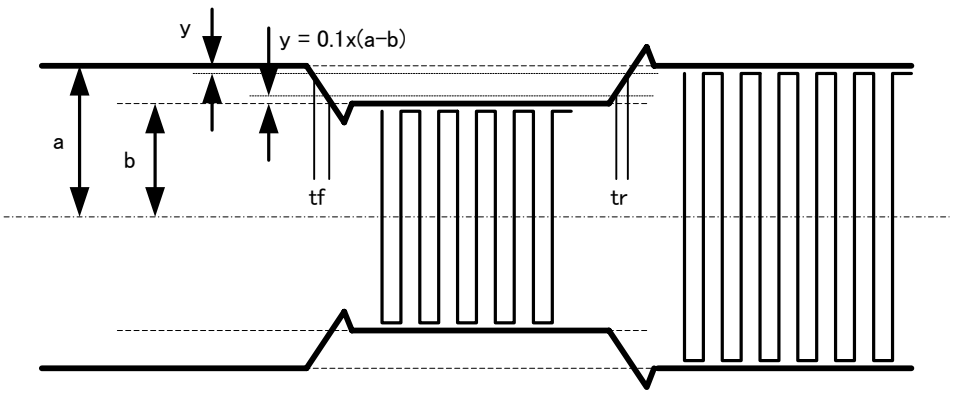


Figure 2-1: Definition of Modulation Index

(5) Bit Coding

Logic “1”: Carrier high field amplitude (no modulation applied)

Logic “0”: Carrier low field amplitude

Figure 2-2 is representing an example of signal from reader/writer. For the data rate of 211.875kbps, data H#55 is transmitted following a start bit of logic "0".

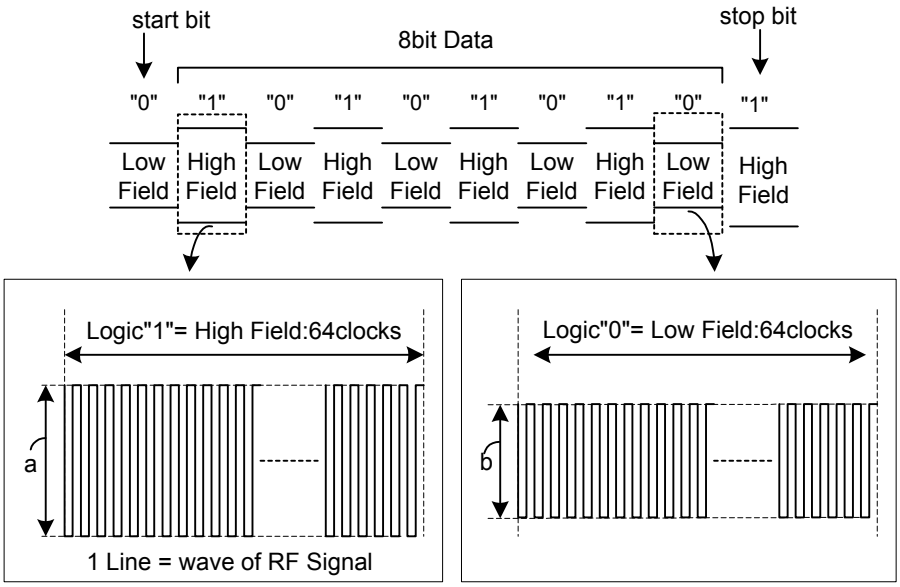


Figure 2-2: Example of transmitted signal from reader/writer.

2.4.2 Communication from Transponder to Reader/Writer

(1) Data Rate fb: 105.9375kbps(fc/128) or 211.875kbps(fc/64).

The data rate can be selected by programming the operation control bit in FRAM during test sequence of this product and this controlled bit cannot be reprogrammed during operation.

(2) Required Frequency Band: fb*10

(3) Method of Data Transmission: Load switching (Load modulation) or equivalent method. The reader/writer is supposed to be transmitting logic "1" during the transponder response.

(4) Minimum Load Modulation Amplitude Vlm: $30/H^{1.2}$ (mV)

H is the rms value of magnetic field strength in A/m

Note: This value is not satisfied around the area, where the magnetic field strength is low, in order to avoid the power down by load modulation.

(5) Load Modulation Subcarrier Frequency fs: 847.5kHz (fc/16)

(6) Subcarrier Modulation: BPSK

The phase shift must only occur at normal position of rising and falling edge of subcarrier.

(7) Bit Representation and Coding: NRZ-L

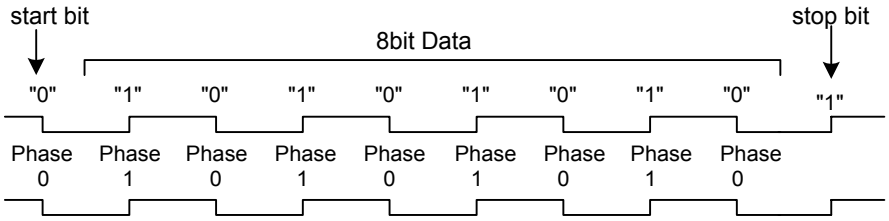
(8) Transponder Response Frame:

Initial Response Guard Time TR0: 64/fs (75.5usec)

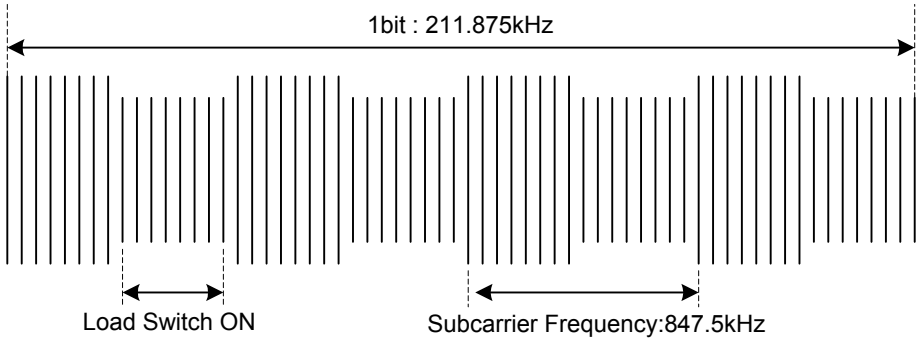
Subcarrier Modulation Guard Time TR1: 80/fs (94.4usec)

Initial Phase State: Logic "1"

Figure 2-3 is an example of transponder response. With the data rate of 211.875kbps, data H#55 is transmitted following a start bit of logic “0”. The each phase is relative to the initially transmitted phase.



＜Phase 0＞



＜Phase 1＞

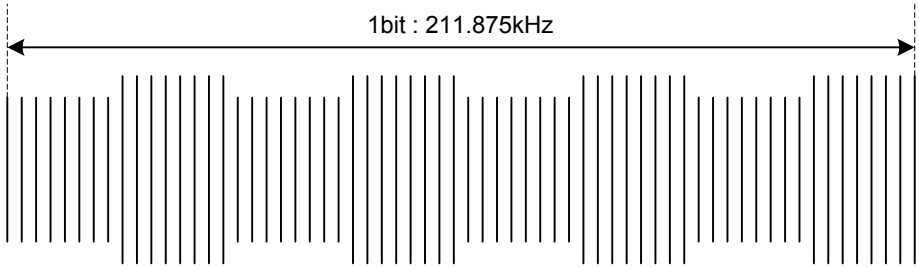


Figure 2-3: Example of transmitted signal from transponder.

2.5 Communication Range

Communication Range: more than 10cm

<Measurement Conditions>

The geometry of transponder and reader/writer antenna strongly affects the communication range. A method for standardizing communication range measurement is described in ISO/IEC 10373, where the sizes of the transponder coil and the reader/writer coil are 72mm(±2%) x 42mm(±2%) [4 turns] and 150mm (diameter) [1 turn], respectively. These coils are made on the printed board and the thickness of the conductor is 35um. The antenna Q factor for each transponder and reader/writer should be higher than 10. In the measurement of the communication range, the transponder coil is placed in parallel with the reader/writer coil, and the environmental noise should be less than -85dBm.

2.6 Other Considerations on Air Interface

(1) Influence of RF radiation to human health including fetus should strongly be cared.

(2) Antenna sizes of both transponder and reader/writer should be optimized for each application by taking account of the communication range and available space.

(3) When multiple transponders are accessed, the communication range and/or transaction time might be degraded due to interference between the responder and the reader/writer or between the responders. Careful system design is required for the multiple transponder systems.

3 Character and Frame Timing

This section defines the communication method between the transponder and reader/writer.

3.1 Character Transmission Format

Data bytes are transmitted and received between the transponder and reader/writer by the character transmission format in ISO/IEC 14443. The character transmission format is configured with:

(1) One-bit start bit having logic "0"
(2) Eight-bit data transmitted from LSB (without the parity bit)
(3) One-bit stop bit having logic "1"

The transmission of one byte is performed with a character requiring 10 ETU (elementary timing unit) as illustrated in Figure 3-1. Bit boundaries within a character shall occur between (n-0.125) and (n+0.125) ETU where n is the number of bit boundaries after the start bit falling edge.

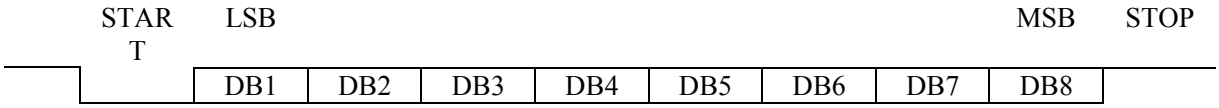


Figure 3-1: Character Format

3.2 Character Spacing

The character transmission format is used. The extra guard time, the spacing between consecutive characters, is set at 0 usec to shorten the transmission time.

3.3 Frame Delimiters

Transponders and reader/writer send characters as frames. The frame is delimited by SOF (Start Of Frame) and by EOF (End Of Frame). The typical frame format is shown in Figure 3-2.

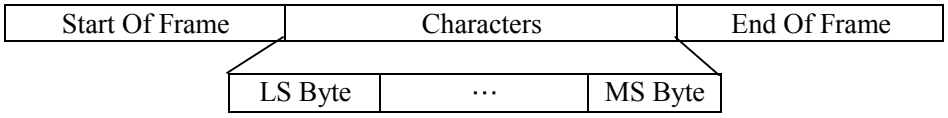


Figure 3-2: Frame Format

3.4 SOF (Start of Frame)

SOF is composed of:

(1) One falling edge

(2) Logic “0” status with 10 ETU, following (1)

(3) One signal rising edge located anywhere within 1ETU, following (2)

(4) Logic "1" status of 2 - 3ETU, following (3)

The format of SOF is presented in Figure 3-3.

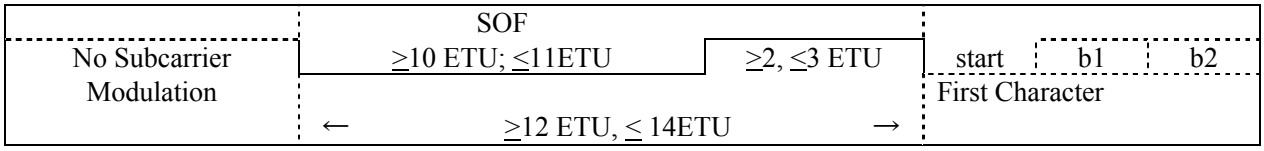


Figure 3-3: SOF

3.5 EOF (End of Frame)

EOF is composed of

(1) One falling edge

(2) Logic "0" status with 10ETU, following (1)

(3) One signal rising edge located anywhere within 1ETU, following (2)

The format of EOF is presented in Figure 3-4.

Figure 3-4: EOF

3.6 Timing of Transponder Response After Reader/Writer Data Transmission

The start of transponder response after a reader/writer data transmission shall respect the timing diagram as illustrated in Figure 3-5. The minimum delay time between EOF of reader/writer and transponder carrier ON, TR0, is 64/fs (8ETU for fb=105.9375kbps, 16ETU for fb=211.875kbps). The minimum period TR1 between transponder carrier ON and first bit transmission is 80/fs (10ETU for fb=105.9375kbps, 20ETU for fb=211.875kbps). Both values of TR0 and TR1 are default in ISO/IEC 14443. A transponder turns on the subcarrier only if its intends to begin transmitting information.

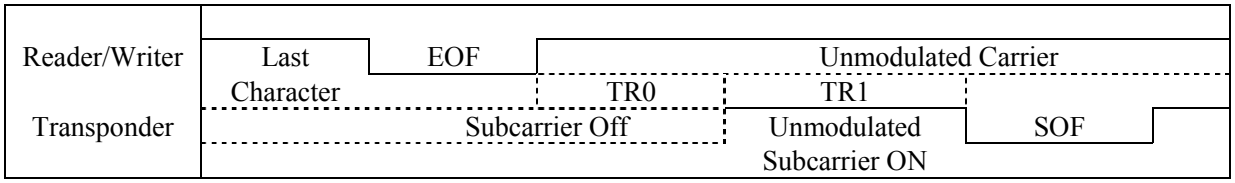


Figure 3-5: Responder Response Timing After Reader/Writer Data Transmission

3.7 Timing of Reader/Writer Command After Transponder's Data Transmission

The start of reader/writer communication after a transponder data transmission shall respect the timing diagram as illustrated in Figure 3-6. The transponder shall turn off its carrier after the transmission of the EOF. The subcarrier signal shall not be stopped before the end of EOF, and be stopped within 2 ETU after the end of EOF. The minimum delay between the start of EOF in transponder (falling edge) and the start of reader/writer SOF is 14ETU.

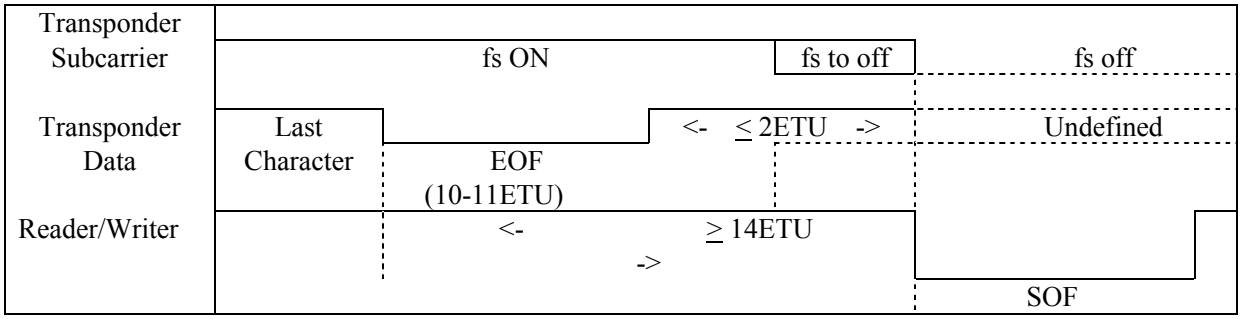


Figure 3-6: Transponder to Reader/Writer EOF

3.8 CRC

A character shall only be considered correct if it is received with a valid CRC value, as is depicted in Figure 3-7. For error checking, two CRC bytes are included after the data bytes and before the EOF. The CRC frame is a function of n data bytes, which consist of all the data bits in the frame except start and stop bits. The details of the CRC are as defined in ISO/IEC 3309. The generator polynomial used to generate the check bit is described in eq. [1].

The initial value of the 16-stage cyclic shift register used for CRC check shall be all ones: "FFFFh".

$$x^{16} + x^{12} + x^5 + 1 \qquad [1]$$

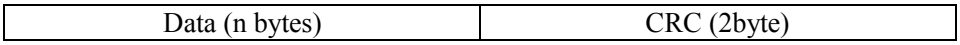


Figure 3-7: Configuration of Data CRC

4 Anticollision Algorithm

4.1 Principle of Anticollision

In the case of communication between plural responders by using the antenna of single reader/writer, data collision might occur when more than one transponder response at the same time, which disables signal detection. In this specification, "anticollision" (plural transponder recognition) is defined as a method for fetching information (ID) unique to each transponder to allow communication between plural transponders by the antenna of a single reader/writer. The reader/writer issues an REQA (REQC) command to execute anticollision, obtains ID from the plural transponders, issues SELECT command and notifies that the transponder having certain ID has been recognized. When the subsequent commands are sent from the reader/writer, communication with one responder is executed by assigning the unique ID for each transponder.

In this section, the algorithm of anticollision adopted in "Babyface2" is explained.

4.2 Algorithm of Anticollision

The ISO/IEC 14443 based slotted ALOHA algorithm is used as the algorithm of anticollision. The data transmission chart of this algorithm is shown in Appendix 1. The four slots are provided for the transponder to transmit ID. When the reader/writer transmits REQA (REQC) command, the transponder checks 2-bit random number and selects a slot among the four slots to respond to the unique ID. When plural transponders respond to the same slot, the reader/writer cannot recognize the ID due to collision of the signal. The reader/writer detects the ID transmitted by the slot that did not generate collision and transmits SELECT command Including the received ID. The transponder that received the SELECT command is set not to respond to the REQA (REQC) commands subsequently transmitted from the reader/writer and transmits ATS (Answer To Select) message which Indicates write protection/enable area in FRAM, which is explained later.

The reader/writer transmits REQA (REQC) command again to save the transponder by which the unique ID is not received by the reader/writer due to collision. As the transponder regenerates 2-bit random number each time it receives REQA (REQC) command, collision can be evaded.

For those customers not requiring anticollision function, fast unique ID transmission and reception are performed by using REQB command.

5 State Diagram

The state diagram of Babyface2 is shown in Figure 5-1. To execute the application command explained in details in Section 7, the transponder must be in ACTIVE status. In a system where plural transponders exist, the transponders can be put in the ACTIVE status by normally executing the REQA (REQC) and SELECT command. In the ACTIVE status, REQC command is not accepted so as to prevent anticollision sequence operation.

HALT status is not used in the normal application command. However, rewriting of Write Access Control Area which assigns write protection for FRAM, which is explained later, is effective only in this state. Prepare an environment where rewriting is surely performed in executing the command.

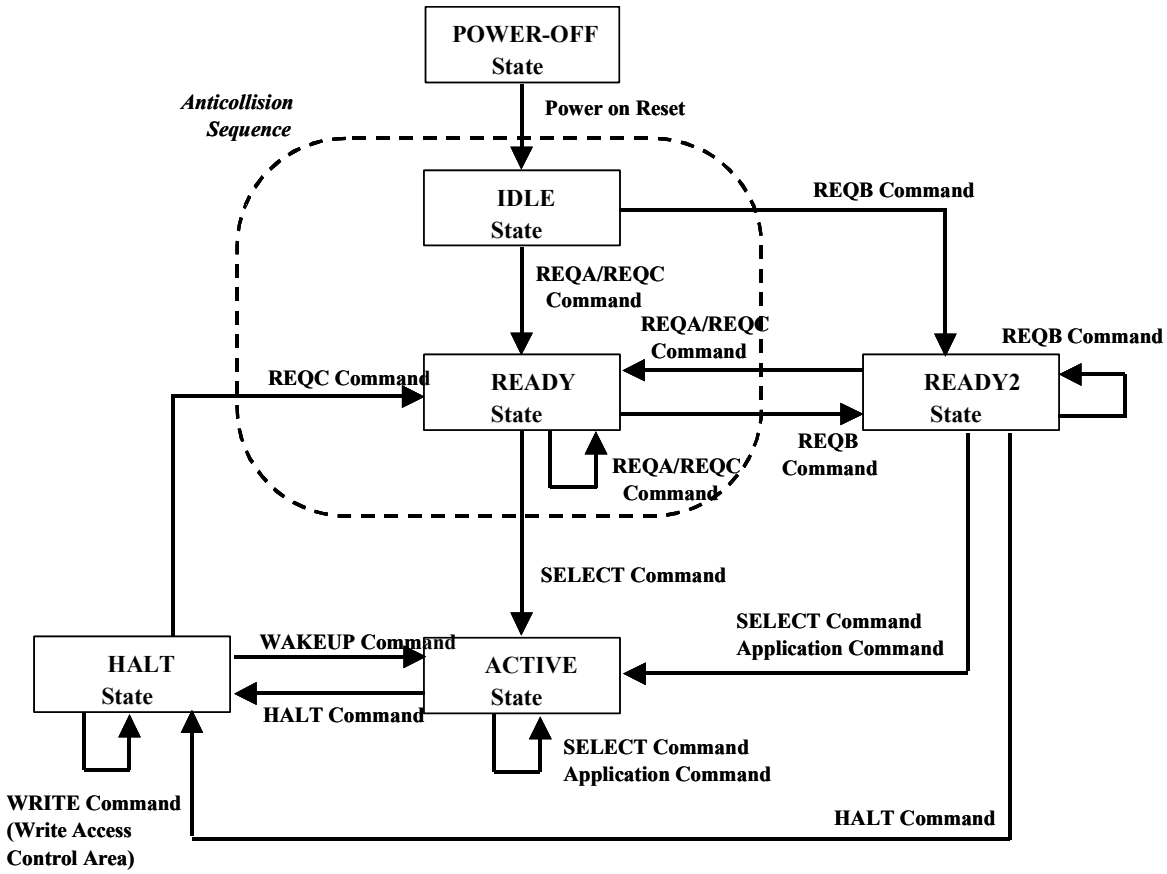


Figure 5-1: State diagram

6 Internal Memory (FRAM) Configuration

6.1 Memory Map

The Babyface2 transponder LSI has 2K-byte FRAM. This FRAM has 128-block, each of which consists of 8 pages as illustrated in Figure 7-1. One page has 2-byte data. To minimize power consumption, actual FRAM should be designed as 1-byte structure. The block is minimum unit of assigning write-protection of FRAM data, while the page is minimum unit for write/read access. The write-protection is set by programming associated bits to zero in Write Access Control Area which is explained later. Once this bit is set to zero, rewriting cannot be performed. As explained in Section 7, in WRITE and ADD commands rewriting will be performed after the transponder confirms that there is no assigning of a command over the blocks. As for FILL command, since it is for writing the same data in many areas, if the leading block is not protected from writing, the command will be executed even when the subsequent blocks are protected from writing.

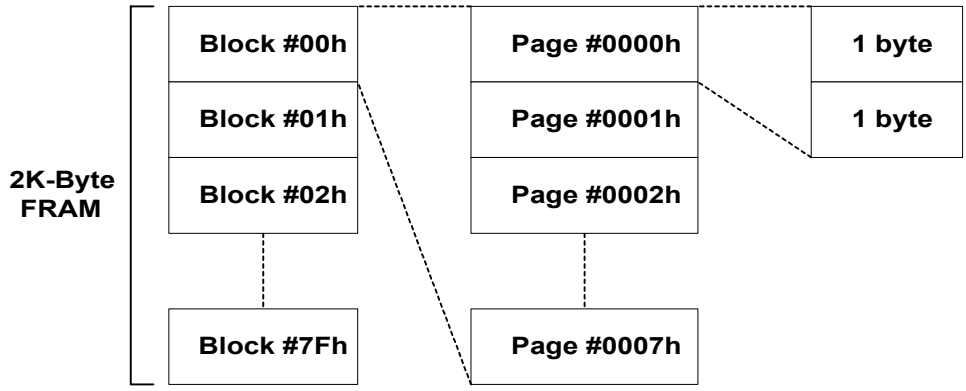


Figure 7-1: FRAM configuration

The FRAM memory map is presented in Figure 6-2. The memory area is divided into the system area and the user area, and the system area is assigned in incremental order from the page of #0000h to #000Fh. The Babyface2 has 32-byte system area. This system area consists of operation control area (4 bytes), user ID/ application ID (4 bytes), device serial number (4bytes), and write access control area (16 bytes).

The device serial number is programmed by manufacturer for shipping, and is used as the unique ID for commands. The user ID (2bytes) and application ID (2bytes, 1 block) are also programmed before shipping, and the latter can be specified by customers. In principal the Operation Control Area, user/application ID and device serial number cannot be rewritten irrespective of assignment of Write Access Control Area.

As for the Operation Control Area, only the page #0000h is used. The configuration of this area is shown in Figure 6-3. Figure 6-4 represents the configuration of the Write Access Control Area.

6.2 Reliability of FRAM

The endurance of FRAM is 1E10 times, and the data retention is 10 years at 70degC.

6.3 FRAM Data Protection from Drop in Supply Voltage during Accessing FRAM and Unintentional Power Shutdown

When power is shut down while data is being accessed in a nonvolatile memory, sometimes the data is replaced with an unexpected value, resulting in affecting the system operation. When drop in supply voltage (Vrst1<Vdd) is recognized, access to FRAM will be suspended for 100usec at maximum in order to avoid FRAM data writing error. In case the supply voltage becomes restored during 100usec suspended time (Vrst1>Vdd), access to FRAM will be restarted. But in case the supply voltage keeps being low over 100usec (Vrst2<Vdd<Vrst1), the command under processing will be canceled. In such a case the command needs to be executed again after supply voltage is restored. In this transponder, the transmitted data is accessed to FRAM with the unit of one byte. In the case of RF power shutdown during access, writing in FRAM is completed by the charges stored in a smoothing capacitor on the transponder LSI and FRAM data writing error is prevented. In such case, when the RF clock stops, writing operation cannot be completed. Therefore, in the case of reader/writer power supply shutdown, customers are requested to reduce RF power for 10usec.

In addition, all the transmitted data cannot be protected against power shutdown. Customers are requested to confirm by READ command that the normal data are written after execution of WRITE command.

2Kbytes		Data	
Block #	Page #	Functional Area	
#00h	#0000h	Operation Control Area (1)	
↓	#0001h	Operation Control Area (2)	
↓	#0002h	User ID / Application ID (1)	
↓	#0003h	User ID / Application ID (2)	
↓	#0004h	Device Serial Number (1)	System Area
↓	#0005h	Device Serial Number (2)	
↓	#0006h	Reserved for Future Use (1)	
↓	#0007h	Reserved for Future Use (2)	
#01h	#0008h	Write Access Control Area (1)	
↓	#0009h	Write Access Control Area (2)	
↓	↓	↓	
↓	#000Eh	Write Access Control Area (7)	
↓	#000Fh	Write Access Control Area (8)	↑
#02h	#0010h	User Area	↓
↓	#0011h	User Area	User Area
(126 blocks) ↓	2016 bytes (1008 pages) ↓	User Area ↓	
#7Fh	#03FDh	User Area	
↓	#03FEh	User Area	
↓	#03FFh	User Area	

Figure 6-2: FRAM memory map

Bit #	Operational Control Area
#0h	Data Rate (00:105.9375kbps, else:211.875kbps,)
#1h	
#2h	RFU (0)
#3h	RFU (1)
↓	↓
#7h	RFU (5)
#9h	Not Used
↓	↓
#Fh	Not Used

Figure 6-3: Configuration of Operational Control Area

Page #	Bit #	Area Assigned for Write Prohibit
#0008h	#0h (LSB)	#00h
↓	#1h	#01h
↓	↓	↓
↓	#Eh	#0Eh
↓	#Fh (MSB)	#0Fh
#0009h	#0h (LSB)	#10h
↓	#1h	#11h
↓	↓	↓
#000Fh	#Eh	#7Eh
↓	#Fh (MSB)	#7Fh

Figure 6-4: Configuration of Write Access Control Area

7 Command

A list of reader/writer commands and transponder messages are shown in Appendix 2. In this section, operations of the transponder are explained in detail for each command. Prior to that, the basic ideas of anticollision and System Area access are depicted.

The reader/writer transmits REQA or REQC command to read ID from plural cards. The card that has normally received the command returns ATQ signal. There is no logical limitation to the number of accessible transponders. However, longer time is required to complete anticollision sequence for more transponders. In actual use, 4 transponders are processed at maximum. In the case where the coils of the transponders overlap one another, communication distance is seriously affected, which might disable communication depending on the coil shape. During HALT status transponders respond to REQC command, while they don't respond to REQA command. In case anticollision sequence is not required, REQB command is transmitted and the card normally received the command returns ATQ signal in the same way as REQA and REQC.

After receiving SELECT command, the card checks CRC and the device serial number. If abnormality is detected, no response is given. The commands having different device serial numbers are regarded as messages to different transponders that exist in the same transmission/reception area and no response is given so as not to disturb the communication. In the case of CRC abnormality, as the device serial number cannot be specified, no response is given. Even if the device serial number matches, no response is given when the status is unmatched or command syntax is abnormal.

The access to FRAM system area is limited by command and status. The accesses to the system area are shown in Table 7-1. As shown in the figure, writing to the system area is allowed only for the Write Access Control Area. In such case, Write command is effective only in the HALT status.

Function page	Read command	Internal read command	Write command
Operational Control Area	(Not Allowed)	REFRESH	(Not Allowed)
User ID/Application ID	(Not Allowed)	REFRESH	(Not Allowed)
Device Serial Number	REQA/REQB/REQC	REFRESH	(Not Allowed)
Write Access Control Area	SELECT	REFRESH	WRITE (In HALT status only)

Table 7-1 Access to System Area

(1) REQA

The reader/writer transmits a command and User and Application ID. When the command is normally received, the transponder transmits ATQ (Answer to Request) signal that includes a device serial number equivalent to unique ID.

<Reader/writer -> transponder>

Command (REQA)	User & Application ID	CRC
1B (05h)	4B	2B

<Transponder -> Reader/writer>

(Normal: ATQ)

Device Serial Number	CRC
4B	2B

(Abnormal: No response)

① CRC nonconformity

② Command nonconformity

③ Unmatched status

④ Unmatched User and Application ID

(2) REQB

The reader/writer transmits a command and User and Application ID in the same manner as for REQA. When the command is normally received, the transponder transmits ATQ (Answer to Request) signal that includes a device serial number equivalent to unique ID.

<Reader/writer -> Transponder>

Command (REQB)	User & Application ID	CRC
1B (0Ah)	4B	2B

<Transponder -> Reader/writer>

(Normal: ATQ)

Device Serial Number	CRC
4B	2B

(Abnormal: No response)

① CRC nonconformity

② Command nonconformity

③ Unmatched status

④ Unmatched User and Application ID

(3) REQC

In the same way as REQC the reader/writer transmits a command and User and Application ID. When the command is normally received, the transponder transmits ATQ (Answer to Request) signal that includes a device serial number equivalent to unique ID.

<Reader/writer -> transponder>

Command (REQC)	User & Application ID	CRC
1B (06h)	4B	2B

<Transponder -> Reader/writer>

(Normal: ATQ)

Device Serial Number	CRC
4B	2B

(Abnormal: No response)

⑤ CRC nonconformity

⑥ Command nonconformity

⑦ Unmatched status

⑧ Unmatched User and Application ID

(4) SELECT

When the reader/writer receives normal unique ID from the transponder, it transmits SELECT command that includes the unique ID. When the transponder receives normal SELECT command, it transmits ATS message. The ATS message transmits the content of Write Access Control Area which indicates the write access information of FRAM. To check the write access status of FRAM, use this command.

<READER/WRITER -> TRANSPONDER>

Command (SELECT)	Device Serial Number	CRC
1B (1Dh)	4B	2B

<Transponder -> Reader/writer>

(Normal: ATS)

ATS Message	CRC
16B	2B

(Abnormal: No response)

① CRC nonconformity

② Unmatched device serial number

③ Command nonconformity

④ Status nonconformity

(5) READ

The transponder that received REQA command, completed ATS message transmission, or received REQB command and transmitted ATQ message is put in the ACTIVE status in Figure 5-1, and the six types of application commands shown in Table A-1 can be executed.

READ command reads the data of the Page Length from the head of the page assigned by the Page Number, in regard to the transponder assigned by the device serial number. The Page Length can be assigned by 1 at minimum to 8 at maximum and is expressed by binary notation as the Page Number. The transponder that received normal READ command reads the information stored in the FRAM in the order of data length, data, CRC.

<Reader/writer -> Transponder>

Command (READ)	Device Serial Number	Page #	Page Length	Data	CRC
1B (D0h)	4B	2B	1B	1B	2B

<Transponder -> Reader/writer>

(Normal: DATA)

Length	Data	CRC
1B	2 to 16B	2B

(Abnormal: No response)

① CRC nonconformity

② Unmatched device serial number

③ Unmatched command

④ Status nonconformity

⑤ Page Number nonconformity (Not of System Area or larger than #03FFh)

⑥ Page Length nonconformity (Number other than #1h to #8h)

(6) WRITE

WRITE command is for writing the data subsequently transmitted to the FRAM of the Page Length from the head of the page assigned by the Page Number, in regard to the transponder assigned by the device serial number. The Page Length can be assigned by 1 at minimum to 8 at maximum and is expressed by binary notation as the Page Number. Prior to executing the WRITE command, the transponder checks;

1) Whether the status is normal for the access to the assigned page,
2) Whether WRITE accessible to the assigned page, and
3) Whether both blocks are WRITE accessible when the assigned block length is over two blocks.

As stated, writing to the Write Access Control Area is performed only in the HALT status, and writing to the User Area is assigned by the Write Access Control Area. When the Write Access Area is over two blocks, writing is performed when the both blocks are accessible. For example, when the Page Number is not at the head of the block and the Page Length is 8, the Write access blocks is over the two areas. In such case, writing is performed when the both block are accessible.

The transponder that received normal WRITE command and completed writing to FRAM transmits ACK message. The ACK message from the transponder by the WRITE command indicates the completion of writing operation. Note that verification of the written data is not performed. Verify the written data by using the READ command.

<Reader/writer -> Transponder>

Command (WRITE)	Device Serial Number	Page #	Page Length	Data	CRC
1B (D1h)	4B	2B	1B	xB	2B

<Transponder -> Reader/writer>

(Normal: ACK)

ACK	CRC
1B(3Fh)	2B

(Abnormal: No response)

① CRC nonconformity
② Unmatched device serial number
③ Command nonconformity
④ Status nonconformity
⑤ Page Number nonconformity (greater than #03FFh, not of User Area at ACTIVE status, or other than Write Access Control Area at HALT status.)
⑥ Assigned page not Write accessible.
⑦ Page Length nonconformity (Number other than #1h to #8h)
⑧ Unmatched Page Length with data length transmitted.

(7) ADD

ADD command is for adding and writing the data of two pages subsequently transmitted to FRAM data of two pages from the page specified by Page Number.

Page Length is fixed to two pages and is not transmitted from Reader/Writer.

Prior to executing the ADD command, the transponder checks;

1) Whether the status is normal,
2) Whether Write is accessible to the assigned page, and
3) Whether both blocks are WRITE accessible when the assigned block length is over two blocks.

In the same way as WRITE command, when the Write Access Area is over two blocks, writing is performed when the both blocks are accessible.

The transponder that received normal ADD command and completed the write to FRAM transmits Data message indicating the result of addition.

Check the addition result with response message since the result is not checked for overflow.

<Reader/Writer -> Transponder>

Command (ADD)	Device Serial Number	Page #	Data	CRC
1B (D6h)	4B	2B	4B	2B

<Transponder -> Reader/Writer>

(Normal: DATA)

Length	Data	CRC
1B	4B	2B

(Abnormal: No response)

① CRC nonconformity
② Unmatched device serial number
③ Unmatched command
④ Status nonconformity
⑤ Data Length nonconformity (Not four bytes)
⑥ Page Number nonconformity (Not of System Area or larger than #03FFh)
⑦ Assigned page not Write accessible

(8) HALT

HALT command changes the transponder specified by device serial number to HALT status. The transponder that received normal HALT command transmits ACK message. The transfer from HALT status to ACTIVE status is performed by WAKEUP command.

<Transponder -> Reader/Writer>

Command (HALT)	Device Serial Number	CRC
1B (50h)	4B	2B

<Transponder -> Reader/Writer>

(Normal: DATA)

ACK	CRC
1B (3Fh)	2B

(Abnormal: No response)

① CRC nonconformity

② Unmatched device serial number

③ Unmatched command

④ Status nonconformity

(9) FILL

FILL command is for writing the two-byte data subsequently transmitted to the FRAM of the Page Length from the head of the page assigned by the Page Number, in regard to the transponder assigned by the device serial number.

Page Number and Page Length are both expressed in two-bytes by binary notation and all blocks in FRAM can be expressed.

Prior to executing the FILL command, the transponder checks;

1) Whether the status is normal,
2) Whether the assigned page is Write accessible, and
3) Whether the assigned block length is over user area.

Note that FILL command writes into FRAM even if there is the block for which WRITE access is prohibited.

The transponder that received normal FILL command and completed writing to FRAM transmits ACK message. The ACK message from the transponder after FILL command indicates the completion of writing operation. Note that verification of the written data is not performed. Verify the written data by using the READ command.

<Reader/Writer -> Transponder>

Command (FILL)	Device Serial Number	Page #	Page Length	Data	CRC
1B (D4h)	4B	2B	2B	2B	2B

<Transponder -> Reader/Writer>

(Normal: ACK)

ACK	CRC
1B (3Fh)	2B

(Abnormal: No response)

① CRC nonconformity

② Unmatched device serial number

③ Unmatched command

④ Status nonconformity

⑤ Data length nonconformity (not two bytes)

⑥ Page Length nonconformity (number larger than #03F0h pages)

⑦ Page Number nonconformity (Not of System Area or larger than #03FFh)

⑧ Initial Page disable to be Write-accessed.

⑨ Whether address area is larger than #03FFh.

(10) REFRESH

REFRESH command is for reading all the data of FRAM and re-writing them, in regard to the transponder assigned by the device serial number.

As REFRESH command is test program improving the characteristics of FRAM data storage, the command is not used for the actual application but used under the conditions that RF power supply is secured.

The transponder that received normal REFRESH command transmits ACK message after REFRESH operation is completed. Note that it requires 28 msec by the time the transponder responds after execution of REFRESH command in 105.9375 kbps data rate, while 14 msec in 211.875 kbps data rate.

<Reader/Writer -> Transponder>

Command (REFRESH)	Device Serial Number	CRC
1B (53h)	4B	2B

<Transponder -> Reader/Writer>

(Normal: DATA)

ACK	CRC
1B (3Fh)	2B

(Abnormal: No response)

① CRC nonconformity

② Unmatched device serial number

③ Command nonconformity

④ Status nonconformity

(11) WAKEUP

WAKEUP command changes the transponder specified by device serial number to ACTIVE status. The transponder that received normal WAKEUP command transmits ACK message.

<Transponder -> Reader/Writer>

Command (WAKEUP)	Device Serial Number	CRC
1B (59h)	4B	2B

<Transponder -> Reader/Writer>

(Normal: DATA)

ACK	CRC
1B (3Fh)	2B

(Abnormal: No response)

① CRC nonconformity

② Unmatched device serial number

③ Command nonconformity

④ Status nonconformity

8 Target Electrical Characteristics

The following tables describe Absolute maximum ratings, recommended operating conditions, and Electric characteristics of Babyface2 LSI.

Parameter	Symbol	min.	typ.	max.	unit	Conditions
Maximum Antenna Input Voltage	Vpmax	—	—	20	Vpp	PWRP-PWRM
Maximum Antenna Input Current	Imax	—	—	60	mApp	PWRP-PWRM
Maximum Voltage	Vmax	—	—	6.5	V	VDD-GND
ESD voltage immunity	V_{ESD}	±2k	—	—	V	Human body model
Storage Temperature	Tstg	-40	—	85	degC	

Table 8-1: Absolute Maximum Ratings

Parameter	Symbol	min.	typ.	max.	unit	Conditions
Maximum Antenna Input Voltage	Vpm	—	16	20	Vpp	PWRP-PWRM
Maximum Antenna Input Current	Ipm	—	—	25	mA(rms)	PWRP-PWRM
Operating Temperature	Ta	-10	—	70	degC	
Supply Voltage	Vdd	5.0	5.2	5.4	V	During voltage control
Minimum OFF Time	Toff	100	—	—	Usec	Time of RF power OFF
Waiting Time for Reception	Trw	1.5	—	—	Msec	Time for initialization

Table 8-2: Recommended Operating conditions

Parameter	Symbol	min.	typ.	max.	unit	Conditions
AC Characteristics						
Input Clock Frequency	Fclk	13.553	13.56	13.567	MHz	
Resonance Capacitor	Cres	18.5	20	21.5	pF	
Current consumption	Idd	—	600	800	uA	
Clock min. detection voltage	Vclk	10	—	—	Vpp	PWRM-PWRP
Reset voltage (At Power ON)	Vrst1	4.3	4.5	4.7	V	VDD-GND
Reset voltage (At Power OFF)	Vrst2	2.8	3.0	3.2	V	VDD-GND
ASK Modulator						
ASK Modulation index	mdem	8	10	14	%	
Data Rate	Fdem		105.9375		kbps	At 105.9375kbps
			211.875		kbps	At 211.875kbps
Start up/down transition time	tr/tf			2	Usec	Fdem=105.9375kbps
Start up/down transition time	tr/tf			1	usec	Fdem=211.875kbps
PSK Modulator						
Load Modulation Resistance	Rmod	3.20	4.27	5.34	kohm	
Data Rate	fmod		105.9375		kbps	At 105.9375kbps
			211.875		kbps	At 211.875kbps
FRAM						
Data Retention	tret	10	—	—	years	Ta=55degC
Write Endurance	Nwrite	10^{10}	—	—	cycles	

Table 8-3: Electrical Characteristics

9 Mounting Conditions

To maintain the FRAM data retention characteristics, please mount the chip at the conditions shown in Figure 9-1 to 9-4.

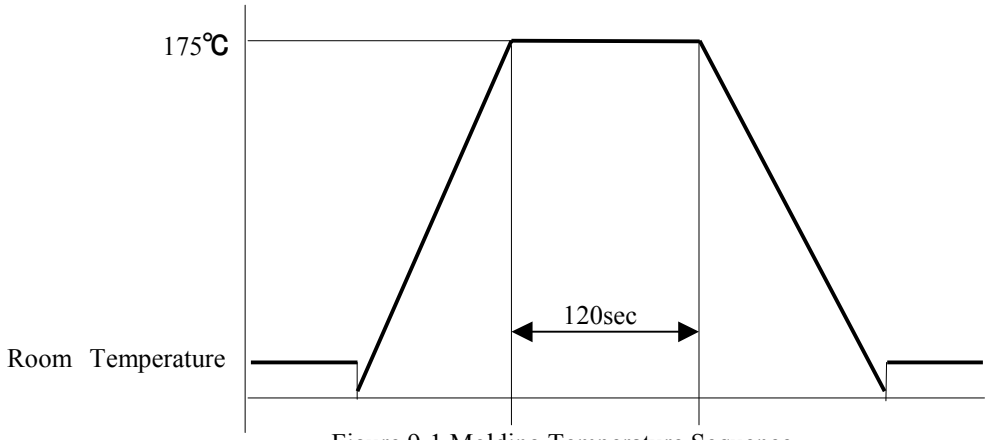


Figure 9-1 Molding Temperature Sequence

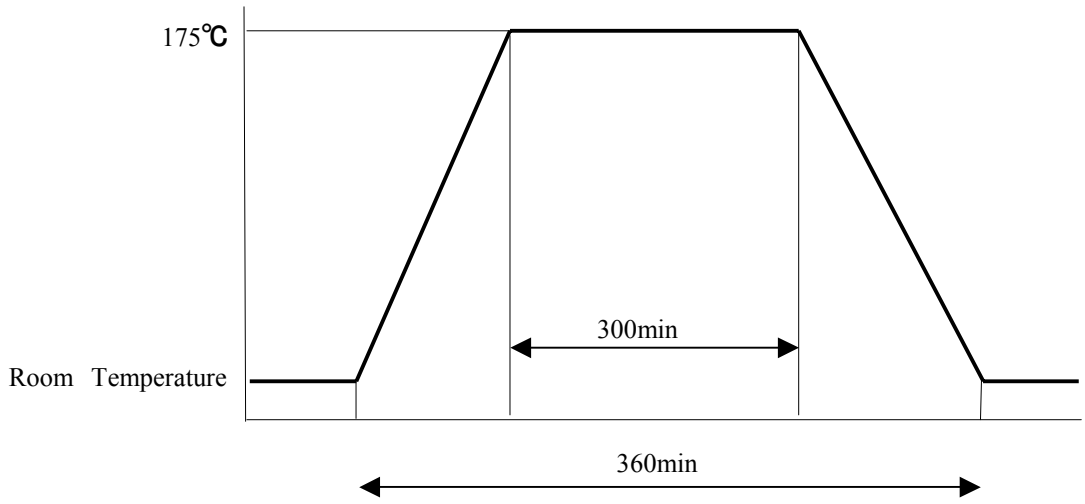


Figure 9-2 Mold Cure Temperature Sequence

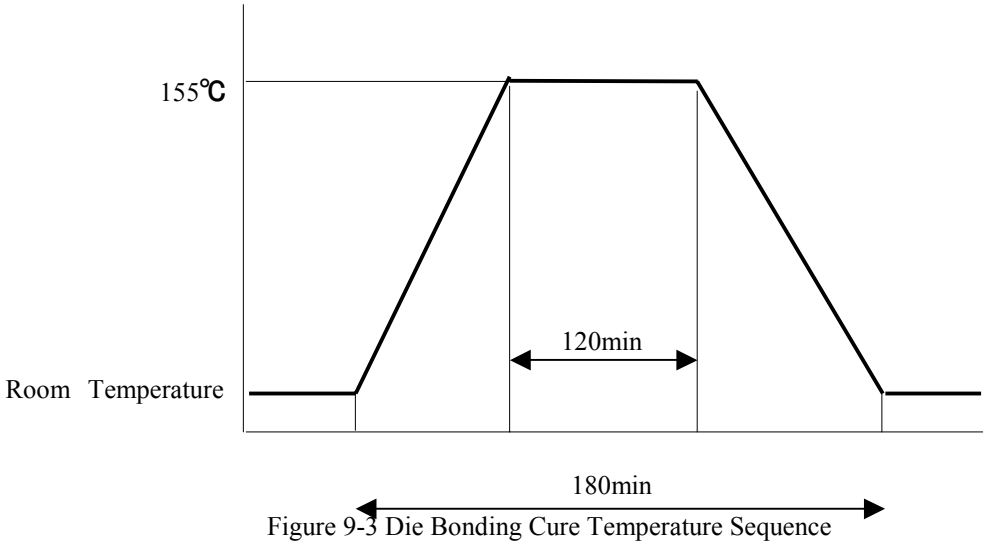


Figure 9-3 Die Bonding Cure Temperature Sequence

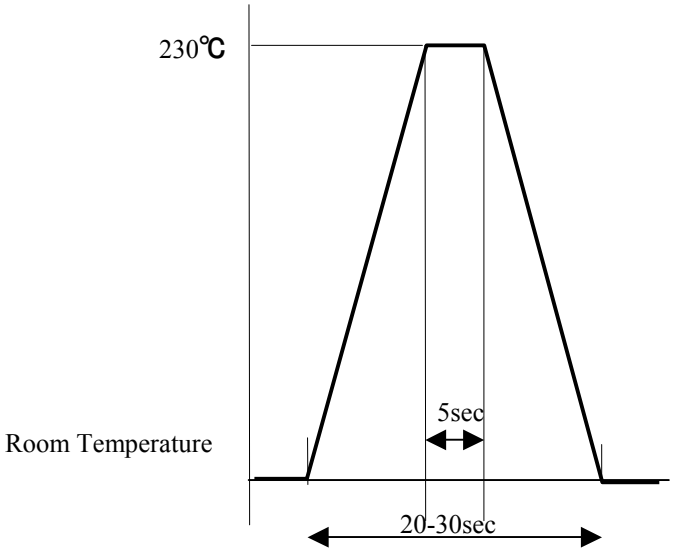


Figure 9-4 Wire Bonding Temperature Sequence

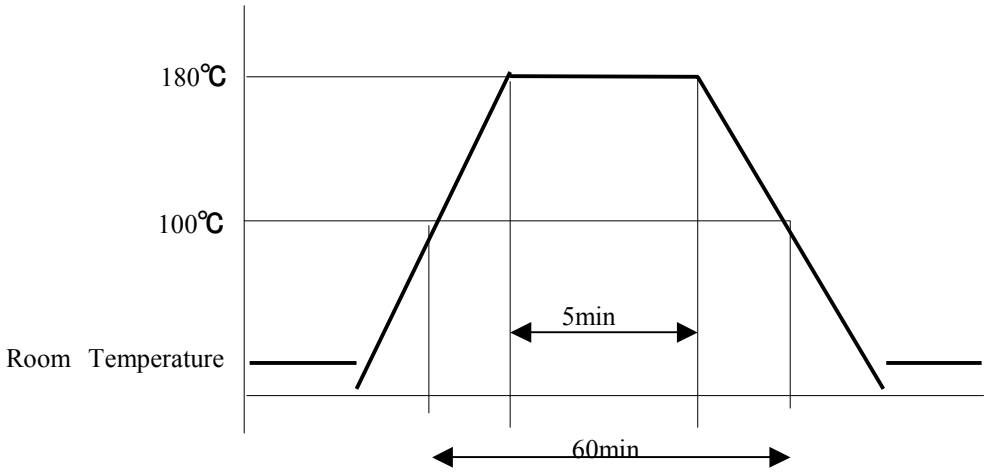


Figure 9-5 Card Assembly Temperature Sequence

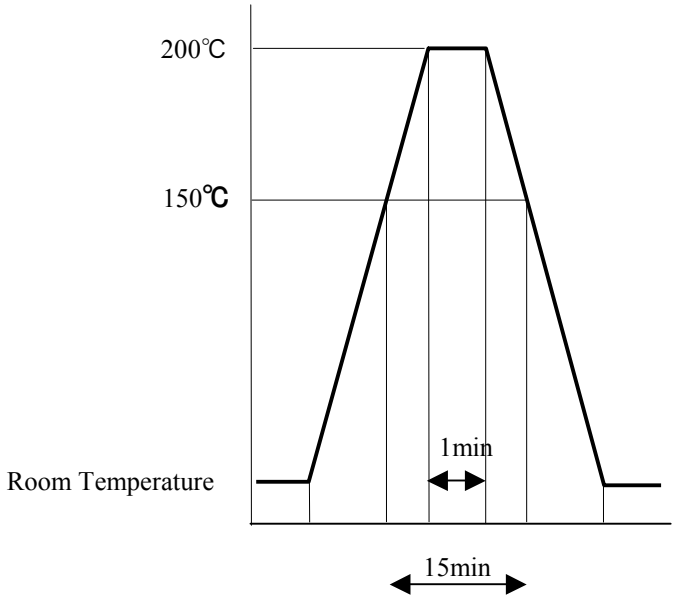


Figure 9-6 Chip Assemblies with ACF Temperature Sequence

10 Block Diagram

Block diagram of Babyface2 LSI is presented in Figure 10-1.

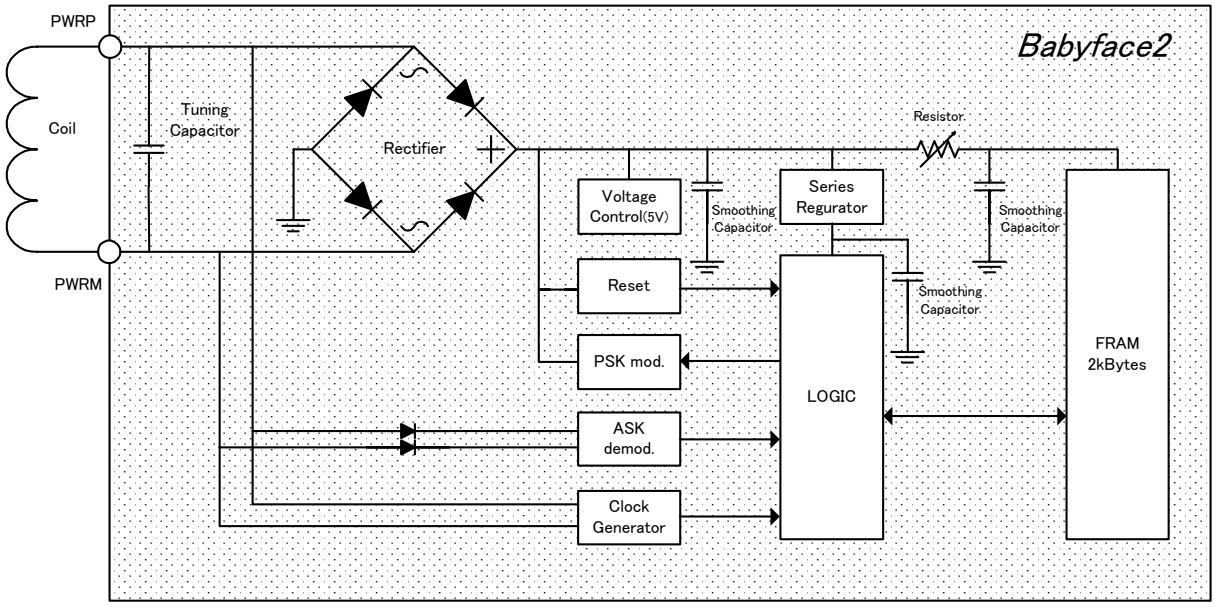
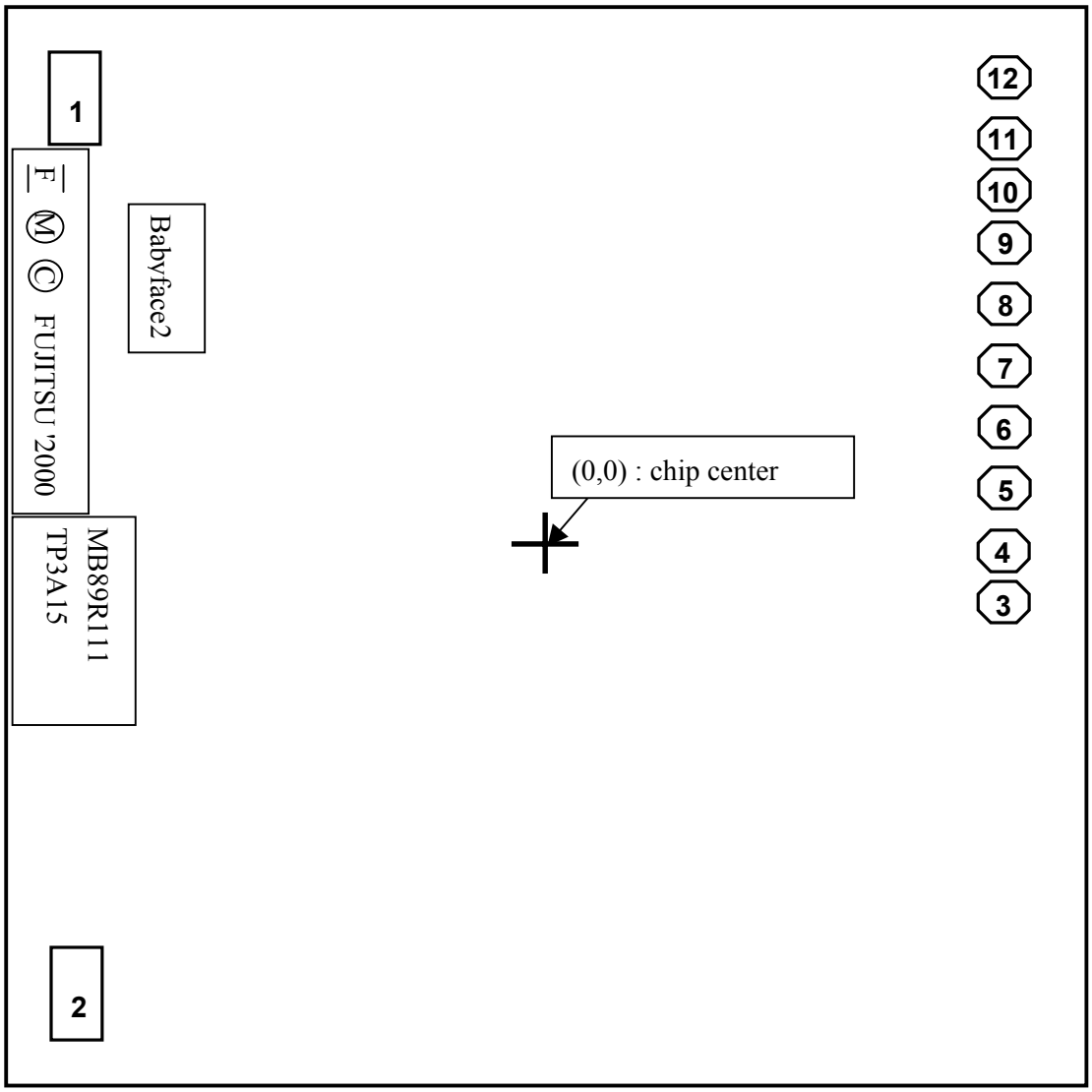


Figure 10-1: Block diagram

11 Pad Layout

Pad layout of Babyface2 LSI is presented in Figure 11-1.



Chip size : 2.50 x 2.50 [mm]

Pad No.	Pin Name	Pad Location [□m]		Pad Size	Pad No.	Pin Name	Pad Location [□m]		Pad Size
		x	y	[□mx□m]			x	y	[□mx□m]
1	PWRM *1)	-1087	1035	100x200	7	Test4	1059	417	110x88
2	PWRP *1)	-1087	-1035	100x200	8	Test5	1059	560	110x88
3	VDD	1059	-132	110x88	9	Test6	1059	702	110x88
4	Test1	1059	-10	110x88	10	GND	1059	823	110x88
5	Test2	1059	132	110x88	11	Test7	1059	945	110x88
6	Test3	1059	275	110x88	12	Test8	1059	1087	110x88

*1) Antenna Pin

Figure 11-1: Pad layout

12 Wafer Shipping Specification

12.1 Wafer Conditions

Material: Si

Diameter : 150mm（6inch）

Thickness : 625μm±30μm

Back wrap: none

Surface Passivation: SiN +Polyimide

Pad material: Al-Cu

12.2 Number of Dies per Wafer

Number of Dies :2294 dies

12.3 Scribe Line Width

X: 90um

Y: 90um

12.4 Die Stepping Width

X: 2500um

Y: 2500um

12.5 Pad Size

2 kinds of pad format exist as shown in Figure 12-1 and 12-2. The shape of Antenna pads is longer than that of other pads.

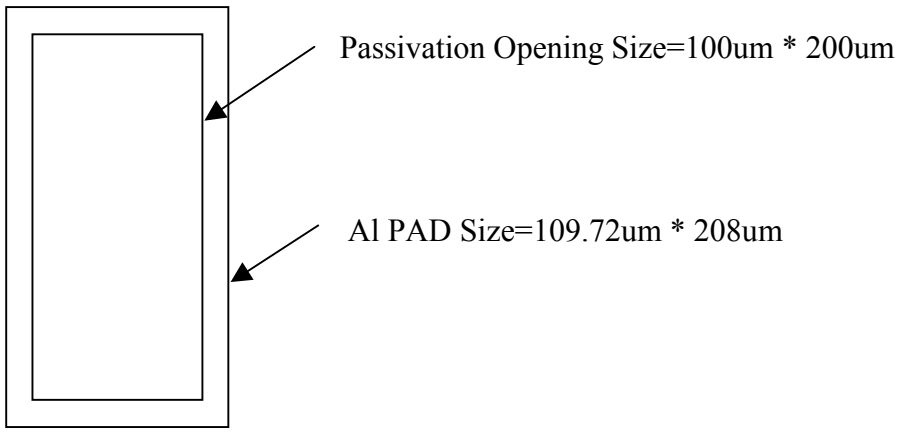


Figure 12-1.PWRP and PWRM PAD for Antenna Terminal

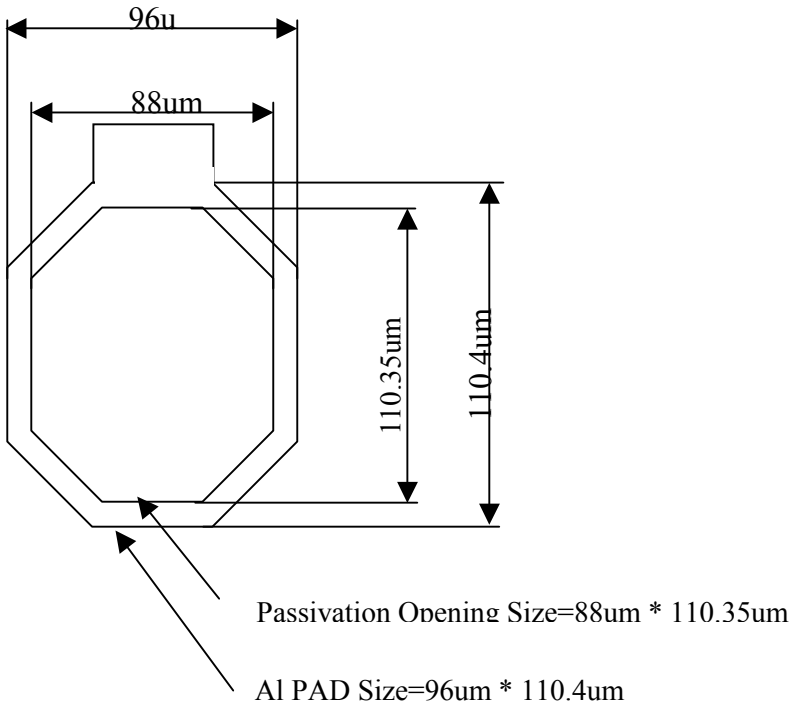


Figure 12-2.Other PAD for Internal Test

12.6 Wire Bonding or Stud Bump

The pads excepting Antenna pad（PWRM, PWRP）and VDD shall not be connected. VDD pad is electrically connected internally, and it shall be used for supporting chip when stud bump is used. VDD pad shall not be connected with antenna pad.

12.7 Ink Mark

Ink mark indicates the failure die, which is marked at the test process. The specification of ink mark is as follows.

Diameter: Minimum 0.2mm

Maximum 1.6mm

Location: Center of Die

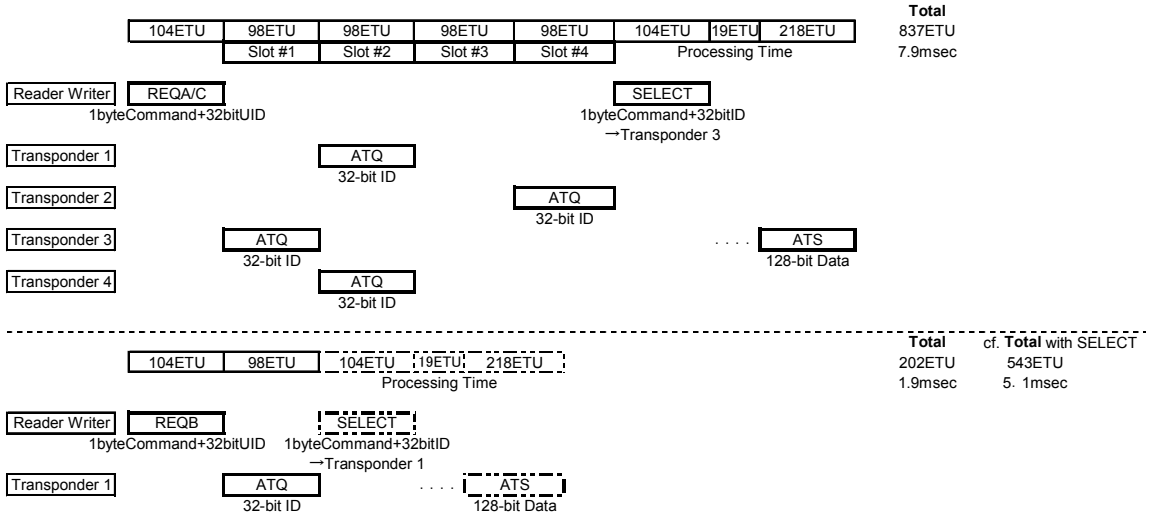
Color: Black

13 Wafer Delivery Specification

The specification of wafer delivery follows to the Fujitsu standard delivery specification. Please refer to the specification document, which is provided separately.

Appendix 1: Anticollision Algorithm

for Data rate fb=105.9375kbps (1ETU = 9.4395usec)

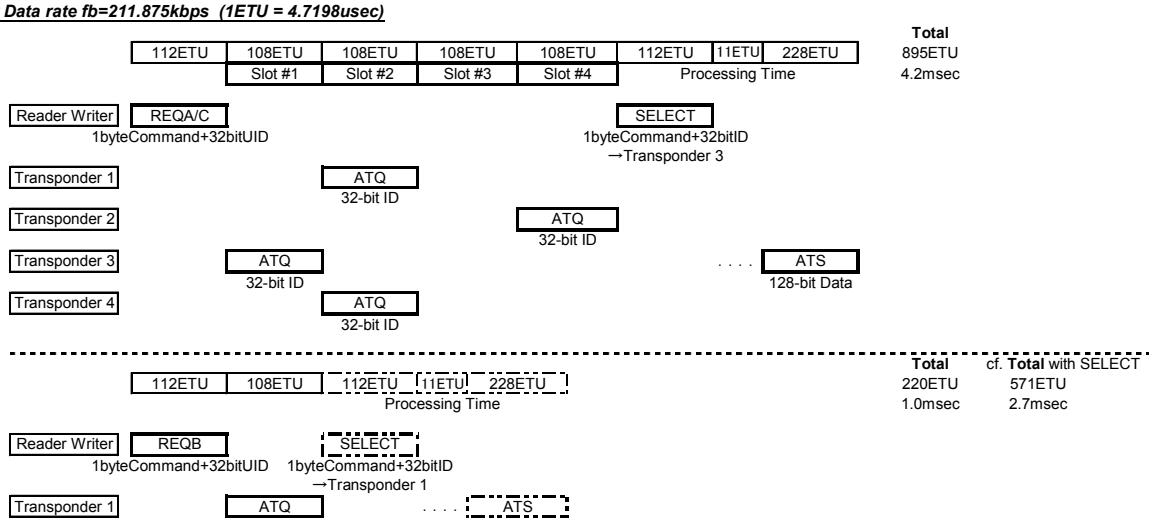


REQA/B/C & SELECT (104ETU)			
SOF	Command	EOF	Guard Time
8bits+32bit ID+16bit CRC			TR0
14ETU	70ETU	12ETU	8ETU

ATQ (98ETU)				
Unmodulated	SOF	Unique ID	EOF	Guard Time
TR1		32bit+16bitCRC		
10ETU	14ETU	60ETU	12ETU	2ETU

ATS (218ETU)				
Unmodulated	SOF	Unique ID	EOF	Guard Time
TR1		128bit+16bitCRC		
10ETU	14ETU	180ETU	12ETU	2ETU

for Data rate fb=211.875kbps (1ETU = 4.7198usec)



Appendix 2: Commands and Responses

Command from Reader/Writer to Transponder

State	Command (data)	Command Sequence (byte length for each transferred data)						Estimated Time fb:105.9375kbps		Estimated Time fb:211.875kbps		Command Description
IDLE	REQA	Command	User&Appl ID	CRC				0.98	ms	0.53	ms	Broadcasting
	(05h)	1	4	2				104	ETU	112	ETU	
	REQB	Command	User&Appl ID	CRC				0.98	ms	0.53	ms	Broadcasting
	(0Ah)	1	4	2				104	ETU	112	ETU	
	REQC	Command	User&Appl ID	CRC				0.98	ms	0.53	ms	Broadcasting
	(06h)	1	4	2				104	ETU	112	ETU	
READY	SELECT	Command	DSN*	CRC				0.98	ms	0.53	ms	*DSN=Device Serial Number
	(1Dh)	1	4	2				104	ETU	112	ETU	
ACTIVE	READ	Command	DSN*	Page #	Page Length	CRC		1.26	ms	0.67	ms	Maximum Data Length :16byte
	(D0h)	1	4	2	1	2		134	ETU	142	ETU	
	WRITE	Command	DSN*	Page #	Page Length	Data	CRC	2.78	ms	1.43	ms	Maximum Data Length :16byte
	(D1h)	1	4	2	1	16	2	294	ETU	302	ETU	(Except for Write Access Control Area)
	ADD	Command	DSN*	Page #	Data	CRC		1.55	ms	0.81	ms	Data Length :4byte (fixed)
	(D6h)	1	4	2	4	2		164	ETU	172	ETU	FRAM data = Original + Transmitted data
	HALT	Command	DSN*	CRC				0.98	ms	0.53	ms	Dectivated till Wake-up command come
	(50h)	1	4	2				104	ETU	112	ETU	
	FILL	Command	DSN*	Page #	Page Length	Data	CRC	1.55	ms	0.81	ms	Data Length :2byte (fixed)
	(D4h)	1	4	2	2	2	2	164	ETU	172	ETU	
	REFRESH	Command	DSN*	CRC				0.98	ms	0.53	ms	Reflesh all FRAM data through Readout
	(53h)	1	4	2				104	ETU	112	ETU	
HALT	WRITE	Command	DSN*	Page #	Page Length	Data	CRC	2.78	ms	1.43	ms	Maximum Data Length :16byte
	(D1h)	1	4	2	1	16	2	294	ETU	302	ETU	(Write Access Control Area Only)
	WAKEUP	Command	DSN*	CRC				0.98	ms	0.53	ms	Activate Halted Transponder
	(59h)	1	4	2				104	ETU	112	ETU	

Response from Transponder to Reader/Writer

State	Message (data)	Data Sequence (byte length for each transferred data)						Estimated Time fb:105.9375kbps		Estimated Time fb:211.875kbps		Message Description
IDLE	ATQ	DSN*	CRC					0.93	ms	0.51	ms	Slotted ALOHA
	(DSN)	4	2					98	ETU	108	ETU	
READY	ATS	ATS message**	CRC					2.06	ms	1.08	ms	**ATS message: Contents of
	(Write Access)	16	2					218	ETU	228	ETU	Write Access Control Area
ACTIVE	DATA	Length	Data	CRC				2.15	ms	1.12	ms	Maximum Length :16byte
	(-)	1	16	2				228	ETU	238	ETU	
	ACK	ACK	CRC					0.64	ms	0.37	ms	
	(3Fh)	1	2					68	ETU	78	ETU	