

ASSP

FeRAM Embedded UHF Band RFID LSI

For Battery-less Solution

MB97R8110

■ 1. OVERVIEW

This document provides LSI specifications for the passive RFID Tag LSI "MB97R8110" (USER bank 8kBytes) based on "EPCglobal Class 1 Generation 2 Ver.1.2.0".

In this specification, the term "interrogator" used in EPCglobal standard is described as R/W (reader/writer). The term "Tag" is used as is.

■ 1.1 FEATURES

- Compliant with EPCglobal Class 1 Generation 2 (C1G2)
 - Carrier frequency: 860 to 960 MHz
 - Data rate
 - R/W → Tag: 26.7 kbps to 128 kbps (assuming equiprobable data)
 - Tag → R/W: 40 kbps to 640 kbps
 - RF Generated Power supply to external devices (3.0V 600uA output from +8dBm RF input)
 - Serial Interface (SPI)
 - Slave mode operation : USER memory area can be read/written through SPI.
 - Master mode operation : External SPI slave device can be controlled through SPI.
 - Arbitration feature between RF and SPI access controlled by SPIREQ and SPIACK.
 - Key Matrix Scan Interface
 - FeRAM: Non-volatile memory with High speed read and write
 - USER bank size: 61,440 bits*
 - EPC length: up to 480bits
 - BlockPermalock: 8 Areas of USER bank to be write-protected in units of 512 words (=8,192bits).
 - Read/Write Endurance: 10^{13} times.
 - Memory data retention: 10 years (+85 °C)
- *In SPI Master communication, 28,672bits of memory can be allocated for the buffer of data to be transferred to external slave device and the storage of response data from external SPI slave device.

Fujitsu Semiconductor Memory Solutions Limited has changed its name to RAMXEED Limited.
RAMXEED Limited will continue to offer and support existing products while maintaining Fujitsu's part number unchanged.

■ 1.2 BLOCK DIAGRAM

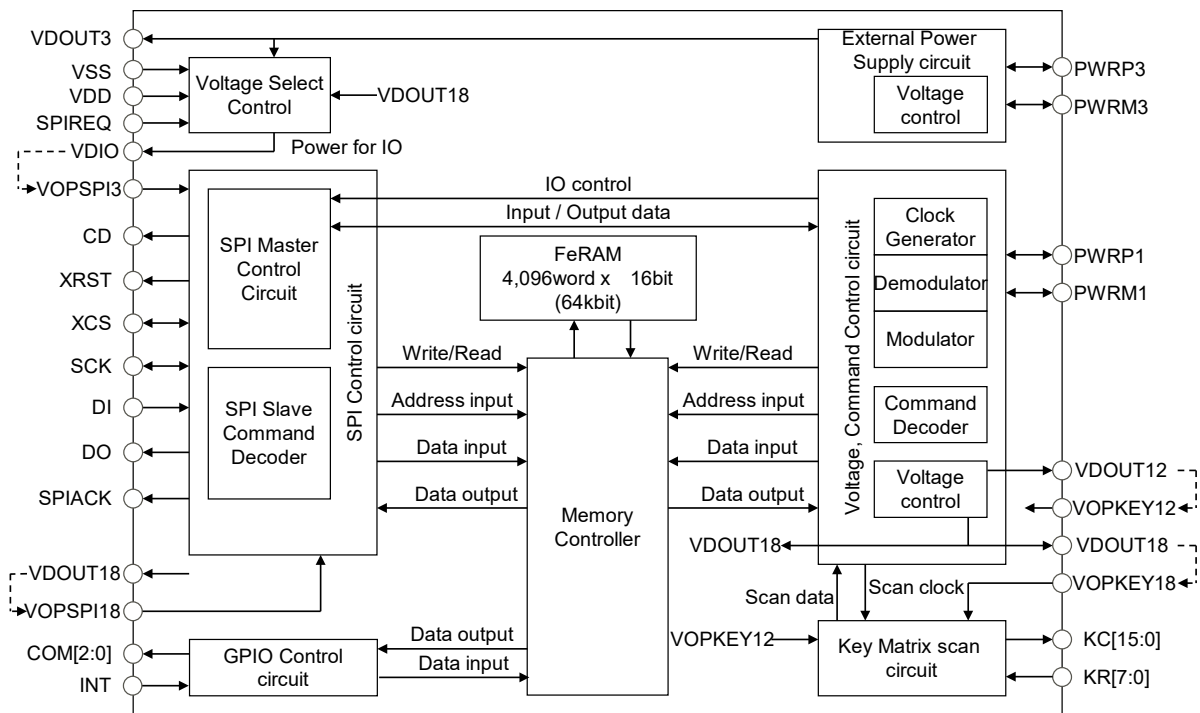


Figure 1.2 - BLOCK DIAGRAM

■ 1.3 PAD CONFIGURATION

■ 1.3.1 Pad Layout

Figure 1.3.1 shows PAD Layout.

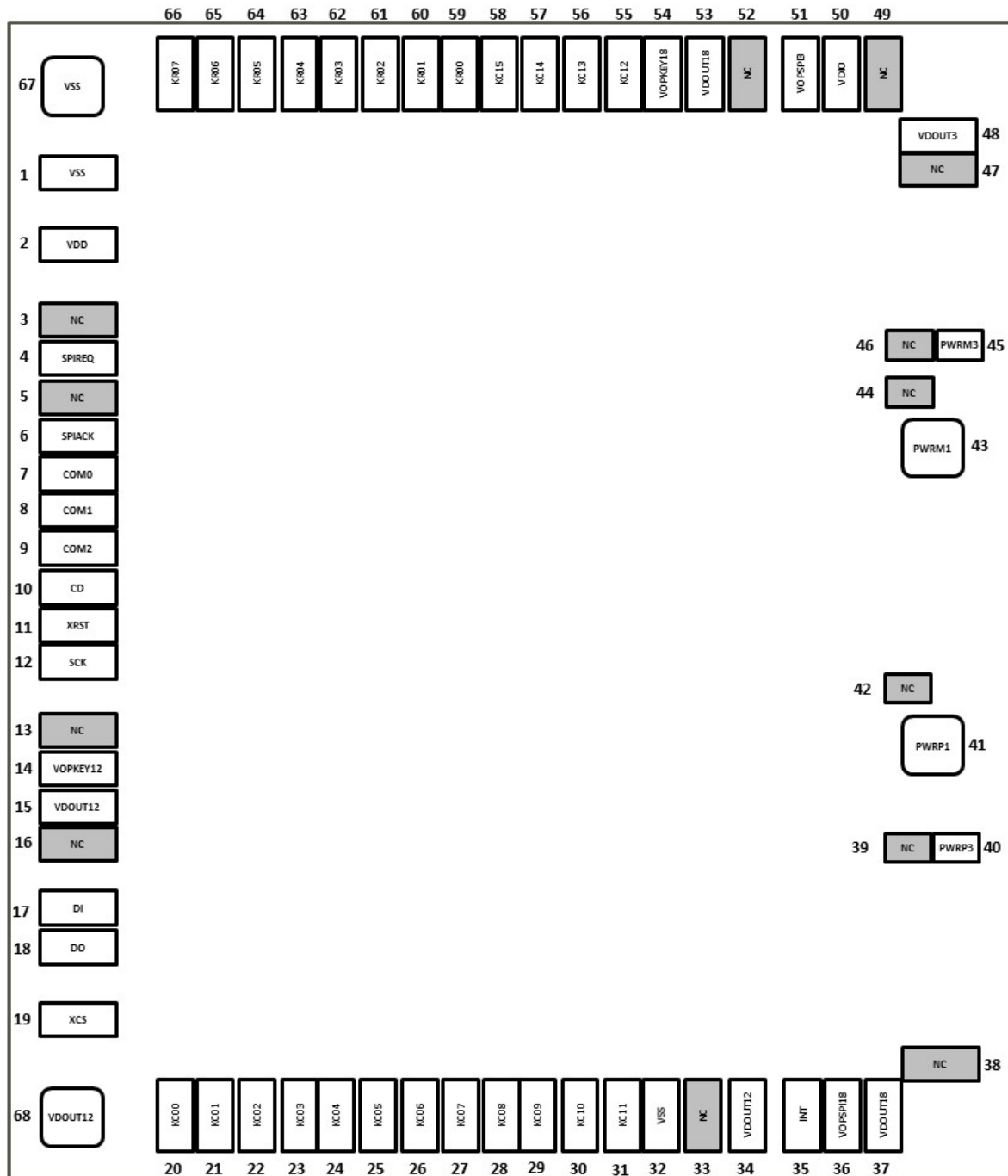


Figure 1.3.1 Pad Layout

■ 1.3.2 Pad Information

Table 1.3.2.1 shows PAD configuration and Power source. Table 1.3.2.2, 1.3.2.3 and Table 1.3.2.4 show Pad status of SPI, GPIO and Key Matrix scan respectively depending on the condition.

Table 1.3.2.1 Pad configuration and Power source

Pad Name	In / Out	Power Source	Terminal	Function Description
1 VSS	VSS	-	-	Ground
2 VDD	In (Power)	-	-	External power input for SPI Slave communication (3V)
3 NC	-	-	-	Open
4 SPIREQ	In	VOPSPI3	Pull Down(1MΩ)	SPI Slave request input
5 NC	-	-	-	Open
6 SPIACK	Out	VOPSPI3	-	Response to SPI Slave request (SPI Status output)
7 COM0	Out	VOPSPI3	-	GPIO (register data output)
8 COM1	Out	VOPSPI3	-	GPIO (register data output)
9 COM2	Out	VOPSPI3	-	GPIO (register data output)
10 CD	Out	VOPSPI3	-	Command/Data output
11 XRST	Out	VOPSPI3	-	Reset output
12 SCK	In/Out	VOPSPI3	-	SPI Clock
13 NC	-	-	-	Open
14 VOPKEY12	In (Power)	-	Pull Down(6MΩ)	Power input for Key Matrix scan circuit (connect to pad15)
15 VDOUT12	Out (Power)	-	-	Internally generated power output (1.2V)
16 NC	-	-	-	Open
17 DI	In	VOPSPI3	-	SPI Data input
18 DO	Out	VOPSPI3	-	SPI Data output
19 XCS	In/Out	VOPSPI3	-	SPI Chip select
20 KC00	Out	VOPKEY18	-	Key Matrix scan pulse output
21 KC01	Out	VOPKEY18	-	Key Matrix scan pulse output
22 KC02	Out	VOPKEY18	-	Key Matrix scan pulse output
23 KC03	Out	VOPKEY18	-	Key Matrix scan pulse output
24 KC04	Out	VOPKEY18	-	Key Matrix scan pulse output
25 KC05	Out	VOPKEY18	-	Key Matrix scan pulse output
26 KC06	Out	VOPKEY18	-	Key Matrix scan pulse output
27 KC07	Out	VOPKEY18	-	Key Matrix scan pulse output
28 KC08	Out	VOPKEY18	-	Key Matrix scan pulse output
29 KC09	Out	VOPKEY18	-	Key Matrix scan pulse output
30 KC10	Out	VOPKEY18	-	Key Matrix scan pulse output
31 KC11	Out	VOPKEY18	-	Key Matrix scan pulse output
32 VSS	VSS	-	-	
33 NC	-	-	-	Open
34 VDOUT12	Out (Power)	-	-	Internally generated power output (for Internal circuit)
35 INT	In	-	-	GPIO (register data input)
36 VOPSPI18	In (Power)	-	Pull Down(6MΩ)	Power input for SPI and GPIO (connect to pad37)
37 VDOUT18	Out (Power)	-	-	Internally generated power output (for FeRAM)
38 NC	-	-	-	Open
39 NC	-	-	-	Open
40 PWRP3	In	-	-	Antenna pad for external power supply
41 PWRP1	In	-	-	Antenna pad for RF communication
42 NC	-	-	-	Open
43 PWRM1	In	-	-	Antenna pad for RF communication
44 NC	-	-	-	Open
45 PWRM3	In	-	-	Antenna pad for external power supply
46 NC	-	-	-	Open
47 NC	-	-	-	Open
48 VDOUT3	Out (Power)	-	-	Power output for external devices
49 NC	-	-	-	Open
50 VDIO	Out (Power)	-	-	IO Power output
51 VOPSPI3	In (Power)	VOPSPI3	Pull Down(6MΩ)	Power input for SPI and GPIO (connect to Pad50)
52 NC	-	-	-	Open
53 VDOUT18	Out (Power)	-	-	Internally generated power output (for FeRAM)
54 VOPKEY18	In (Power)	VOPKEY18	Pull Down(6MΩ)	Power input for Key Matrix scan circuit (connect to pad53)
55 KC12	Out	VOPKEY18	-	Key Matrix scan pulse output
56 KC13	Out	VOPKEY18	-	Key Matrix scan pulse output
57 KC14	Out	VOPKEY18	-	Key Matrix scan pulse output
58 KC15	Out	VOPKEY18	-	Key Matrix scan pulse output
59 KR00	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
60 KR01	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
61 KR02	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
62 KR03	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
63 KR04	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
64 KR05	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
65 KR06	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
66 KR07	In	VOPKEY18	Pull Down(150kΩ)	Key Matrix scan data input
67 VSS	VSS	-	-	
68 VDOUT12	Out (Power)	-	-	Internally generated power output (for Internal circuit)

Table 1.3.2.2 SPI pad status

PadName	Initial		SPI Master(En=0)		SPI Master(En=1)		SPI Slave	
	In/Out	Value	In/Out	Value	In/Out	Value	In/Out	Value
SPIREQ	In	—(PD)	In	0(PD)	In	0(PD)	In	1
SPIACK	Out	L	Out	L	Out	L	Out	H
XCS	In/Out	HiZ	Out	HiZ	Out	H/L	In	1/0
SCK	In/Out	HiZ	Out	HiZ	Out	L/H	In	0/1
DI	In	—	In	—	In	0/1	In	0/1
DO	Out	HiZ	Out	HiZ	Out	L/H/HiZ	Out	L/H/HiZ
XRST	Out	L	Out	L	Out	L/H	Out	—

*. The initial state is reset state. SPI Master is in the state of SPI=L. SPI slave is in the state of SPIACK=H. Refer to Chapter 7.1.1 for SPI master setting (En=0/1).

(Information in the table) 0/1 : Input value, L/H : Output value, PD : PullDown,
— : Invalid

Table 1.3.2.3 GPIO pad status

PadName	Initial		FuncEn=0		FuncEn=1	
	In/Out	Value	In/Out	Value	In/Out	Value
COM2-0	Out	HiZ	Out	HiZ	Out	L/H(ComDat)
INT	In	—	In	—	In	0/1

*. Refer to Chapter 7.2.1 for GPIO setting (FuncEn=0/1)

Table 1.3.2.4 Key Matrix scan pad status

PadName	Initial		KeyMatrixscanOff		KeyMatrixscanON	
	In/Out	Value	In/Out	Value	In/Out	Value
KC15-KC00	Out	HiZ	Out	HiZ	Out	HiZ/H
KR07-KR00	In	—(PD)	In	—(PD)	In	0(PD)/1

*. Refer to Chapter 7.3.1 for Key Matrix scan setting (Off/On).

■ 1.4 POWER SUPPLY

This operational power is internally generated from RF power. For extended feature other than RFID tag feature, such as SPI Master, SPI Slave, and Key Matrix scan, the optional power (VOPSPI3, VOPSPI18, VOPKEY18, VOPKEY12) will be provided by connecting the designated pads as shown in Table 1.4.

Table 1.4 Power generation

Extended Feature	Internal generated Power (Output pad)		Optional Power (Input pad)	
SPI Master	50	VDIO	51	VOPSPI3
	37	VDOUT18	36	VOPSPI18
SPI Slave	50	VDIO	51	VOPSPI3
	37	VDOUT18	36	VOPSPI18
Key Matrix Scan	15	VDOUT12	14	VOPKEY12
	53	VDOUT18	54	VOPKEY18

■ 2 RF INTERFACE

RF signal interface is compliant with EPCglobal Class 1 Generation 2 Ver.1.2.0.

■ 2.1 Modulation type, communications timing

Compliant with EPCglobal Class 1 Generation 2 Ver.1.2.0

■ 2.2 Inventory, Tag selection

Compliant with EPCglobal Class 1 Generation 2 Ver.1.2.0

■ 2.3 Tag state-transition

Compliant with EPCglobal Class 1 Generation 2 Ver.1.2.0

■ 2.4 RF communication Error code

This LSI replies error code if it encounters an error when executing a handle-based command under Open state or Secured state. Error code described in EPCglobal Class 1 Generation 2 Ver.1.2.0 (AnnexI) and a proprietary error code are supported as shown in Table2.4.

Table 2.4 Error code

Error code	Error code name	Error description
00h	Other errors	Other errors not covered by the following errors
03h	Memory overrun	The specified memory location does not exist.
04h	Memory locked	The specified memory location is locked or permalocked
0Bh	Insufficient power	Insufficient power to perform the operation ※1
8Eh	No detection of Keys ※2	No pressed key detected during the Key Matrix scan operation

※1. This error covers not only RF command operation but also extended application (refer to Chapter 7).

If the power is insufficient to backscatter, the LSI cannot reply error code,

※2. Proprietary Error code for Key Matrix scan application

■ 3 SPI Interface

■ 3.1 Overview

This LSI has SPI (Serial Peripheral Interface) interface that enables to operate the following features.

- As SPI slave device, the memory data can be accessed through the SPI interface (External power is required for the operation).
- As SPI master device, the external SPI slave device can be controlled by RF command (RF generated power is supplied for the external device).

■ 3.2 SPI Mode

This LSI supports SPI mode 0 (CPOL=0, CPHA=0).

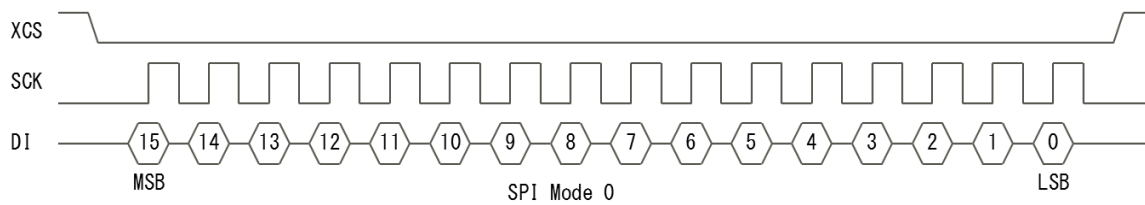


Figure 3.2 – SPI mode

■ 3.3 SPI Slave Interface

■ 3.3.1 Connection to SPI Interface

When this LSI is used as SPI slave device, the connection with SPI controller (master) shall be as shown in Figure 3.3.1.

In order to start SPI slave communication, external SPI master device shall set SPIREQ to “H” level to request the communication. After SPIACK outputs “H” level, XCS shall be set to “L” level. And then SPI slave communication will be enabled. SPI controller shall stay SPIREQ “H” level, and can continue to execute commands without any interruption from RF interface during when SPIACK is “H” level. Any command from RF interface is invalid during SPI slave operation. When SPIACK is “L” level, SPI slave communication cannot be enabled.

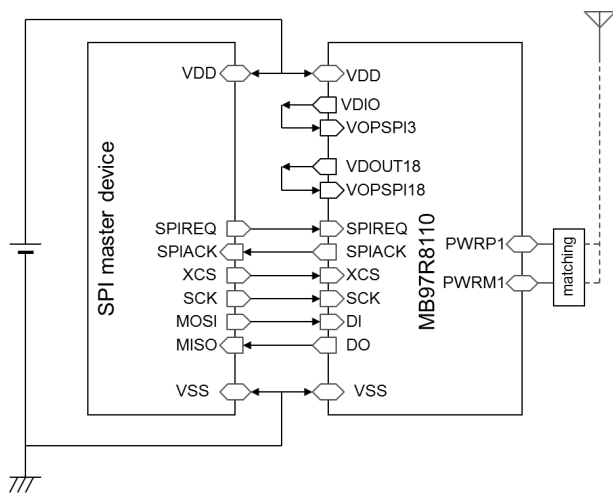


Figure 3.3.1 - SPI Slave interface connection

■ 3.3.2 Power down mode

When SPI master operation is disabled, if SPIREQ is switched to “L” level, this LSI will be in power down mode, which enables to reduce current consumption between VDD-VSS. (refer to 8.4.1) All the input pins excepting VDD shall be “L” level during power down mode. When SPI master operation is enabled and SPIREQ is “L” level, it is prohibited to make XCS and SCK “L” level in order to avoid conflict with SPI master operation.

■ 3.3.3 Usage

Please refer to Chapter 5.2 and 5.3 regarding the usage of SPI slave interface.

■ 3.4 SPI Master Interface

■ 3.4.1 Connection to SPI Interface

When this LSI is used as SPI master device, the connection with external SPI slave device shall be as shown in Figure 3.4.1.1 and Figure 3.4.1.2. It is recommended to connect capacitor between VDOUT3 and VSS, when external SPI slave device operation causes rapid current consumption. And power supply to external SPI slave device is recommended to be controlled by “H” level output from any bit out of COM[2:0] of GPIO (refer to Chapter 7.2.1). VDIO output shall be connected to VOPSPI3, and VDOUT18 output shall be connected to VOPSPI18. In this case “H” level output of COM[2:0] will be the same as the voltage level input from VOPSPI3 (Refer to Chapter 7.1.7).

Figure 3.4.1.1 shows an example of SPI master interface connection, in which XRST and CD pins are used for the connection. And DI and DO are connected with external SPI slave device respectively. Busy signal of external SPI slave device is connected to INT pin, which is assigned in GPIO interface, and busy status can be read by Reader/Writer (refer to 7.2.2).

Figure 3.4.1.2 shows another example of SPI master interface connection, in which XRST, CD, and INT pins are not used for the connection. And DI and DO is used as common bus connection (Mux).

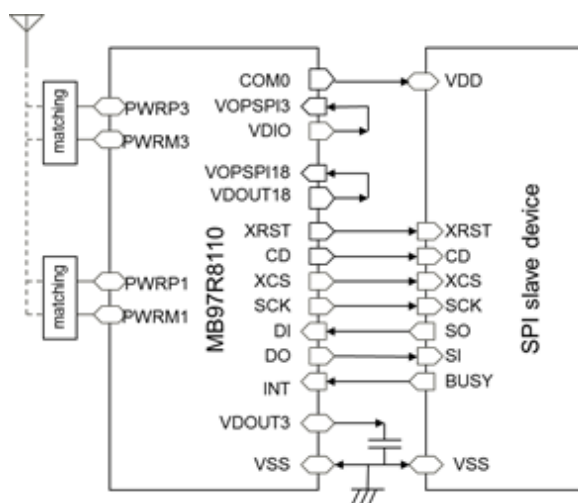


Figure 3.4.1.1 - SPI master interface connection 1

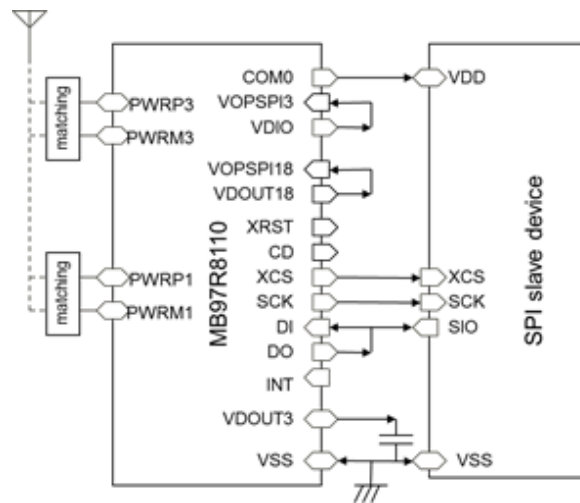


Figure 3.4.1.2 - SPI master interface connection 2

■ 3.4.2 Usage

Please refer to Chapter 7.1 regarding the usage of SPI master interface.

■ 3.5 GPIO Interface

■ 3.5.1 GPIO

GPIO interface enables to output 3bits of register value to COM[2:0] pins (refer to chapter 4.2.4.2 about address allocation). The value can be updated by BlockWrite command of RF communication. The state of INT can be read by Read command of RF communication.

■ 3.5.2 Usage

GPIO can be utilized as the following use cases.

- LED ON/OFF control
- Power supply to external SPI slave device under SPI master operation
- Status monitoring of external connected devices

For the detail, refer to Chapter 7.2.

■ 3.6 Key Matrix scan interface

■ 3.6.1 Connection method

The Key Matrix scan interface enables to be connected to matrix key input device which returns key data on scan clock.

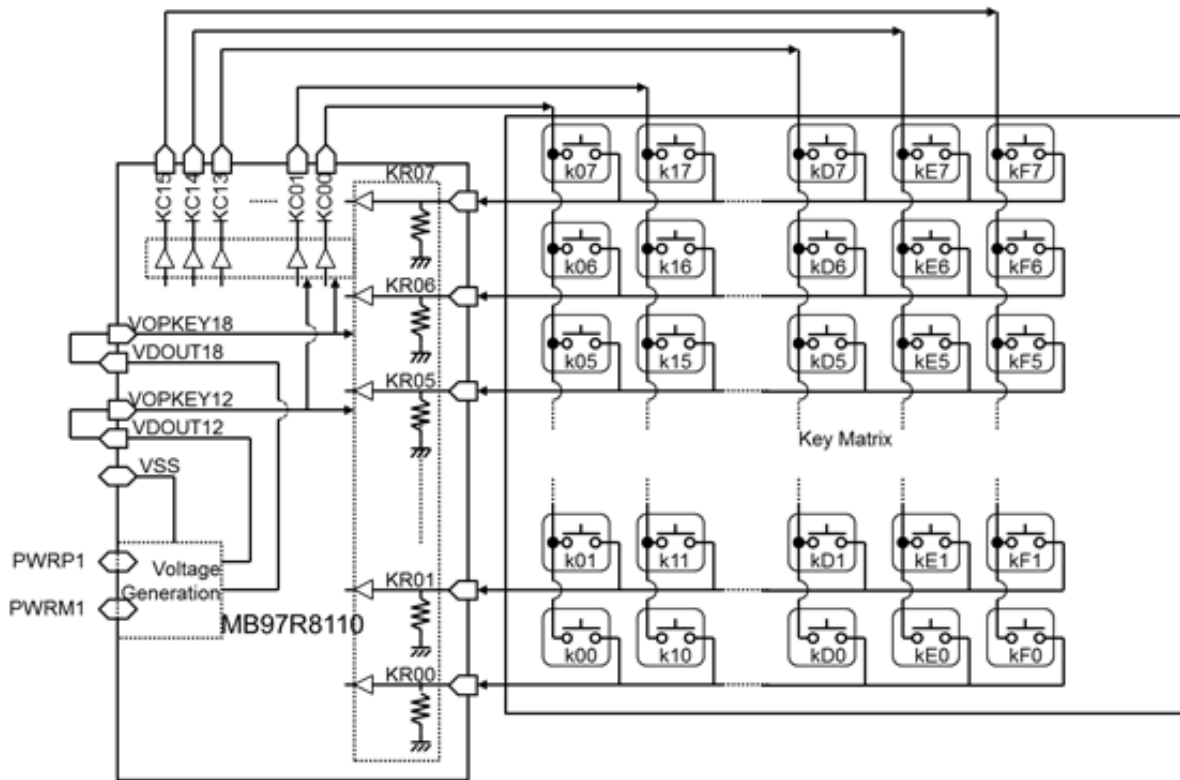


Figure 3.6.1 – Key Matrix and connection example

■ 3.6.2 Usage

Refer to Chapter 7.3 regarding the usage of Key Matrix scan interface

■ 3.7 Power sequence and Arbitration

■ 3.7.1 Arbitration between RF and SPI slave communication

The arbitration feature manages memory access from either RF interface or SPI interface in order to avoid any interruption to each other. SPIREQ and SPIACK manages to switch communication from RF interface to SPI interface by activating VDD, and vice versa.

In order to start SPI slave communication, the external SPI master device connected to this LSI shall set SPIREQ to “H” level to request communication. Upon the request, this LSI sets SPIACK to “H” level after completing active communication from RF interface. Then XCS shall be set to “L” level, and SPI slave communication will be ready. It is possible to start SPI slave communication during the period when SPIACK is “L” level, even if XCS is “L” level.

The example of arbitration sequence between RF and SPI slave communication is shown in Figure 3.7.1.

As described, when SPIACK is “L” level, any command input from SPI slave interface is prohibited even if XCS is in “L” level. When SPIACK is “H” level, any command from RF interface is invalid and SPI slave communication will be continued. In this case, SPIREQ shall be set to “L” after completing active communication from SPI interface in order to switch to RF communication.

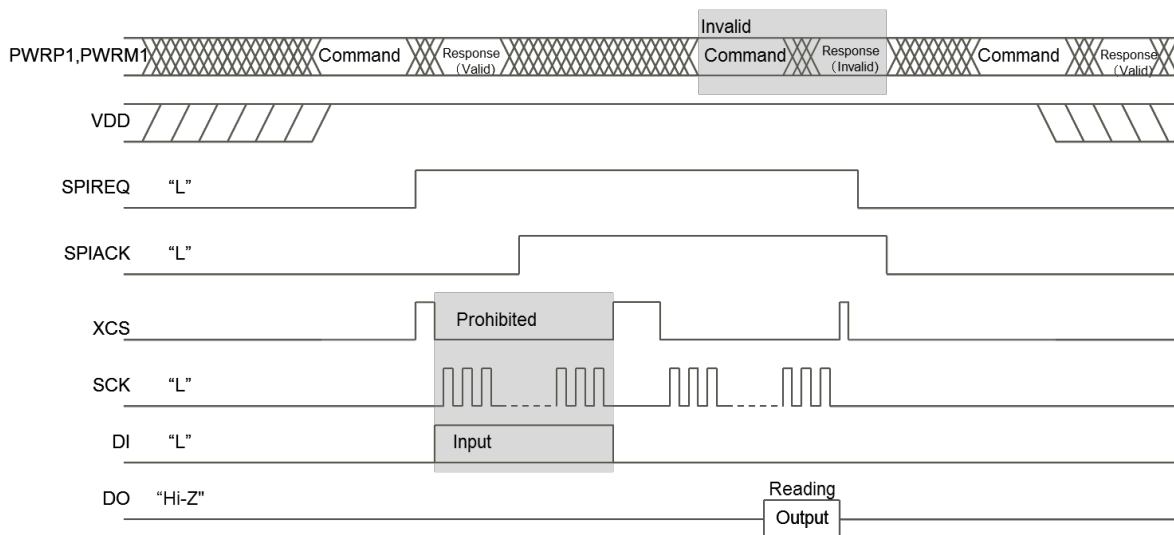


Figure 3.7.1 —The arbitration sequence between RF communication and SPI slave communication

In addition, SPI master function and Key Matrix scan function works as RF communication under the arbitration sequence above.

■ 4 Memory

■ 4.1 Memory address

■ 4.1.1 Address description

The memory address is allocated in the units of 16bits (=1word). The logical address in each memory bank is described as WordAdr in this document. WordPtr is the address specified by RF command access, which is described in EBV(Extensible bit vectors) format conforming to EPCglobal Class 1 Generation 2 standard (AnnexA). EBV format is shown in Table4.1.1. The address description in this document is shown in Table4.1.2. The address specified by SPI slave communication command from external SPI master device shall be 2bits of MemBank and 14bits of WordAdr(Total 16bits).The practical examples of the comparison between WordPtr and WordAdr are shown in Table4.1.3.

Table 4.1.1 EBV format (Excerpt from EPCglobal standard)

	0	0	0000000						
	1	0	0000001						
$2^7 - 1$	127	0	1111111						
2^7	128	1	0000001	0	0000000				
$2^{14} - 1$	16383	1	1111111	0	1111111				
2^{14}	16384	1	0000001	1	0000000	0	0000000		

Table 4.1.2 Address description in this document

Address range	WordAdr[13:0]*1	WordPtr[7:0] or WordPtr[15:8] (RF access)	Comparison between WordPtr and WordAdr
0000h to 007Fh	0000h to 007Fh	00h to 7Fh	WordPtr={ <u>0</u> , WordAdr[6:0]} *2
0080h to 0F3Fh	0080h to 0F3Fh	8100h to 9E3Fh	WordPtr={ <u>1</u> , WordAdr[13:7], <u>0</u> , WordAdr[6:0]} *2

*1. The address specified by SPI slave access is 2bits of MemBank and 14bits of WordAdr (16bits total).

*2. Underlined 0,1 is defined by EBV format.

Table 4.1.3 Comparison between WordPtr and WordAdr

WordAdr = 0000h

WordAdr[13:0]			13	12	11	10	9	8	7	6	5	4	3	2	1	0
0000h			0	0	0	0	0	0	0	0	0	0	0	0	0	0
WordPtr[7:0]									7	6	5	4	3	2	1	0
00h									0	0	0	0	0	0	0	0
SPI Slave address[15:0]	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0000h	MemBank		0	0	0	0	0	0	0	0	0	0	0	0	0	0

WordAdr = 007Fh

WordAdr[13:0]			13	12	11	10	9	8	7	6	5	4	3	2	1	0
007Fh			0	0	0	0	0	0	0	1	1	1	1	1	1	1
WordPtr[7:0]									7	6	5	4	3	2	1	0
7Fh									0	1	1	1	1	1	1	1
SPI Slave address[15:0]	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0000h	MemBank		0	0	0	0	0	0	0	1	1	1	1	1	1	1

WordAdr = 0080h

WordAdr[13:0]			13	12	11	10	9	8	7	6	5	4	3	2	1	0
0080h			0	0	0	0	0	0	1	0	0	0	0	0	0	0
WordPtr[15:0]	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
8100h	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
SPI Slave address[15:0]	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0080h	MemBank		0	0	0	0	0	0	1	0	0	0	0	0	0	0

WordAdr = 0F3Fh

WordAdr[13:0]			13	12	11	10	9	8	7	6	5	4	3	2	1	0
0F3Fh			0	0	1	1	1	1	0	0	1	1	1	1	1	1
WordPtr[15:0]	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
9E3Fh	1	0	0	1	1	1	1	0	0	0	1	1	1	1	1	1
SPI Slave address[15:0]	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0F3Fh	MemBank		0	0	1	1	1	1	0	0	1	1	1	1	1	1

* The data stored in bit15, bit7 of WordPtr is defined by EBV format.

■ 4.2 Memory Map

■ 4.2.1 Memory bank

The Non-volatile memory (FeRAM) of this LSI is divided into the following four banks.

Table 4.2.1 Memory map

Bank		Address		Command Accessibility							
MemBank [1:0]	Definition	WordAdr[13:0]	WordPtr[15:8] WordPtr[7:0]	RF						SPI Slave	
				Read	Write	BlockWrite	BlockErase	BlockPermalock	Select	SpiRead	SpiWrite
11	USER	0000h to 0EFFh	00h to 9D7Fh	✓	✓	✓	✓	✓	✓	✓	✓
		0F00h to 0F3Fh	9E00h to 9E3Fh	✓	✓	✓*	✓*	—	✓	✓	—
10	TID	0000h to 000Ch	00h to 0Ch	✓	—	—	—	—	✓	✓	—
01	EPC	0000h to 001Fh	00h to 1Fh	✓	✓	✓	✓	—	✓	✓	—
00	RESERVED	0000h to 003Fh	00h to 3Fh	✓	✓	—	—	—	—	—	—

*. The command works for executing extended application on some specific address.

USER, TID, EPC, and RESERVED memory banks contain the data in the format defined by EPCglobal C1G2 specification (Chapter 6.3.2.1). In each memory bank, the WordAdr and the WordPtr start from zero (00h).

■ 4.2.2 TID bank

The memory map of TID bank is shown in Table 4.2.2. TID bank can only be read, and the setting values cannot be changed. For details, please refer to EPCglobal Class 1 Generation 2 standard.

Table 4.2.2 TID bank memory map

MSB																LSB															
WordAdr	WordPtr	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Setting Value													
00h	00h	Allocation Class										Designer								E281h											
01h	01h	Designer					Product ID								Version					0081h											
02h	02h	XTID header																	3C00h												
03h	03h	Serial Number																	unique												
04h	04h	Serial Number																	unique												
05h	05h	Serial Number																	unique												
06h	06h	optional command support																	1DDEh												
07h	07h	BlockErase parameter																	0002h												
08h	08h	BlockErase parameter																	0310h												
09h	09h	BlockWrite parameter																	0002h												
0Ah	0Ah	BlockWrite parameter																	0310h												
0Bh	0Bh	Permalock Block size																	0200h												
0Ch	0Ch	User memory size																	0F00h												

■ 4.2.3 EPC bank

The memory map of EPC bank is shown in Table 4.2.3.

Table 4.2.3 EPC bank memory map

MSB																LSB				Default Value
WordAdr	WordPtr	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0			
00h	00h	Stored CRC																		
01h	01h	Stored PC																3400h		
02h	02h	EPC data																0000h		
03h	03h	EPC data(Serial Number *)																unique		
04h	04h	EPC data(Serial Number *)																unique		
05h	05h	EPC data(Serial Number *)																unique		
06h	06h	EPC data																0000h		
07h	07h	EPC data																0000h		
08h	08h	EPC data																0000h		
09h	09h	EPC data																0000h		
0Ah	0Ah	EPC data																0000h		
0Bh	0Bh	EPC data																0000h		
0Ch	0Ch	EPC data																0000h		
0Dh	0Dh	EPC data																0000h		
0Eh	0Eh	EPC data																0000h		
0Fh	0Fh	EPC data																0000h		
10h	10h	EPC data																0000h		
.	EPC data																0000h		
1Fh	1Fh	EPC data																0000h		

*. As default value, the same serial number is stored in WordAdr=03h to 05h of EPC bank as the number stored in WordAdr=03h to 05h of TID bank.

The length of EPC is specified by EPC length field of Stored PC. The length is preprogrammed to 6 (words) as default value, which indicates 6words of EPC (WordAdr 02h to 07h). It is possible to expand the length up to 30words (WordAdr 02h to 1Fh) by programming the data of EPC length field

This LSI does not support XPC_W1 and XPC_W2. Stored CRC is not preprogrammed, because it is reflected after the response to ACK command.

■ 4.2.4 USER bank

USER bank of this LSI consists of 3,840words of Data field and 64words of Application field.

■ 4.2.4.1 USER bank (Data field)

Data field of USER bank is divided into 8 Area groups as shown in Table.4.2.4.1.

Table 4.2.4.1 USER bank (Data field) memory map

		MSB															LSB	
WordAdr	WordPtr	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default Value
000h to 1FFh	00h to 837Fh	User data (Area0)																0000h
200h to 3FFh	8400h to 877Fh	User data (Area1)																0000h
400h to 5FFh	8800h to 8B7Fh	User data (Area2)																0000h
600h to 7FFh	8C00h to 8F7Fh	User data (Area3)																0000h
800h to 9FFh	9000h to 937Fh	User data (Area4)																0000h
A00h to BFFh	9400h to 977Fh	User data (Area5)																0000h
C00h to DFFh	9800h to 9B7Fh	User data (Area6)																0000h
E00h to EFFh	9C00h to 9D7Fh	User data (Area7)																0000h

Each area can be protected by Area Password (refer to Chapter6.2). And the same area is allocated for PermalockBlock (refer to Chapter5.1.3).

Regarding the memory access from RF communication (BlockWrite, BlockErase, and Read command), when the address reaches to WordPtr=8F7Fh (WordAdr=7FFh) among the range specified by WordCount, the address

to be followed will be WordPtr=9000h (WordAdr=800h). In the same case from SPI slave communication (SpiWrite, SpiRead command), the address counter rollovers from WordAdr=7FFh to 000h.

■ 4.2.4.2 USER bank (Application field)

Application field of USER bank allocated in WordPtr=9E00h to 9E3Fh (WordAdr=F00h to F3Fh) is used for the extensive applications described in Chapter 7, which consists of 16bit registers, command control, and data storage. This field is writable only from RF interface. The registers located in WordPtr=9E00h to 9E03h

(WordAdr=F00h to F03h) are volatile, and the stored value will be reset to “0”, if the internal voltage drops below the lower limit. Memory map of the field is shown in Table.4.2.4.2. The data stored in WordPtr=9E10h to 9E13h (WordAdr=F10h to F13h) are non-volatile and they are updated with the latest data. The area located in WordPtr=9E2xh and 9E3xh (WordAdr=F2xh and F3xh), which is allocated for SPI master application, consists of volatile memory and non-volatile memory.

Table 4.2.4.2 USER bank (Application field) memory map

WordAdr	WordPtr	MSB																LSB	
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Reset Value	Volatile /Non-Volatile
F00h	9E00h	GPIO Setting																0000h	Volatile
F01h	9E01h	Key Matrix scan setting																0000h	Volatile
F02h	9E02h	SPI Master setting																0000h	Volatile
F03h	9E03h	VDOUT3 setting																0000h	Volatile
F04h	9E04h	Reserved																0000h	
F05h	9E05h	Reserved																0000h	
...	...	Reserved																0000h	
F0Fh	9E0Fh	Reserved																0000h	
F10h	9E10h	Key Matrix scan command control and Pressed Key data buffer																0000h	Non-Volatile
F11h	9E11h	Pressed Key data buffer																0000h	Non-Volatile
F12h	9E12h	Pressed Key data buffer																0000h	Non-Volatile
F13h	9E13h	Pressed Key data buffer																0000h	Non-Volatile
F14h	9E14h	Reserved																0000h	
...	...	Reserved																0000h	
F1Fh	9E1Fh	Reserved																0000h	
F2xh	9E2xh	Application area																0000h	-
F3xh	9E3xh	Application area																0000h	-

■ 4.2.5 RESERVED bank

RESERVED bank is used for Password data management.

32bits Password can be set by 2steps of 16bits writing, 1st for [31:16] and 2nd for [15:0] by Req_RN and Write command as a set of sequence respectively without any other command between the steps.

Table 4.2.5 RESERVED bank memory map

MSB																	LSB		
WordAdr	WordPtr	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default Value	
00h	00h	Kill password												[31:16]				0000h	
01h	01h	Kill password												[15:0]				0000h	
02h	02h	Access password												[31:16]				0000h	
03h	03h	Access password												[15:0]				0000h	
04h	04h	Reserved																	0000h
.																		0000h
1Fh	1Fh	Reserved																	0000h
20h	20h	Area password (Setting) (Area0)												[31:16]				0000h	
21h	21h	Area password (Setting) (Area0)												[15:0]				0000h	
22h	22h	Area password (Setting) (Area1)												[31:16]				0000h	
23h	23h	Area password (Setting) (Area1)												[15:0]				0000h	
24h	24h	Area password (Setting) (Area2)												[31:16]				0000h	
25h	25h	Area password (Setting) (Area2)												[15:0]				0000h	
26h	26h	Area password (Setting) (Area3)												[31:16]				0000h	
27h	27h	Area password (Setting) (Area3)												[15:0]				0000h	
28h	28h	Area password (Setting) (Area4)												[31:16]				0000h	
29h	29h	Area password (Setting) (Area4)												[15:0]				0000h	
2Ah	2Ah	Area password (Setting) (Area5)												[31:16]				0000h	
2Bh	2Bh	Area password (Setting) (Area5)												[15:0]				0000h	
2Ch	2Ch	Area password (Setting) (Area6)												[31:16]				0000h	
2Dh	2Dh	Area password (Setting) (Area6)												[15:0]				0000h	
2Eh	2Eh	Area password (Setting) (Area7)												[31:16]				0000h	
2Fh	2Fh	Area password (Setting) (Area7)												[15:0]				0000h	
30h	30h	Area password (Authentication) (Area0)												[31:16]				0000h	
31h	31h	Area password (Authentication) (Area0)												[15:0]				0000h	
32h	32h	Area password (Authentication) (Area1)												[31:16]				0000h	
33h	33h	Area password (Authentication) (Area1)												[15:0]				0000h	
34h	34h	Area password (Authentication) (Area2)												[31:16]				0000h	
35h	35h	Area password (Authentication) (Area2)												[15:0]				0000h	
36h	36h	Area password (Authentication) (Area3)												[31:16]				0000h	
37h	37h	Area password (Authentication) (Area3)												[15:0]				0000h	
38h	38h	Area password (Authentication) (Area4)												[31:16]				0000h	
39h	39h	Area password (Authentication) (Area4)												[15:0]				0000h	
3Ah	3Ah	Area password (Authentication) (Area5)												[31:16]				0000h	
3Bh	3Bh	Area password (Authentication) (Area5)												[15:0]				0000h	
3Ch	3Ch	Area password (Authentication) (Area6)												[31:16]				0000h	
3Dh	3Dh	Area password (Authentication) (Area6)												[15:0]				0000h	
3Eh	3Eh	Area password (Authentication) (Area7)												[31:16]				0000h	
3Fh	3Fh	Area password (Authentication) (Area7)												[15:0]				0000h	

■ 5 Command (Battery-less operation)

■ 5.1 RF communication command

All mandatory commands and optional commands specified in EPCglobal C1G2 Ver.1.2.0. (Chapter 6.3.2.11) are supported as described in Table 5.1.

However, Parts of the specification of BlockWrite, BlockErase, BlockPermalock command (Optional command), and Read command (Mandatory command) are different from EPC C1G2 standard as described in Chapter 5.1.1, 5.1.2, 5.1.3, and 5.1.4.

Table 5.1 – RF mode command

Type	Command name	Command code
Mandatory	QueryRep	00
	ACK	01
	Query	1000
	QueryAdjust	1001
	Select	1010
	NAK	1100 0000
	Req_RN	1100 0001
	Read	1100 0010
	Write	1100 0011
	Kill	1100 0100
	Lock	1100 0101
Optional	Access	1100 0110
	BlockWrite	1100 0111
	BlockErase	1100 1000
	BlockPermalock	1100 1001

※Differences from EPCglobal C1G2 Ver. 1.2.0

(1) Stored CRC-16

If Stored PC and/or EPC data stored in EPC bank are renewed, StoredCRC-16 will not be updated when the power is turned on, but it is updated on the response to ACK command without truncation.

(2) UMI

UMI is fixed to “1” on this LSI. According to EPCglobal C1G2 Ver. 1.2.0, UMI stored in bit[10] of StoredPC in EPC bank shall be calculated by OR of bit[12:8] of WordAdr=00h in USER bank.

(3) Response to Read command when the WordCount is specified to 00h

According to EPCglobal C1G2 Ver. 1.2.0, the tag shall reply the whole data from the specified WordPtr to the last address of the bank, when the WordCount is specified to 00h.

USER bank of this LSI consists of 8 areas and can be protected by Area Password. Therefore, if parts of the data to be read is protected by Area Password, any data cannot be read and error code “04h” (indicating Memory locked) will be replied.

(4) Commands for extended applications

As described in Chapter 7, Write, BlockWrite and BlockErase commands are used for executing extended application when the commands access to the specific address allocated in WordPtr=9E00h to 9E3Fh

(WordAdr=F00h to F3Fh) of USER bank. In this case, these commands do not work as simple Write and Erase command.

(5) Area Password

Area Password for data protection is stored in WordPtr=20h to 3Fh (WordAdr=20h to 3Fh) of RESERVED bank. As described in Chapter 6, Write command is used for Area Password setting and authentication when the command accesses to the specific address.

■ 5.1.1 BlockWrite (Optional command)

BlockWrite command format is shown in Table 5.1.1. Part of the function are different from what is specified in EPCglobal C1G2 Ver.1.2.0 as following.

- MemBank specifies only EPC and USER bank. If BlockWrite command is executed on RESERVED and TID bank, error code “03h” (indicating Memory overrun) is replied. In this case, the data will not be written into the specified address.

- WordCount specifies the number of words to be written. If 00h is specified, the command will be ignored.

When the specified address is located in EPC bank or some address located in WordPtr=00h to 8F7Fh (WordAdr=000h to 7FFh) of USER bank, WordCount shall be 16(10h) or less. If it is 17(11h) or more, error code “03h” (indicating Memory overrun) will be replied. When the specified address is located in WordPtr=9000h to 9D7Fh (WordAdr=800h to EFFh), WordCount shall be specified up to 255(FFh). In this case, the data up to 16words is to be written into the specified address after CRC verification, but the data over 16words is to be written continuously without CRC verification. Therefore if the communication is terminated without any response because of low power detection, some data may have been written before the termination. When the specified address is all or partially locked by the BlockPermalock command or protected by Area Password, any data will not be written and error code “04h” (indicating Memory locked) is replied.

Table 5.1.1 — BlockWrite command

	Command	MemBank	WordPtr	WordCount	Data	RN	CRC
Number of bits	8	2	EBV	8	WordCount *16	16	16
Description	1100 0111	01:EPC 11:USER	Starting Address Pointer	Number of words to write	Data to be written	handle	CRC-16

When the address reaches WordPtr=8F7Fh (WordAdr=7FFh) among the range specified by WordCount, the address to be followed will be WordPtr=9000h (WordAdr=800h).

* In SPI slave communication, the address counter rollovers from WordAdr=7FFh to 000h.

■ 5.1.2 BlockErase (Optional command)

BlockErase command format is shown in Table 5.1.2. Parts of the function are different from what is specified in EPCglobal C1G2 Ver.1.2.0 as described as follows.

- MemBank specifies only EPC and USER bank. If BlockErase command is executed on RESERVED and TID bank, error code “03h” (indicating Memory overrun) is replied. In this case, the data will not be erased.

- WordCount specifies the number of data to be erased. If 00h is specified, the command will be ignored. 01h to 10h shall be specified. When the specified address is all or partially locked by the BlockPermalock command or protected by Area Password, any data will not be erased and error code “04h” (indicating Memory locked) is replied.

Table 5.1.2 - BlockErase Command

	Command	MemBank	WordPtr	WordCount	RN	CRC
Number of bits	8	2	EBV	8	16	16
Decription	1100 1000	01:EPC 11:USER	Starting Address Pointer	Number of words to erase	handle	CRC-16

■ 5.1.3 BlockPermalock (Optional command)

The unit of Block to be locked is defined as 512 words for this LSI. The BlockPermalock command can be executed to the 8 blocks of USER bank which is 7 areas of 8k bits and 1 area of 4k bits.

■ 5.1.3.1 BlockPermalock (Setting)

The format of the BlockPermalock command for Permalock setting is shown in Table 5.1.3.1. The Read/Lock value is set to “1”, and the specified bock will be locked permanently. Lock data field is described in Chapter 5.1.3.3.

Table 5.1.3.1 – BlockPermalock command (Permalock)

	Command	RFU	Read /Lock	MemBank	BlockPtr	Block Range	LockData	RN	CRC
Number of bits	8	8	1	2	8	8	16	16	16
Description	1100 1001	000 0 000 0	1:Perma Lock	11:USER	0000 0000	0000 0001	0:Retain current permalock setting 1:Assert permalock	handle	CRC-16

There is a limitation as follows. If any other value is set, error code “03h” (indicating Memory overrun) will be replied and permalock operation is terminated.

- MemBank: Only executed for USER bank.
- BlockPtr: Only 00h is supported.
- BlockRange: Only 01h is supported.

■ 5.1.3.2 BlockPermalock (Read)

The format of the BlockPermaLock command for reading permalock status is shown in Table 5.1.3.2.1. The Read/Lock value is set to “0”, and the permalock status of 8blocks of USER bank can be read. The response is shown in Table 5.1.3.2.2.

Table 5.1.3.2.1 – BlockPermalock command (Read)

	Command	RFU	Read /Lock	MemBank	BlockPtr	Block Range	RN	CRC
Number of bits	8	8	1	2	8	8	16	16
Description	1100 1001	0000 0000	0:Read	11:USER	0000 0000	0000 0001	handle	CRC-16

Table 5.1.3.2.2 – Response to BlockPermalock command (Read)

	Header	LockData	RN	CRC
Number of bits	1	16	16	16
Description	0	Permalock bits	handle	CRC-16

There is a limitation as follows. If any other value is set, error code “03h” (indicating Memory overrun) will be replied and reading operation is terminated.

- MemBank: Only executed for USER bank.
- BlockPtr: Only 00h is supported.
- BlockRange: Only 01h is supported.

■ 5.1.3.3 BlockPermalock and Permalocked Block

16bits of Lock data and corresponded block is shown in Table 5.1.3.3.

Table 5.1.3.3 – BlockPermalock data

Bit	Area	WordAdr	WordPtr
15	0	000h to 1FFh	00h to 837Fh
14	1	200h to 3FFh	8400h to 877Fh
13	2	400h to 5FFh	8800h to 8B7Fh
12	3	600h to 7FFh	8C00h to 8F7Fh
11	4	800h to 9FFh	9000h to 937Fh
10	5	A00h to BFFh	9400h to 977Fh
9	6	C00h to DFFh	9800h to 9B7Fh
8	7	E00h to EFFh	9C00h to 9D7Fh
7	—	—	—
6	—	—	—
5	—	—	—
4	—	—	—
3	—	—	—
2	—	—	—
1	—	—	—
0	—	—	—

When Lock data is set by BlockPermalock command (refer to Chapter 5.1.3.1), Bit[7:0] shall be set to “0” because of no target block.

■ 5.1.4 Read (Mandatory)

The command format is shown in Table 5.1.4.1

Table 5.1.4.1– Read command

	Command	MemBank	WordPtr	WordCount	RN	CRC
Number of bits	8	2	EBV	8	16	16
Description	1100 0010	00:RESERVED 01:EPC 10:TID 11:USER	Starting Address Pointer	Number of Words to read	handle	CRC-16

When the address reaches WordPtr=8F7Fh (WordAdr=7FFh) among the range specified by WordCount, the address to be followed will be WordPtr=9000h (WordAdr=800h).

* In SPI slave communication, the address counter rollovers from WordAdr=7FFh to 000h.

When WordCount is set to “00h”, the response will be as shown in Table 5.1.4.2.

Table 5.1.4.2– Response to Read command when WordCount is set to “00h”

MemBank	Area Password	Response
11:USER	Zero Password (All Area)	The data from the specified WordPtr (Table 5.1.4.1) to 9D7Fh (WordAdr=EFFh) are replied as normal response.
	Non zero Password (Some Area)	No data is read. Error code “04h” (indicating Memory locked) is replied. (refer to Chapter 2.4)
10:TID	—	The data from the specified WordPtr (Table 5.1.4.1) to 0Fh are replied as normal response.
01:EPC	—	The data from the specified WordPtr (Table 5.1.4.1) to the WordPtr corresponding to the length of EPC are replied as normal response.
00:RESERVED	—	The data from the specified WordPtr (Table 5.1.4.1) to 3Fh are replied as normal response.

■ 5.1.5 Lock (Mandatory)

The command format is shown in Table 5.1.5. When the Access Password (WordAdr=02h to 03h(WordPtr=02h to 03h)) is locked by setting Payload bit [17,16] and [7,6], Area Passwords(WordAdr=20h to 3Fh (WordPtr=20h to 3Fh)) are also locked automatically.

Regardless whether the password is locked or not, Area Password authentication can be executed by Write command. The detail of the command is specified in EPCglobal C1G2 Ver.1.2.0 (Chapter 6.3.2.11.3.5).

Table 5.1.5– Lock command

	Command	Payload	RN	CRC
Number of bits	8	20	16	16
Description	1100 0101	Mask and Action Fields	handle	CRC-16

■ 5.2 SPI slave communication command

This LSI will support 3 types of operate-code for SPI slave interface. The operate-code is 8bits code described in Table 5.2. If other codes are used, the command is ignored. If XCS is raised during the input sequence of operate-code, the command cannot be executed.

Table 5.2 - Operate-code for SPI slave interface

Code name	Function	Operate-code
SpiRead	Read data in units of 16bits from USER memory area.	0000 0011
SpiWrite	Write data in units of 16bits into USER memory area.	0000 0010
SpiRDSR	Read 16bits of Error information register(SPI slave)	0000 0101

■ 5.2.1 SpiRead

SpiRead command is to read memory data in units of 16bits (1word). The address shall be specified as 2bits of MemBank followed by 14bits of WordAdr (Total 16bits). The command sequence is described in Figure 5.2.1. Through DI pin, the following data shall be input synchronously to the rising edge of SCK after XCS is fallen. SpiRead operate code (8bit:03h)

MemBank (2bit)

WordAdr (14bit)

USER bank, TID bank and EPC bank are readable banks. The upper 2 bit of WordAdr shall be fixed to “00”.

In response to the command input, the reading data will be output from DO synchronously to the falling edge of SCK. During the period of output from DO, any input from DI will be ignored. SpiRead command will be terminated when XCS is raised, and the output from DO will be “Hi-Z”.

The command keeps on reading with automatically incremented address by continuous 16cycles of clock to SCK before XCS rising. If WordAdr is specified as 000h to 7FFh of USER bank and the incremented address reaches to WordAdr=7FFh, the address will roll over to WordAdr=000h and read operation is continued. If WordAdr is specified as 800h to EFFh of USER bank and the incremented address reaches to WordAdr=EFFh, the address will not roll over to WordAdr=000h nor WordAdr=800h. In this case, the DO output will be “0”.

When Membank is specified as TID bank or EPC bank, the address will be automatically incremented up to the most significant WordAdr described in Chapter 4.2, and the address will not roll over after that. In this case, the DO output will be “0” until when XCS is raised.

In the following cases, the memory data will not be read out and DO output will be “0”.

- 1) LSI is in Killed state
- 2) The specified address is protected by Password
- 3) MemBank is specified with RESERVED bank

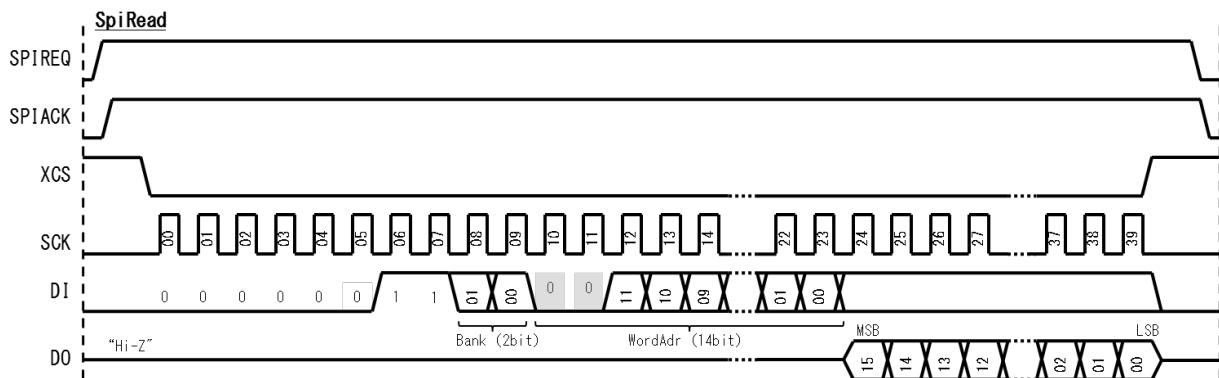


Figure 5.2.1 – SpiRead command sequence

When AccessPassword is set, the data cannot be read and the output will be “0”. Therefore AccessPassword shall be cleared before SPI slave communication. If the specified area includes the WordAdr protected by Area Password, only unprotected address will be read and “0” will be output instead from protected address.

■ 5.2.2 SpiWrite

SpiWrite command is to write data into memory in units of 16 bits (1 word). The address shall be specified as 2bits of MemBank followed by 14bits WordAdr (Total 16bits). The command sequence is described in Figure 5.2.2. Through DI pin, the following data shall be input synchronously to the rising edge of SCK after XCS is fallen.

SpiWrite operate-code (8bit:02h)

MemBank (2bit)

WordAdr (14bit)

Written data (N*16bit)

USER bank is writable bank, and the other banks are not writable. The upper 2 bit of WordAdr shall be fixed to “00”.

The command keeps on writing with automatically incremented address by continuous 16 cycles of clock to SCK and 16bits of writing data together before XCS rising. If XCS is raised on the timing before completing 16cycles of clock, the writing data will not be written into memory. If WordAdr is specified as 000h to 7FFh of USER bank and the incremented address reaches to WordAdr=7FFh, the address will roll over to WordAdr=000h and write operation is continued. If WordAdr is specified as 800h to EFFh of USER bank and the incremented address reaches to WordAdr=EFFh, the address will not roll over to WordAdr=000h nor WordAdr=800h. In this case, writing operation completes at WordAdr =EFFh.

In the following cases, the writing data cannot be written, and error information will be stored into SPI error information. (refer to Chapter 5.3.1 for detail).

- 1) LSI is in Killed state
- 2) The specified address is protected by Password
- 3) The specified MemBank is not USER bank
- 4) WordAdr is over EFFh
- 5) The specified address is in the locked area

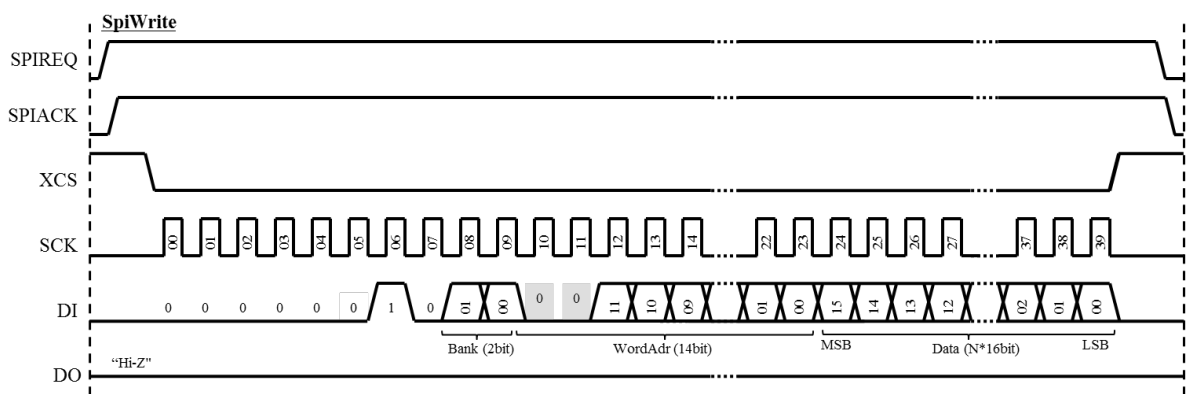


Figure 5.2.2 – SpiWrite command sequence

When AccessPassword is set, the data cannot be written. Therefore AccessPassword shall be cleared before SPI slave communication. If the specified area includes the WordAdr protected by Area Password, only unprotected address will be written and nothing will happen on protected address. If the specified area includes the WordAdr locked by Lock command or BlockPermalock command, only writable address will be written and nothing will happen on locked address for writing.

■ 5.2.3 SpiRDSR

The SpiRDSR command is to read 16 bits of error information on SPI slave communication (refer to Chapter 5.3.1). The command sequence is described in Figure 5.2.3.

Through DI pin, the following data shall be input synchronously to the rising edge of SCK after XCS is fallen.

SpiRDSR operate-code (8bit:05h)

In response to the command input, the 16 bits of error information will be output from DO synchronously to the falling edge of SCK. And SpiRDSR command will be completed when XCS is raised. If XCS is raised before the command completes 16 cycles of clock to SCK, the command will be terminated and the output from DO will be “Hi-Z”. During the period of output from DO, any input from DI will be ignored. If XCS keeps “L” level after the command complete reading, the output from DO will be “L” level. The error information will be cleared after SpiRDSR command is completed.

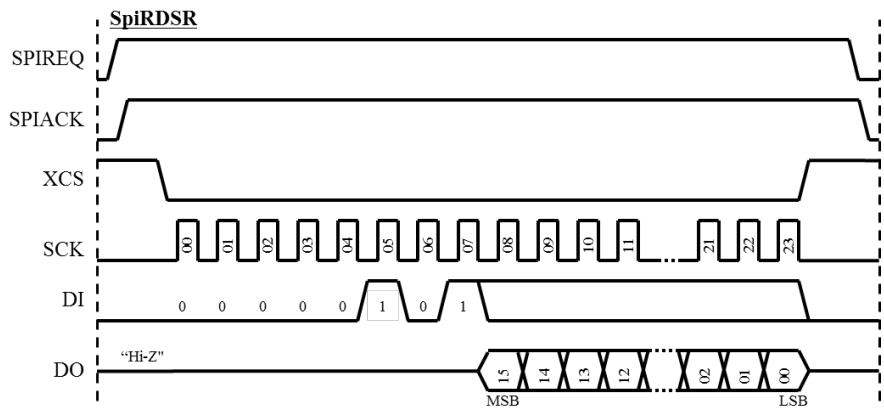


Figure 5.2.3 – SpiRDSR command sequence

■ 5.3 Error handling to SPI slave communication

On SPI slave communication, an error occurs under the following condition. If an error occurs in SPIRead command operation, the output from DO will be “0” and error information will be stored in error information register.

- Specified memory are is locked.
- Killed status

The data stored in error information register can be read by SpiRDSR command.

■ 5.3.1 Error information register (SPI slave communication)

Error information during SPI slave communication will be stored in the error information as shown in Table 5.3.1. These information can be read by SpiRDSR command.

The information will be cleared after the following operation.

- SpiRDSR command execution
- Power is off

Writing operation to error information register is ignored.

Table 5.3.1 Error information register format

Bit	Description
15	0 (Fixed)
14	0 (Fixed)
13	0 (Fixed)
12	0 (Fixed)
11	0 (Fixed)
10	0 (Fixed)
9	0 (Fixed)
8	0 (Fixed)
7	0 (Fixed)
6	0 (Fixed)
5	0 (Fixed)
4	0 (Fixed)
3	0 (Fixed)
2	0 (Fixed)
1	0: Normal 1: Specified address partly locked
0	0: Normal 1: Killed status

■ 6 Data protection

■ 6.1 LOCK Command, BlockPermalock Command, and Data protection area

This chapter describes the access control (hereinafter referred to as “Data protection”) for writing and reading memory. LOCK command can protect data in units of Bank except RESERVED Bank. And Kill Password and Access Password stored in RESERVED bank is protected. Area Password (refer to Chapter 6.2) stored in WordPtr=20h to 2Fh (WordAdr=20h to 2Fh) of RESERVED bank are also protected by the same payload [7:6] of Lock command as Access Password protection.

Table 6.1.1 Memory bank and Lock/BlockPermalock

MemBank	LOCK	WordPtr	BlockPermalock	Remarks
00:RESERVED	payload[9:8]	00h to 01h	—	Kill Password
	payload[7:6]	02h to 03h	—	Access Password
		20h to 2Fh	—	Area Password
01:EPC	payload[5:4]	all	—	
10:TID	payload[3:2]	all	—	
11:USER	payload[1:0]	000h to 1FFh	Mask[15]	Area0
		200h to 3FFh	Mask[14]	Area1
		400h to 5FFh	Mask[13]	Area2
		600h to 7FFh	Mask[12]	Area3
		800h to 9FFh	Mask[11]	Area4
		A00h to BFFh	Mask[10]	Area5
		C00h to DFFh	Mask[9]	Area6
		E00h to EFFh	Mask[8]	Area7

Please refer to EPCglobal C1G2 Ver.1.2.0 6.3.2.11.3.9) for the behavior to the combination of Lock command and BlockPermalock command.

■ 6.2 Data Protection for USER bank

USER bank is divided by 8 areas and each area can control to be accessed by Password Authentication.

■ 6.2.1 Area Password setting

Area Password can be set to the WordPtr=20h to 2Fh (WordAdr=20h to 2Fh) of RESERVED bank (refer to Table 4.2.5) by Write command as described in Table 6.2.1. This command is executed only in Secured state.

Table 6.2.1 Write command (Area Password setting)

	Command	MemBank	WordPtr	Data	RN	CRC
Number of bits	8	2	EBV	16	16	16
Description	1100 0011	00:RESERVED	Starting Address Pointer (20h-2Fh)	RN16 × Password to be set	handle	CRC-16

■ 6.2.2 Area Password Authentication

Area Password authentication can be set to the WordPtr=30h to 3Fh (WordAdr=30h to 3Fh) of RESERVED bank (refer to Table 4.2.5) by Write command as described in Table 6.2.2. 16bits of Password data will be sent twice for authentication as well as Access command. This command is executed only in Secured state.

Table 6.2.2 Write command (Area Password authentication)

	Command	MemBank	WordPtr	Data	RN	CRC
Number of bits	8	2	EBV	16	16	16
Description	1100 0011	00:RESERVED	Starting Address Pointer (30h-3Fh)	RN16 × (1/2 Password)	handle	CRC-16

When the authentication is failed, LSI will not reply, which is the same as failure case in the authentication of Access command. When the authentication is succeeded, the state of LSI will be transferred into AreaSecured state, and the area becomes be readable and writeable.

If the Password is set to 0, the state returns to Secured state regardless whether it was AreaSecured state or not. Because the authentication shall be applied to area by area, it is necessary to execute additional Area Password Authentication to the target area under Secured state.

■ 7 Extended Application

■ 7.1 SPI master

■ 7.1.1 SPI master setting

SPI master mode is enabled by Write command to WordPtr=9E02h(WordAdr=F02h) of USER bank. It is necessary to enable setting every power on cycle. The setting value can be read by Read command, but the value will be reset to “0000h” under the following condition.

- Power off after setting
- Internal reset by low power detection

In these cases, it is necessary to set the value again by Write command in order to enable SPI master mode. The data format of SPI master setting register is shown in Table 7.1.1.

Table 7.1.1 –Data format of SPI Master setting

MSB													LSB		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
En	Mux Dio	Rst Ctl	Re-served	SetupStart				Reserved				DivClk			

En: Master operation Enable/Disable setting

bit	Initial value	Setting	Setting description
15	0	0	SPI master operation Disable
		1	SPI master operation Enable

MuxDio: Multiplex setting for DI and DO (refer to Chapter 7.1.2)

bit	Initial value	Setting	Setting description
14	0	0	Separate for DI and DO
		1	Multiplex for DI and DO

RstCtl: XRST control

bit	Initial value	Setting	Setting description
13	0	0	XRST is "L" level output
		1	XRST is "H" level output

Reserved

bit	Initial value	Setting	Setting description
12	0	0	Set to 0

SetupStart[3:0]: setting number of clock cycles between command receiving and XCS dropping

bit	Initial value	Setting	Setting description
11:8	0h	N	Setup=N*8 clock (N=1 to 15)

Clock Frequency above is SCK output frequency described in DivClk.

Reserved

bit	Initial value	Setting	Setting description
7:4	0h	0h	Set to 0

DivClk[3:0] Clock division setting (SCK output frequency)

bit	Initial value	Setting	SCK output frequency	Setting description
3:0	0h	M	0.5MHz/(M+1)	DR=1(64/3)
			0.5MHz/(M+1)	DR=0(8), TRcal<62.5us
			0.5MHz/(M+1)/2	DR=0(8), 62.5us<TRcal<100us
			0.5MHz/(M+1)/4	DR=0(8), 100us<TRcal<150us
			0.5MHz/(M+1)/8	DR=0(8), 150us<TRcal<200us

4bits of DivClk setting “M” is one of the parameters to determine SCK output frequency. When the DR value specified by Query command is 1(64/3), SCK output frequency will be “0.5MHz divided by (M+1)”. When the DR value specified by Query command is 0(8), SCK output frequency will be calculated as shown in the table above depending on the TRCal value on Preamble.

■ 7.1.2 SPI master command

SPI master operation can be executed by BlockWrite command, when the command specifies WordPtr=9E20h (WordAdr=F20h) or WordPtr=9E30h (WordAdr=F30h) of USER bank. In this case, the data or the command contained in Data bits of BlockWrite command will be output through SPI interface, and the response data will be stored in the specified WordAdr of USER bank. The Block Write command format is shown in Table 7.1.2.

Table 7.1.2 — SPI master control by BlockWrite command

	Command	MemBank	WordPtr	WordCount	Data	RN	CRC
Number of bits	8	2	16(EBV)	8	WordCount *16	16	16
Description	1100 0111	11:USER	Starting Address Pointer	Number of Words to write (01h to 10h)	refer to 7.1.2.1 refer to 7.1.2.2	handle	CRC-16

■ 7.1.2.1 Bridge through RF communication

If BlockWrite command specifies WordPtr=9E20h (WordAdr=F20h) of USER bank, specified data or command can be output through SPI interface and the response data from the connected external SPI slave device will be stored in WordPtr=9E31h to 9E3Fh (WordAdr=F31h to F3Fh) of USER bank. The response data shall be read by Read command to WordPtr=9E31h to 9E3Fh (WordAdr=F31h to F3Fh).

The data or command contained in Data bits of BlockWrite command shall be stored into WordPtr=9E20h to 9E2Fh (WordAdr=F20h to F2Fh) of USER bank and the maximum length of data is 16 words.

More detail is upon individual request.

■ 7.1.2.2 SPI master operation with memory data

If BlockWrite command specifies WordPtr=9E30h (WordAdr=F30h) of USER bank, the data stored in the specified area of USER bank can be output through SPI interface and the response data from the connected slave device will be stored in the same area of USER bank.

More detail is upon individual request.

■ 7.1.3 Control for XRST and CD

■ 7.1.3.1 Control for XRST

XRST outputs the value specified in bit13 of SPI master setting (refer to 7.1.1). The output from XRST is “L” level during the period from power supply until SPI master setting.

Bit13 controls XRST output level regardless of SPI master setting (bit15). As shown in Figure 7.1.3, it is used as reset signal to the external SPI slave device by “L” level output.

■ 7.1.3.2 Control for CD

CD outputs the data specified in CdData of SPI master command (refer to 7.1.2). The output from CD is “L” level during the period from power supply until the output of SPI master command.

The output level is controlled regardless of SPI master setting (bit15).

Figure 7.1.3 shows an example timing chart of XRST and CD based on the connection of Figure 3.4.1.1.

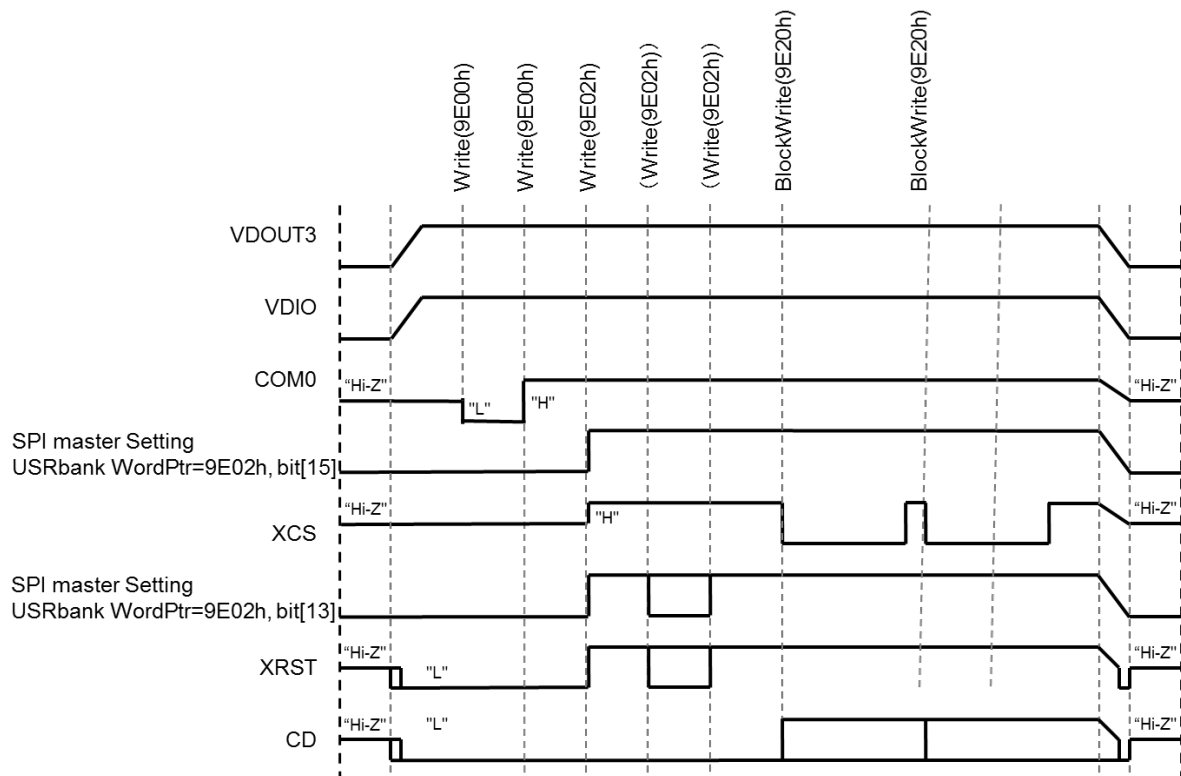


Figure 7.1.3 Control example of SPI Master communication using XRST and CD.

VDO3 is generated from RF and outputs to VDIO as IO power source. After SPI Master function is enabled by bit15 of SPI Master setting (refer to 7.1.1), XCS will be “H” level to output voltage to external SPI slave device through COM0.

XRST, which is controlled by bit13, outputs “L” level reset signal with a toggle to the slave device. CD, which is controlled by bit15, holds “H” level even after SPI master communication is finished.

■ 7.1.4 DI and DO Control (MuxDio)

■ 7.1.4.1 Separate DI and DO

Figure 7.1.4.1 shows the SPI master sequence with separate DI and DO, when bit14 of WordPtr=9E02h (WordAdr=F02h) of USER bank is set to “0”. During the SPI master operation, the output from DO is always “L” level or “H” level. The input to DI starts from the specified byte position.

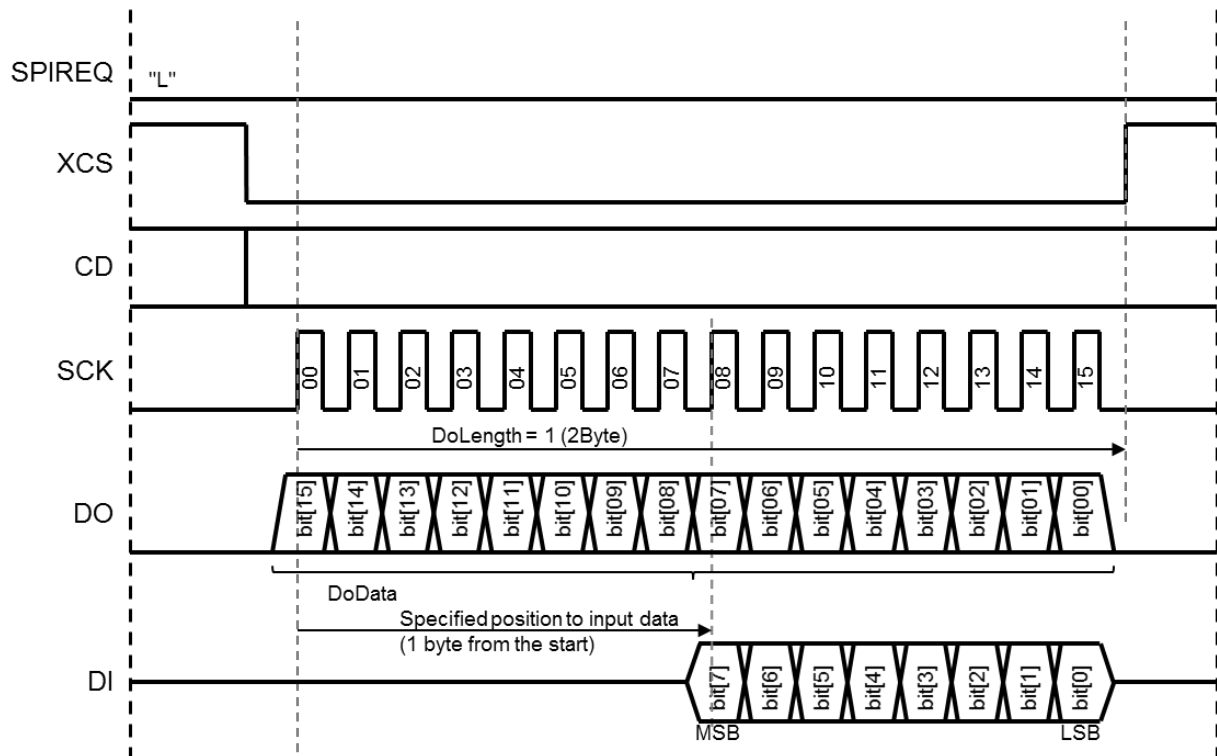


Figure 7.1.4.1 –Separate DI and DO (MuxDio=0)

■ 7.1.4.2 Multiplex DI and DO

Figure 7.1.4.2.1 and Figure 7.1.4.2.2 show examples of SPI master sequence with multiplex DI and DO, when bit14 of WordPtr=9E02h (WordAdr=F02h) of USER bank is set to “1”. In this condition, DI and DO is assumed to share common bus (DI/DO bus). During the period of the output from DO, the external SPI slave device shall stay DI/DO bus “Hi-Z”. The input to DI starts from the specified byte position and receive data until XCS will be raised. The other period is invalid.

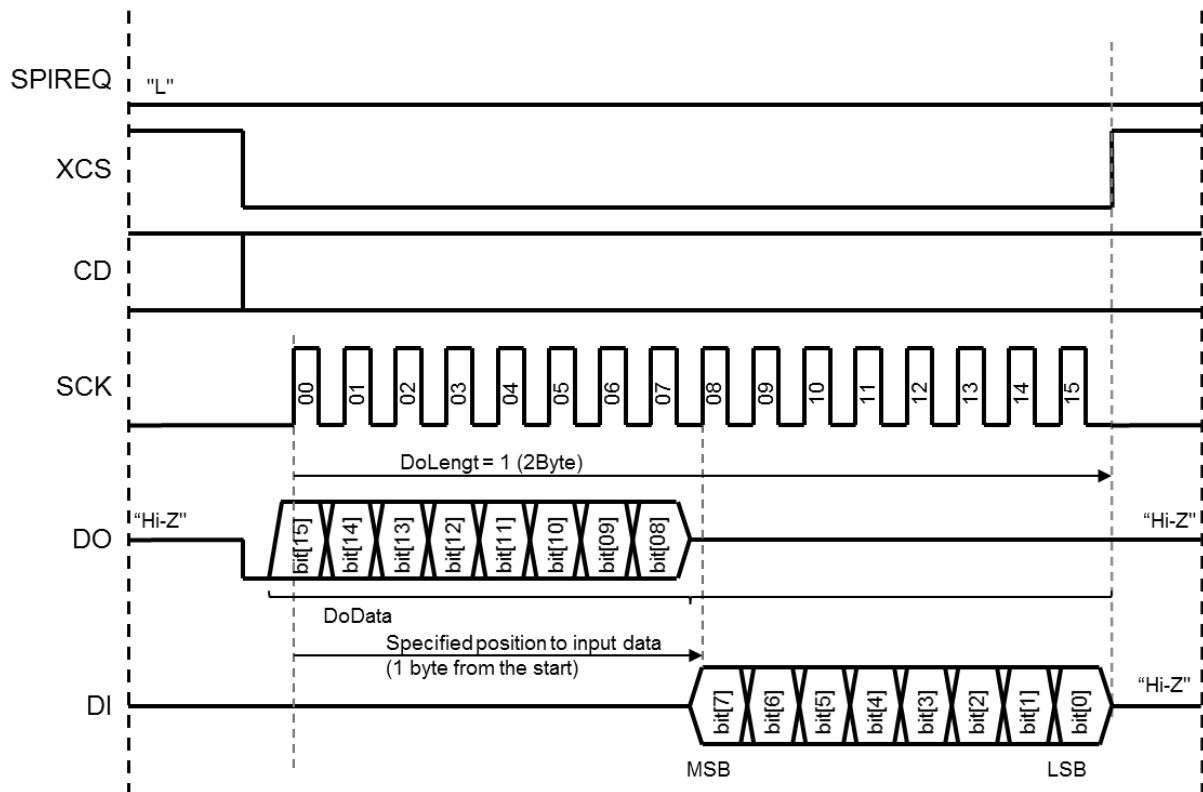


Figure 7.1.4.2.1 - Multiplex DI and DO (MuxDio=1)

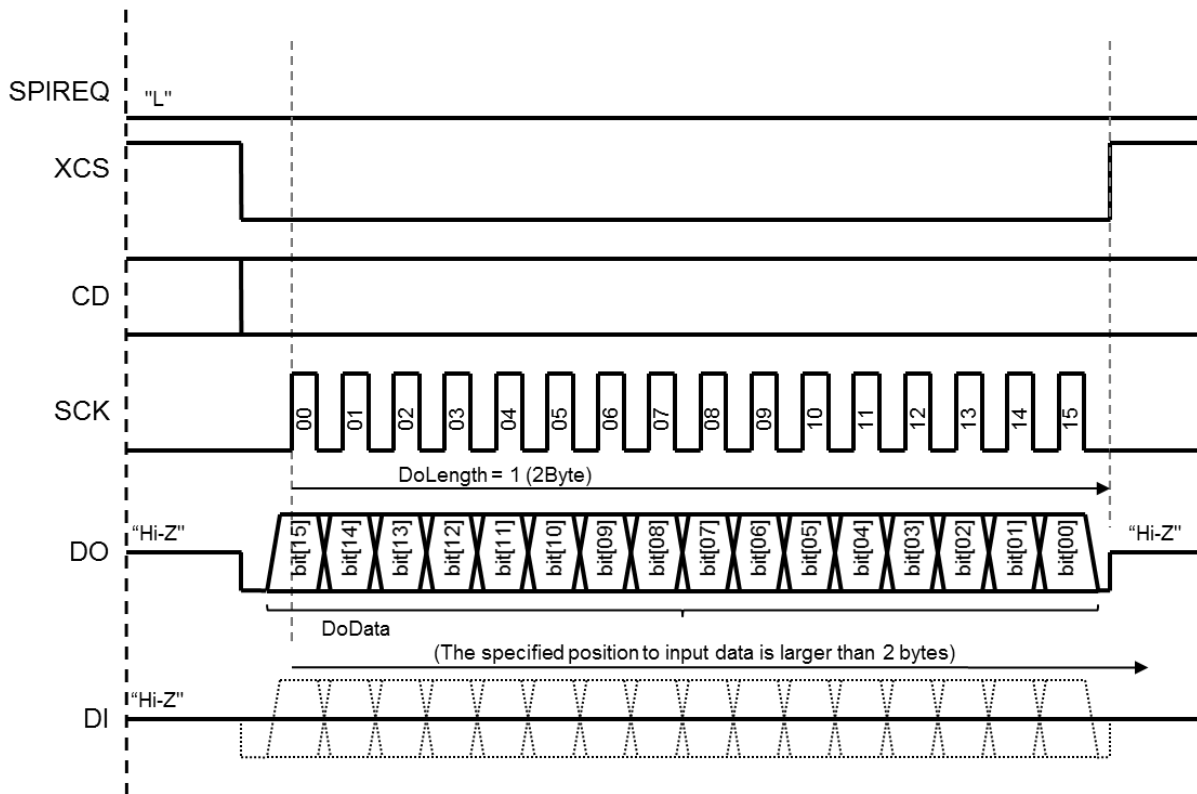


Figure 7.1.4.2.2 – Multiplex DI and DO /No data reception (MuxDio=1)

7.2 GPIO

7.2.1 GPIO Setting by Write operation

GPIO function is enabled by Write command to WordPtr=9E00h (WordAdr=F00h) of USER bank in order to control the status of COM[2:0] and INT. The setting value can be read by Read command, but the value will be reset to “0000h” under the following condition.

- Power off after setting
- Internal reset by low power detection

In these cases, it is necessary to set the value again by Write command in order to enable GPIO function. The data format of GPIO setting is shown in Table 7.2.1.

Table 7.2.1 GPIO control register format

MSB															LSB	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
FuncEn[3:0]				Reserved				SetEn[3:0]				IntDat	ComDat[2:0]			

FuncEn[3] : INT data input control

bit	Initial value	Setting value	Description
15	0	0	INT Input is rejected.
		1	INT input is enabled and readable from IntDat.

Note. FuncEn[3] is updated only when SetEn[3] is 1. If not, FuncEn[3] cannot be updated.

FuncEn[2:0] : COM2-0 output control of ComDat[2:0] setting value

bit	Initial value	Setting value	Description
14	0	0	COM2 stays “Hi-Z” level.
		1	COM2 outputs ComDat[2] setting value.
13	0	0	COM1 stays “Hi-Z” level.
		1	COM1 outputs ComDat[1] setting value.
12	0	0	COM0 stays “Hi-Z” level.
		1	COM0 outputs ComDat[0] setting value.

Note. FuncEn[2:0] is updated only when the corresponded bit of SetEn[2:0] is 1. If not, FuncEn[2:0] cannot be updated

Reserved

bit	Initial value	Setting value	Description
11:8	0h	0h	Set to 0.

SetEn[3:0] : Update control for FuncEn[3:0] and {IntDat,ComDat[2:0]}

bit	Initial value	Setting value	Description
7	0	0	Neither Func[3] nor IntDat are updated. The value before setting is not updated.
		1	Both Func[3] and IntDat are updated.
6	0	0	Neither Func[2] nor ComDat[2] are updated. The value before setting is not updated.
		1	Both Func[2] and ComDat[2] are updated.
5	0	0	Neither Func[1] nor ComDat[1] are updated. The value before setting is not updated.
		1	Both Func[1] and ComDat[1] are updated.
4	0	0	Neither Func[0] nor ComDat[0] are updated. The value before setting is not updated.
		1	Both Func[0] and ComDat[0] are updated.

Note. SetEn[3:0] manages to update the status of FuncEn[3:0] and {IntDat,ComDat[2:0]} , or not. Regardless of the setting value, 0h will be responded to Read command.

IntDat : INT input data

bit	Initial value	FuncEn[3]	Setting	Description
3	0	0	0	Return “0” to Read command.
			1	Return “1” to Read command.
		1	-	Input value from INT pin is returned to Read command. Written value is invalid.

Note. IntDat is updated only when SetEn[3] is 1

ComDat [2:0] : Output data control to COM2-0

bit	Initial value	FuncEn[*]	Setting	Description
2	0	0	-	Written value is invalid and COM2 is not affected. Return "0" to Read command.
		1	0	"L" level output to COM2.
			1	"H" level output to COM2.
1	0	0	-	Written value is invalid and COM1 is not affected. Return "0" to Read command.
		1	0	"L" level output to COM1.
			1	"H" level output to COM1.
0	0	0	-	Written value is invalid and COM0 is not affected. Return "0" to Read command.
		1	0	"L" level output to COM0.
			1	"H" level output to COM0.

Note. ComDat[2:0] will be updated only when the corresponded SetEn bit is 1.

The number(*) of FuncEn[*] indicates the corresponded bit number to ComDat[2:0] respectively

■ 7.2.2 Reading GPIO setting

The GPIO status information (Table 7.2.1) can be read by Read command to WordPtr=9E00h (WordAdr=F00h).

FuncEn[3] : IINT data input control

bit	Initial value	Read value	Description
15	0	0	INT Input is rejected.
		1	INT input is readable from InDat.

FuncEn[2:0] : Com[2:0] output control of ComDat[2:0] setting value

bit	Initial value	Read value	Description
14	0	0	COM2 is "Hi-Z" level.
		1	ComDat[2] setting value is output to COM2.
13	0	0	COM1 is "Hi-Z" level.
		1	ComDat[1] setting value is output to COM1.
12	0	0	COM0 is "Hi-Z" level.
		1	ComDat[0] setting value is output to COM0.

Reserved

bit	Read value	Description
11:8	0h	Reserved bits always return "0".

SetEn[2:0] : Update control for FuncEn[3:0] and {IntDat,ComDat[2:0]} FuncEn[3:0]

bit	Read value	Description
7:4	0h	Regardless of the written value, read value is always "0". The Written value is for updating FncEn[3:0],IntDat,ComDat[2:0], which do not affect to read value.

IntDat :

bit	Initial value	FuncEn[3]	Description
3	0	0	The written value for setting is returned as read value. It is possible to apply for test use such as branch test with INT value when INT is not connected to external devices.
		1	Input value from INT is returned to Read command.

ComDat [2:0] : Output data control to COM2-0

bit	Initial value	FuncEn[*]	Read value	Description
2	0	0	0	COM2 is "Hi-Z" level. Regardless of the written value, read value is always "0".
		1	0	"L" level output to COM2.
			1	"H" level output to COM2.
1	0	0	0	COM1 is "Hi-Z" level. Regardless of the written value, read value is always "0".
		1	0	"L" level output to COM1.
			1	"H" level output to COM1.
0	0	0	0	COM0 is "Hi-Z" level. Regardless of the written value, read value is always "0".
		1	0	"L" level output to COM0.
			1	"H" level output to COM0.

: The number() of FuncEn[*] indicates the corresponded bit number to ComDat[2:0] respectively

■ 7.2.3 GPIO Truth Table

■ 7.2.3.1 INT control


Truth table of INT control is shown in Table 7.2.3.1.

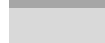
Table 7.2.3.1 INT Truth Table

Status before Setting		Written Data			Status after Setting					Description
FuncEn	IntDat	SetEn	FuncEn	IntDat	INT IO	FuncEn	IntDat Setting value	IO Control	IntDat Read value	
0	0	0	-	-	-	0	0*	Input Reject	0	The status is not changed by setting, and IntDat read value is "0".
0	1	0	-	-	-	0	1*	Input Reject	1	The status is not changed by setting, and IntDat read value is "1".
1	-	0	-	-	0*	1	-	Input Valid	0	The status is not changed by setting, and INT IO value "0" is read.
1	-	0	-	-	1*	1	-	Input Valid	1	The status is not changed by setting, and INT IO value "1" is read.
-	-	1	0	0	-	0	0*	Input Reject	0	The statu is updated and IndDat value "0" is read.
-	-	1	0	1	-	0	1*	Input Reject	1	The status is updated and IndDat value "1" is read.
-	-	1	1	-	0*	1	-	Input Valid	0	The Status is updated and INT IO value "0" is read.
-	-	1	1	-	1*	1	-	Input Valid	1	The Status is updated and INT IO value "1" is read.

- Any data dose not affect status update or read value.

* INT IO data is readable on FuncEn=1.

 Status is not updated on SenEn=0.

 Status is updated on SenEn=1.

7.2.3.2 COM[2:0] control

Truth table of COM[2:0] control is shown in Table 7.2.3.2.

Table 7.2.3.2 COM[2:0] Truth Table

Status before Setting		Written Data			Status after Setting			ComDat
FuncEn	ComDat	SetEn	FuncEn	ComDat	FuncEn	ComDat	IO output	Read value
0	-	0	-	-	0	-	Hi-Z	0
1	0	0	-	-	1	0	0	0
1	1	0	-	-	1	1	1	1
-	-	1	0	-	0	-	Hi-Z	0
-	-	1	1	0	1	0	0	0
-	-	1	1	1	1	1	1	1

- Any data does not affect status update or read value.

Status is not updated on SenEn=0.

Status is updated on SenEn=1.

■ 7.3 Key Matrix scan

■ 7.3.1 Key Matrix scan setting

Key Matrix scan function is enabled by Write command to WordPtr=9E01h(WordAdr=F01h) of USER bank. It is necessary to enable setting every power on cycle. The setting value can be read by Read command, but the value will be reset to “0000h” under the following condition.

- Key Matrix scan Disable (bit15="0")
- Power off after setting
- Internal reset by low power detection

In these cases, it is necessary to set the value again by Write command in order to enable Key Matrix scan function. The data format of Key Matrix scan setting register is shown in Table7.3.1.

Table 7.3.1 –Data format of Key Matrix scan setting

MSB														LSB	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
En	Time Sample	Reserved						LastColumn				Reserved			

En: Key Matrix scan operation Enable/Disable

bit	Initial value	Setting value	Setting description
15	0h	0	Key Matrix scan operation Disable
		1	Key Matrix scan operation Enable

TimeSample : Activate time for Column 1 (Reference value for enough power supply)

bit	Initial value	Setting value	Setting description
14:13	0h	0h	256us
		1h	512us
		2h	64us
		3h	128us

Reserved

bit	Initial value	Setting value	Setting description
12:8	0h	0h	Set to 0

LastColumn

bit	Initial value	Setting value	Setting description
7:4	0h	3h* to Fh	Specify “the connected Number of Column -1”

*. When the number of column is less than 4, set to “3h”.

Reserved

bit	Initial value	Setting value	Setting description
3:0	0h	0h	Set to 0

■ 7.3.2 Block Erase Command for Key Matrix scan

Key Matrix scan function is executed by BlockErase command to WordPtr=9E10h (WordAdr=F10h) of USER bank, and detects the key input status of the connected device as shown in Figure 3.6.1. Up to 4 columns of key information, which include pressed key, are stored in WordPtr=9E10h to 9E13h (WordAdr=F10h to F13h). The Command format is shown in Table.7.3.2.

Table 7.3.2 - Key Matrix scan with BlockErase command

	Command	MemBank	WordPtr	WordCount	RN	CRC
Number of bits	8	2	16(EBV)	8	16	16
Description	1100 1000	11:USER	1001 1110 0001 0000	LastColumn+1 (refer to 7.3.1)	handle	CRC-16

■ 7.3.3 Response to Block Erase Command

The error code “8Eh” will be replied if there are no pressed Keys when Key Matrix scan command is executed by BlockErase. The normal reply will be returned if the pressed keys of 1Column to 4Column are detected. The error code “0Bh” (indicating Insufficient power) will be replied if internal voltage during Key Matrix scan operation caused is dropped down.

■ 7.3.4 Read Command for reading Key data

The pressed Key data will be confirmed by Read command to WordPtr= 9E10h to 9E13h (WordAdr=F10h to F13h). The Command format is shown in Table.7.3.4.

Table 7.3.4 - Key data confirmation with Read command

	Command	MemBank	WordPtr	WordCount	RN	CRC
Number of bits	8	2	16 (EBV)	8	16	16
Description	1100 0010	11:USER	1001 1110 0001 0000	04h Count of key data to read	handle	CRC-16

■ 7.3.5 Key data format

The pressed key data is stored to WordPtr=9E10h to 9E13h (WordAdr=F10h to F13h) in the format as shown in Table 7.3.5

Table 7.3.5 Key Matrix scan data format

MSB															LSB
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0h				KC				KR							

KC: Column number (KC00 to KC15) of Key Matrix

bit	Initial value	Retrieved value	Description
11:8	0h	N	KC Pin Number (N= 0 to Fh) e. g. 0111b for KC7

KR : Raw data (KR00 to KR07) of Key Matrix

bit	Initial value	Retrieved value	Description
7:0	0h	xxxx xxxxb	8bits of Key information on the detected KC[11:8] e. g. 00110000b for the input to KR04 and KR05 (refer to Figure 7.3.8)

One command cycle updates WordPtr=9E10h to 9E13h (WordAdr=F10h to F13h), where 4 columns of data is stored. If the detected number of columns is less than 4, the same number of word will be updated and the rest will be cleared to 0000h. For example, if the detected column is only 1, the data stored in WordPtr=9E11h to 9E13h (WordAdr=F11h to F13h) will be cleared to 0000h.

■ 7.3.6 Key Matrix scan interface input/output

Once Key Matrix scan starts, “H” level of activation signal switches to select to the columns from KC00 to KC15. When the column is not selected, the output is “Hi-Z”. When the pressed key is detected, the data outputs. Figure 7.3.6 describes an example that KR05 is pressed on KC01 Column, and it takes 4ms to scan 16 Columns.

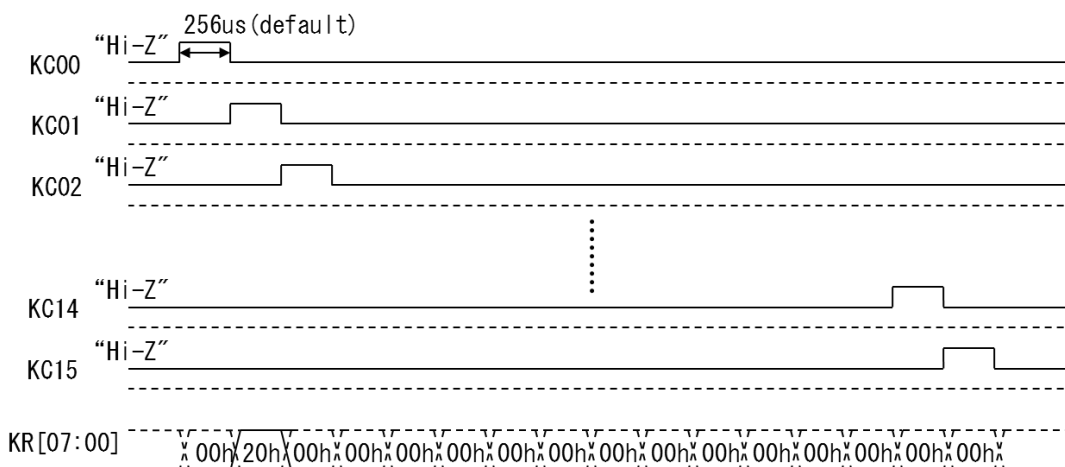


Figure 7.3.6 -Key Matrix scan signal input/output

■ 7.3.7 Communication flow

The communication flow among reader/writer, this LSI and Key input device is described in Figure 7.3.7
The scan operation for Key input device will be processed during T5 time (Max 20ms) of EPC starting from receipt of BlockErase command to reply

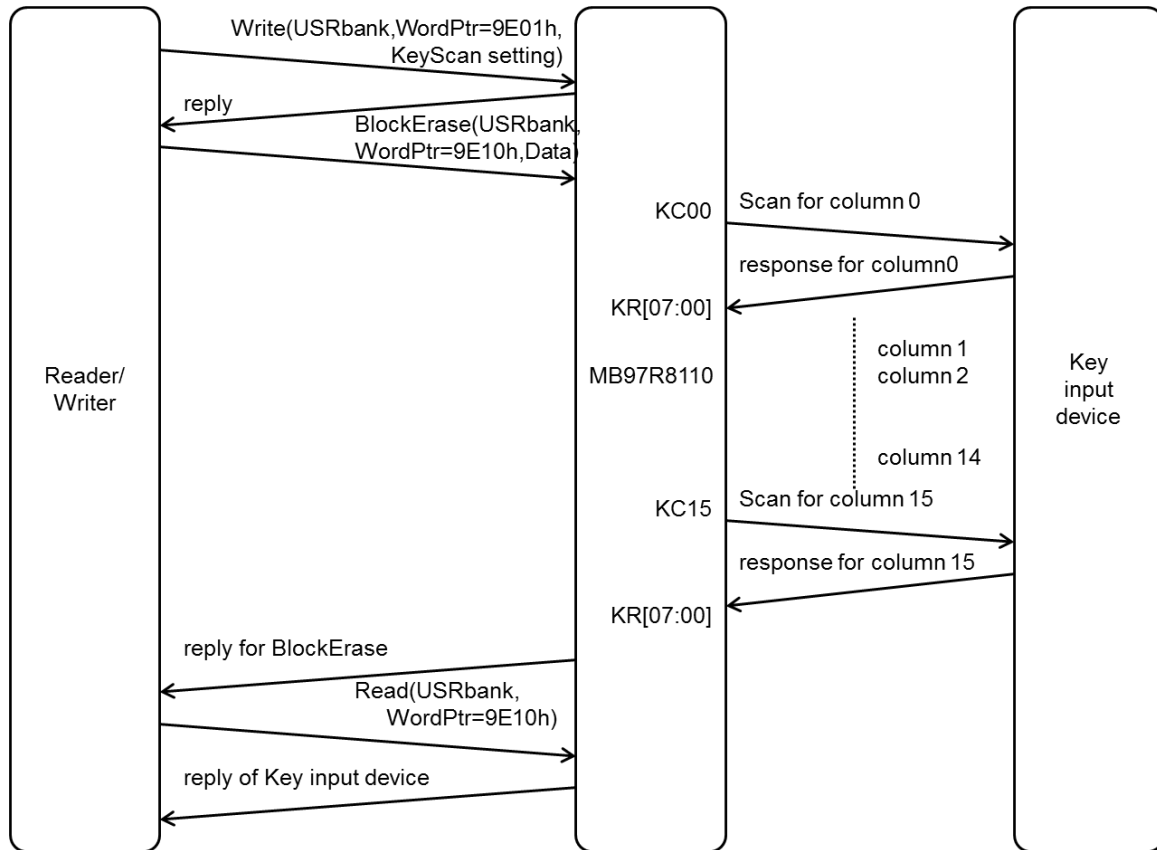


Figure 7.3.7 - Key Matrix scan operation communication flow

■ 7.3.8 The pressed Key number and Key Matrix scan clock operation

The number of scanned data is up to 4 columns once one BlockErase command is executed. Figure 7.3.8 describes an example of 8x16 Key Matrix scan that there are 5 columns with pressed Keys.

In the example, the scan column will stop at KC10 where the 4th Key data is scanned, and the data 0080h, 0102h, 0430h, 0A01h will be stored respectively into WordPtr=9E10h to 9E13h (WordAdr=F10h to F13h) of USER bank as the 1st output of scan. It is identified that KR05 and KR04 Keys are pressed simultaneously on KC04. This LSI will reply to BlockErase command normally after 4 column data is stored in the memory. Upon the next BlockErase command, the scan will start from KC11 which is the next column to KC10 the last scan of the 1st output. If the Key Matrix scan operation reaches to KC15, it backs to KC00 as 2nd round and continues scanning until detecting all 4 column data or accumulated scanning column reaches 16, and then data will be stored as the 2nd output. The example shows that the data 0F40h, 0080h, 0102h, 0430h will be stored respectively into WordPtr=9E10h to 9E13h (WordAdr=F10h to F13h) of USER bank.

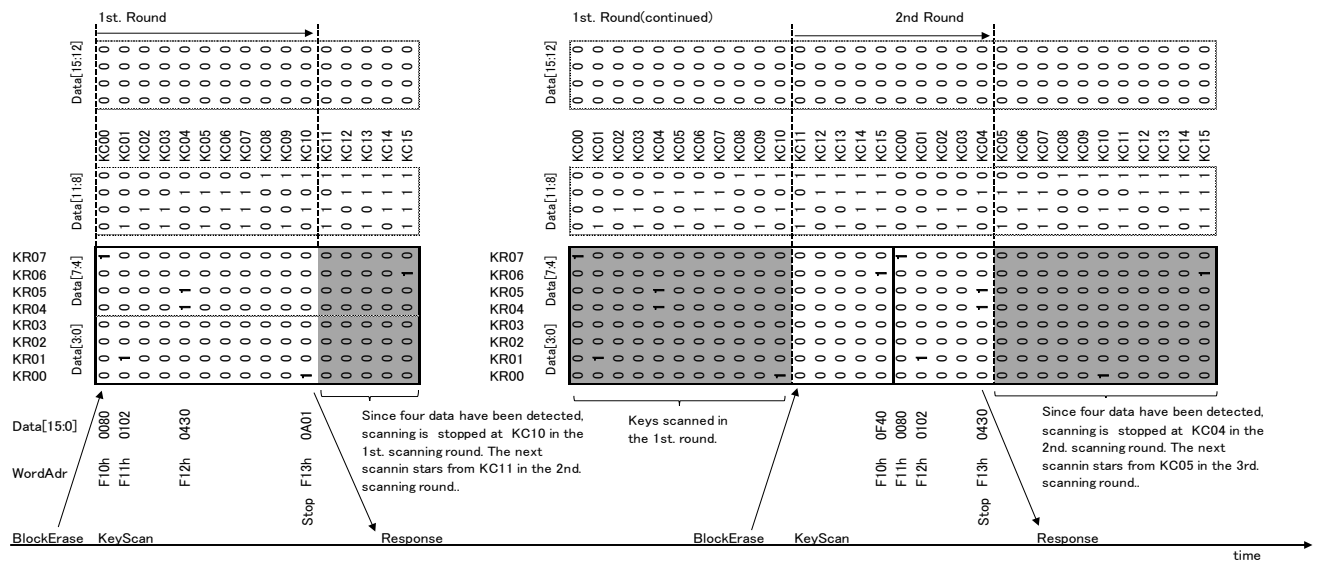


Figure 7.3.8 - Key Matrix scan operation communication flow

■ 7.4 VDOUT3 Power output

■ 7.4.1 VDOUT3 setting

VDOUT3 is power output function, which generates RF power through PWRP3-PWPM3 and provide it for external devices. This function is enabled by Write command to WordPtr=9E03h(WordAdr=F03h) of USER bank in order to set the VDOUT3 output voltage and detection voltage. It is necessary to enable setting every power on cycle. The status of actual output voltage to the detection voltage is updated accordingly in bit1 to 2 and can be confirmed by Read command.

The data format of VDOUT3 setting by Write command is shown in Table7.4.1.

Table 7.4.1 –Data format of VDOUT3 setting

MSB															LSB	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
En Det1	SetVolDet1			En Det2	SetVolDet2			Reserved					VolDet			

EnDet1 Voltage detection enable/disable for SetVolDet1

bit	Initial value	Setting value	Setting description
15	0	0	Voltage detection Disabled (SetVoDet1 is invalid)
		1	Voltage detection Enabled (SetVoDet1 is valid)

SetVolDet1 Lower limit voltage setting for the detection

bit	Initial value	Setting value	Detection voltage
14:12	0h	0h	3.1±0.25V
		1h	3.0±0.25V
		2h	2.9±0.25V
		3h	2.8±0.25V
		4h	2.7±0.25V
		5h	2.6±0.25V
		6h	2.5±0.25V
		7h	2.4±0.25V

EnDet2 Voltage detection enable/disable for SetVolDet2

bit	Initial value	Setting value	Setting description
11	0	0	Voltage detection Disabled (SetVoDet2 is invalid)
		1	Voltage detection Enabled (SetVoDet2 is valid)

SetVolDet2

bit	Initial value	Setting value	Detection voltage	Output Voltage*	
				Typ.	Max.
10:8	0h	0h	3.3±0.25V	3.4V	3.6V
		1h	3.2±0.25V	3.4V	3.6V
		2h	3.1±0.25V	3.3V	3.5V
		3h	3.0±0.25V	3.3V	3.5V
		4h	3.0±0.25V	3.2V	3.4V
		5h	2.9±0.25V	3.2V	3.4V
		6h	2.8±0.25V	3.1V	3.3V
		7h	2.7±0.25V	3.1V	3.3V

*.VDOUT3 output voltage setting is always valid regardless of the EnDet2 setting. When the power from reader is insufficient, VDOUT3 output voltage may not reach the expected value.

Reserved

bit	Initial value	Setting value	Setting description
7:2	0h	0h	Set to 0

VolDet (Read only) VDOUT3 output voltage detection

bit	Initial value	Setting value	Setting description
1	-	0	VDOUT3 < SetVolDet1
		1	VDOUT3 > SetVolDet1
0	-	0	VDOUT3 < SetVolDet2
		1	VDOUT3 > SetVolDet2

- VolDet bit1,0=0 : VDOUT3 output voltage is lower than the voltage set in SetVolDet1,2
- VolDet bit1,0=1 : VDOUT3 output voltage is higher than the voltage set in SetVolDet1,2

■ 7.4.2 VDOUT3 Output current on receiving power

Figure 7.4.2 shows the VDOUT3 output current with 3V power supply on different receiving power level from RF (PWRP3-PWRM3 antenna). In this figure, 600μA with 3V output requires +8dBm as receiving power from RF.

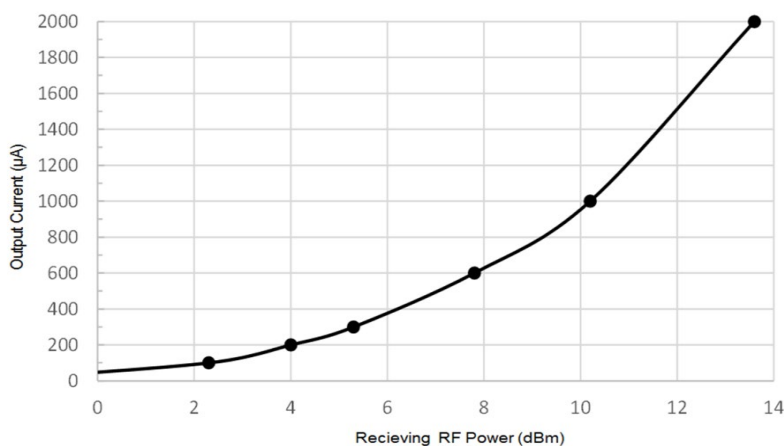


Figure 7.4.2 VDOUT3 output current with 3V power supply

■ 8 ELECTRICAL CHARACTERISTICS

■ 8.1 Absolute Maximum Rating

Table 8.1 - Absolute Maximum Rating

Parameter	Symbol	Value			Unit	Conditions/Remarks
		MIN	TYP	MAX		
Maximum input voltage	Vmax	—	—	4.0	V	PWRP1-PWRM1,PWRP3-PWRM3
Power supply voltage	VDD	-0.5	—	+4.0	V	
Input voltage	VIN	-0.5	—	VDD+0.5	V	
Output voltage	VOUT	-0.5	—	VDD+0.5	V	
ESD voltage immunity	VESD	-	—	±1200	V	Human Body Model
Storage temperature	Tstg	-40	—	+85	°C	

■ 8.2 Recommended Operation Conditions

Table 8.2 - Recommended Operation Conditions

Parameter	Symbol	Value			Unit	Conditions/Remarks
		MIN	TYP	MAX		
Operating ambient temperature	Ta	-40	—	+85	°C	
Retention guaranteed temperature	Trtn1	-40	—	+85	°C	Retention guaranteed period: 10years
RF communication						
Antenna input frequency	Fclk	860	—	960	MHz	
Receiving modulation depth	(A-B)/A	80	90	100	%	
Receiving bit rate	F_fwd	26.7	—	128	kbps	PIE code: mark rate =1/2
Receiving waveform rise time	Tr	1	—	500	μs	
Receiving waveform settling time	Ts	—	—	1500	μs	
Receiving waveform fall time	Tf	1	—	500	μs	
SPI slave communication						
Power supply voltage	VDD	1.8	—	3.6	V	

■ 8.3 RF Communication Characteristics

Table 8.3 - RF Communication Characteristics

Parameter	Symbol	Value			Unit	Conditions/Remarks
		MIN	TYP	MAX		
Minimum operating power when reading	PR_MIN	—	−12	—	dBm	Measured with bare die Tari=25us, RTcal=2.5Tari, TRcal=3.0RTcal, DR=8, FM0, BLF=43kbps, DSB-ASK, Modulation depth=90% memory access length ≤ 6Word (※1)
Minimum operating power when writing	PW_MIN	—	−12	—	dBm	
Maximum operating power	PMAX		+20		dBm	
Equivalent input capacitance (PWRP1-PWRM1)	CP	—	0.8	—	pF	920MHz: Input power= -12dBm, parallel model
		—	0.8	—	pF	866MHz: Input power= -12dBm, parallel model
Equivalent input resistance (PWRP1-PWRM1)	RP	—	4.1	—	KΩ	920MHz: Input power= -12dBm, parallel model
		—	4.9	—	KΩ	866MHz: Input power= -12dBm, parallel model
Equivalent input capacitance (PWRP3-PWRM3)	CP	—	2.5	—	pF	920MHz: Input power= +8dBm, parallel model
		—	2.3	—	pF	866MHz: Input power= +8dBm, parallel model
Equivalent input resistance (PWRP1-PWRM1)	RP	—	140	—	Ω	920MHz: Input power= +8dBm, parallel model
		—	155	—	Ω	866MHz: Input power= +8dBm, parallel model
Returning bit rate	F_rtn	40		640	kbps	

※1 These characteristics are the values for the standalone LSI, and do not specify the values when the LSI is connected to other devices.

■ 8.4 SPI Slave Communication

■ 8.4.1 DC Characteristics

Table 8.4.1 - DC Characteristics

Parameter		Symbol	Value			Unit	Conditions
			MIN	TYP	MAX		
Input leakage current		ILI	—	—	±5	μA	VIN = VDD (SPIREQ pin)
			—	—	±1	μA	VIN = 0V (SPIREQ pin) VIN = 0V to VDD (the other pins※1)
Output leakage current		ILO	—	—	±1	μA	VOUT = 0V to VDD, when output is "Hi-Z" (output pin ※2)
Power supply	ICC	ICC	—	70	200	μA	SCK = 2MHz, Vdd=3.0V
	IPD1	IPD1	—	1	10	μA	SPIREQ = 0V or open No RF reception
	ISB	ISB	—	20	40	μA	SPIREQ = VDD XCS=VDD
"H" level Input voltage		VIH	VDDx0.7	—	VDD+0.3	V	※3
"L" level Input voltage		VIL	−0.3	—	VDDx0.3	V	※3
"H" level Output voltage		VOH	VDD-0.5	—	VDD	V	IOH= −2mA ※2
"L" level Output voltage		VOL	0	—	0.4	V	IOL= 2mA ※2
SPI pin pull-down resistance		RIN	0.8	1	1.2	MΩ	VIN = VDD SPIREQ Pin

※1 : XCS, SCK, DI Pin ※2 : DO, SPIACK Pin ※3 : SPIREQ, XCS, SCK, DI Pin

■ 8.4.2 AC Characteristics

Table 8.4.2 - AC Characteristics

Parameter	Symbol	Value			Unit	Pin
		MIN	TYP	MAX		
SCK clock frequency	f_{CK}	—	—	2	MHz	SCK
Clock high time	t_{CH}	200	—	—	ns	SCK
Clock low time	t_{CL}	200	—	—	ns	SCK
Chip select set time	t_{CSU}	60	—	—	ns	XCS,SCK
Chip select hold time	t_{CSH}	20	—	—	ns	XCS,SCK
Output enable time	t_{ODLZ}	20	—	—	ns	DO,SCK
Output disable time	t_{ODZ}	—	—	60	ns	DO,SCK
Output data valid time	t_{ODV}	—	—	80	ns	DO,XCS
Output hold time	t_{OH}	0	—	—	ns	DO,SCK
Deselect time	t_D	280	—	—	ns	XCS
Data rise time	t_R	—	—	5	ns	DI,XCS,SPIREQ
Data fall time	t_F	—	—	5	ns	DI,XCS,SPIREQ
Data set up time	t_{DIS}	20	—	—	ns	DI,SCK
Data hold time	T_{DIH}	20	—	—	ns	DI,SCK

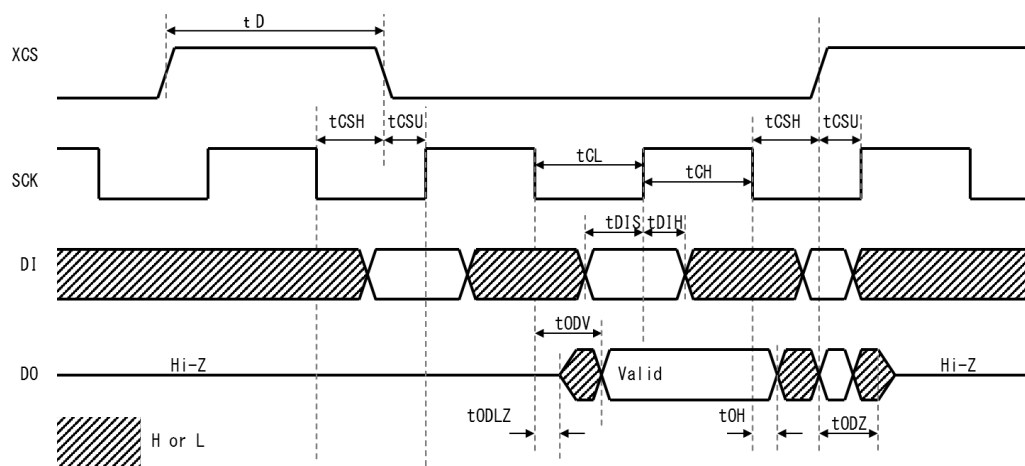


Figure 8.4.2 - SPI slave timing

■ 8.4.3 Power sequence (SPI Master function is not used)

In SPI slave communication mode, the power sequence when SPI master function is not used is shown in Figure 8.4.3.1 (with VDD off control), and Figure 8.4.3.2 (without VDD off control). And the timing specification of the sequence is shown in Table.8.4.3.

Power-up sequence of SPI slave communication;

Before starting communication, VDD shall be set to “H” level and SPIREQ shall be set to “H” level in a row. Then SPIACK outputs “H” level in the time of t_{OAV} from the rising edge of SPIREQ. In parallel, XCS shall be set to “H” level within the time of t_{CUS} from the rising edge of SPIREQ. SPI slave communication can start when XCS is set to “L” level in the time of t_{PU} from the rising edge of SPIACK.

Power-down sequence of SPI slave communication;

After taking the period of t_{PD} from the rising edge of XCS, SPIREQ shall be set to “L” level. Then SPIACK outputs “L” level in the time of t_{OHA} from the falling edge of SPIREQ. In parallel, XCS shall be set to “L” level within the time of t_{CHS} from the falling edge of SPIREQ. When VDD will be turned off, VDD shall be set to “L” level in more than the time of t_{PH} from the falling edge of SPIACK.

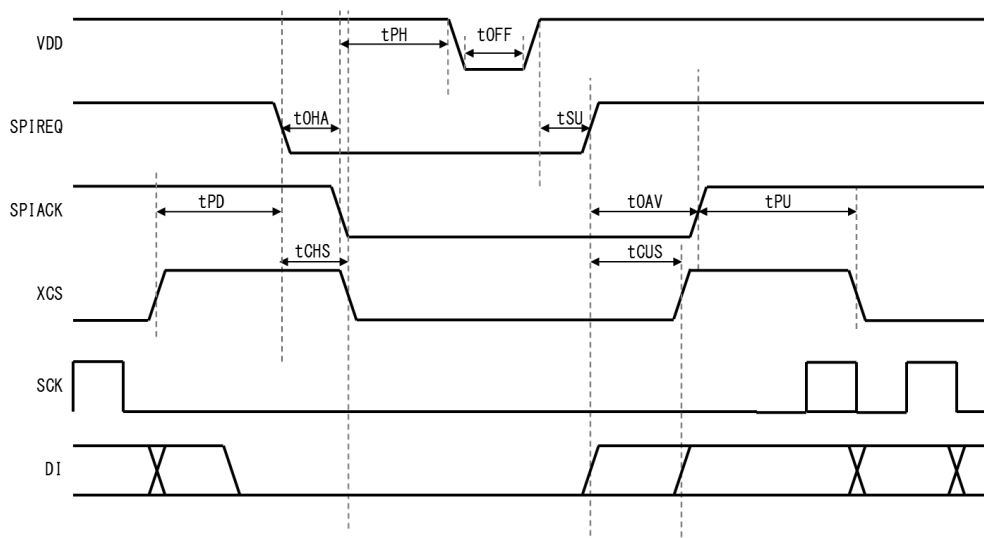


Figure 8.4.3.1 Power sequence (SPI master function is not used with VDD off control)

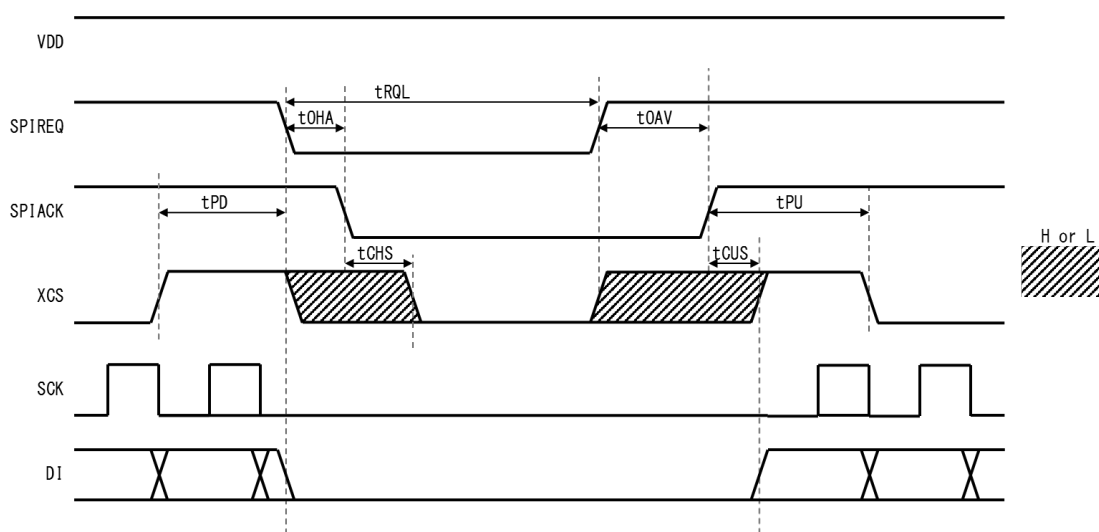


Figure 8.4.3.2 Power sequence (SPI master function is not used without VDD off control)

Table 8.4.3 Timing specifications during SPI slave communication

Parameter	Symbol	Value			Unit
		MIN	TYP	MAX	
SPIREQ rising start time	tSU	500	—	—	μs
SPIREQ low time	tRQL	1000	—	—	μs
Power hold time	tPH	0	—	—	μs
XCS level hold time at power ON	tPU	10	—	—	μs
XCS level hold time at power OFF	tPD	1	—	—	μs
Power off time	tOFF	1000	—	—	μs
Output SPIACK definite time	tOAV	1	—	20000	μs
Output SPIACK hold time	tOHA	5	—	10000	ns
XCS setup time(start)	tCUS	—	—	1	μs
XCS hold time(start)	tCHS	0	—	—	μs

If the device does not operate within the specified conditions of cycle or power on/off sequence, memory data cannot be guaranteed.

■ 8.4.4 Power Sequence (SPI Master function is used)

In SPI slave communication mode, the power sequence when SPI master function is used is shown in Figure 8.4.4.1 (with VDD off control), and Figure 8.4.4.2 (without VDD off control). And the timing specification of the sequence is in common as shown in Table.8.4.3.

Power-up sequence of SPI slave communication;

Before starting communication, VDD shall be set to “H” level and SPIREQ shall be set to “H” level in a row. Then SPIACK outputs “H” level in the time of t_{OAV} from the rising edge of SPIREQ. At this point, XCS and SCK shall be “Hi-Z” because SPI master operation may have been used during the period when SPI has been “L” level. XCS shall be set to “H” level within the period of t_{CUS} from the rising edge of SPIACK, and SCK shall be set to “L” level at the same time. SPI slave communication can start when XCS is set to “L” level in the time of t_{PU} from the rising edge of SPIACK.

Power-down sequence of SPI slave communication;

After taking the period of t_{PD} from the rising edge of XCS, SPIREQ shall be set to “L” level. Then SPIACK outputs “L” level in the time of t_{OHA} from the falling edge of SPIREQ. After taking the time of t_{CHS} from the falling edge of SPIACK, the input to XCS and SCK will be invalid and shall be set to “Hi-Z” in order to enable XCS and SCK for SPI master communication. When VDD will be turned off, VDD shall be set to “L” level in the period of t_{PH} from the falling edge of SPIACK.

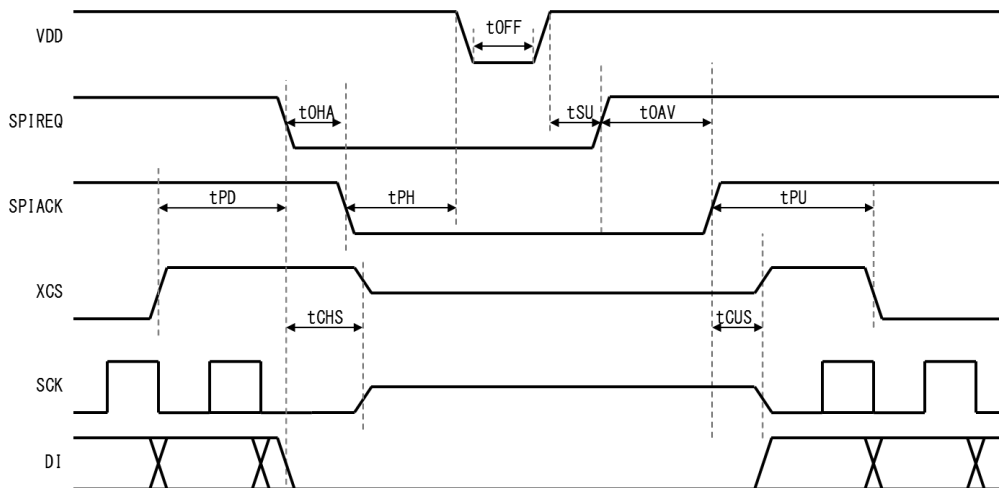


Figure 8.4.4.1 Power sequence (SPI master function is used with VDD off control)

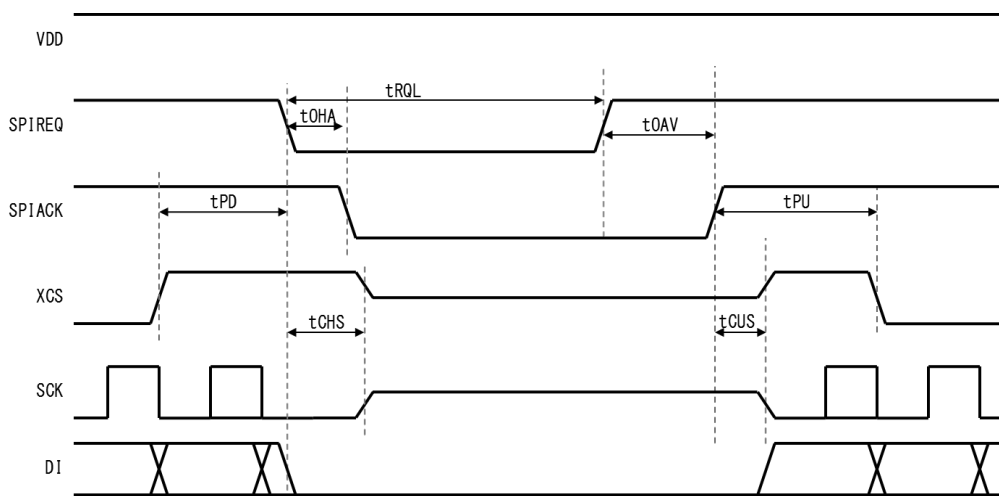


Figure 8.4.4.2 Power sequence (SPI master function is used without VDD off control)

■ 8.5 SPI Master Communication

■ 8.5.1 DC Characteristics

Table 8.5.1 - DC Characteristics

Parameter	Symbol	Value			Unit	Conditions
		MIN	TYP	MAX		
Input leakage current	ILI	—	—	±1	μA	※1
Output leakage current	ILO	—	—	±1	μA	"Hi-Z" state ※3
Power output voltage	VDOUT3	2.95	—	3.6	V	refer to 7.4.2 ※2
"H" level Input voltage	VIH	VOPSP13×0.7	—	VOPSP13+0.5	V	※1
"L" level Input voltage	VIL	-0.5	—	VOPSP13×0.3	V	※1
"H" level Output voltage	VOH	VOPSP13-0.5	—	—	V	IOH = -0.5mA ※3
"L" level Output voltage	VOL	—	—	0.4	V	IOL = 0.5mA ※3

※1 : DI Pin ※2 : VDOUT3, VDIO Pin ※3 : XCS, SCK, DO, CD, XRST Pin

■ 8.5.2 AC Characteristics

Table 8.5.2 - AC Characteristics

Parameter	Symbol	Value			Unit	Related Pin
		MIN	TYP	MAX		
SCK clock frequency	fCK	3.9	—	500	kHz	SCK
Clock high time	tCH	300	—	—	ns	SCK
Clock low time	tCL	300	—	—	ns	SCK
Chip select setup time	tCSU	600	—	—	ns	XCS,CD,SCK
Chip select hold time	tCSH	300	—	—	ns	XCS,CD,SCK
Input enable time	tIDLZ	10	—	—	ns	DI
Input disable time	tIDZ	—	—	1200	ns	DI,XCS
Output setup time	tDOS	35	—	—	ns	DO,SCK
Output hold time	tDOH	300	—	—	ns	DO,SCK
Output disable time	tODZ	0	—	10	ns	DO
Data rise time	tR	—	—	5	ns	DI
Data fall time	tF	—	—	5	ns	DI
Data confirm time	tIDV	—	—	100	ns	DI,SCK
Data hold time	tIDH	10	—	—	ns	DI,SCK

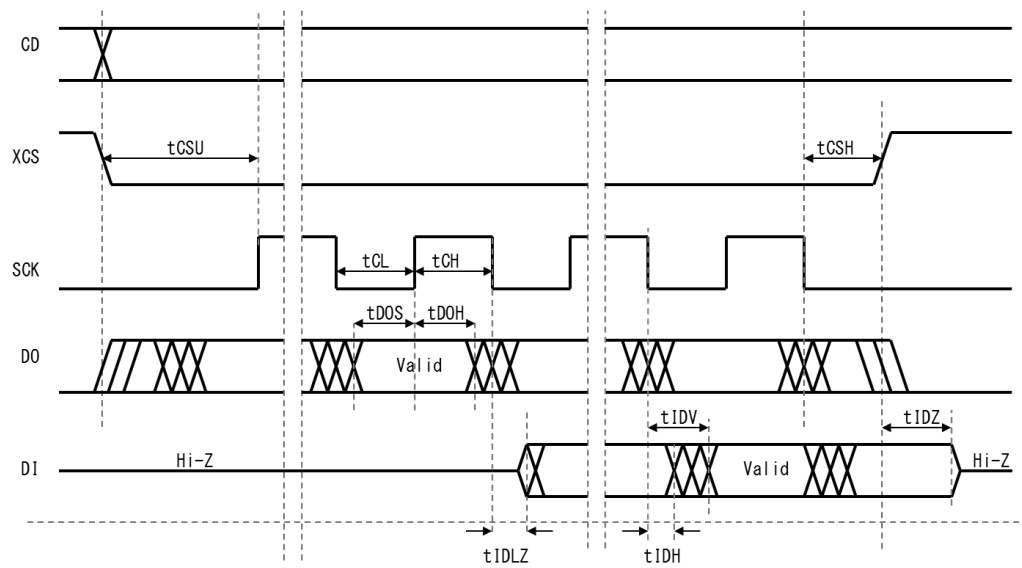


Figure 8.5.2.1 - SPI master timing(MuxDio=0)

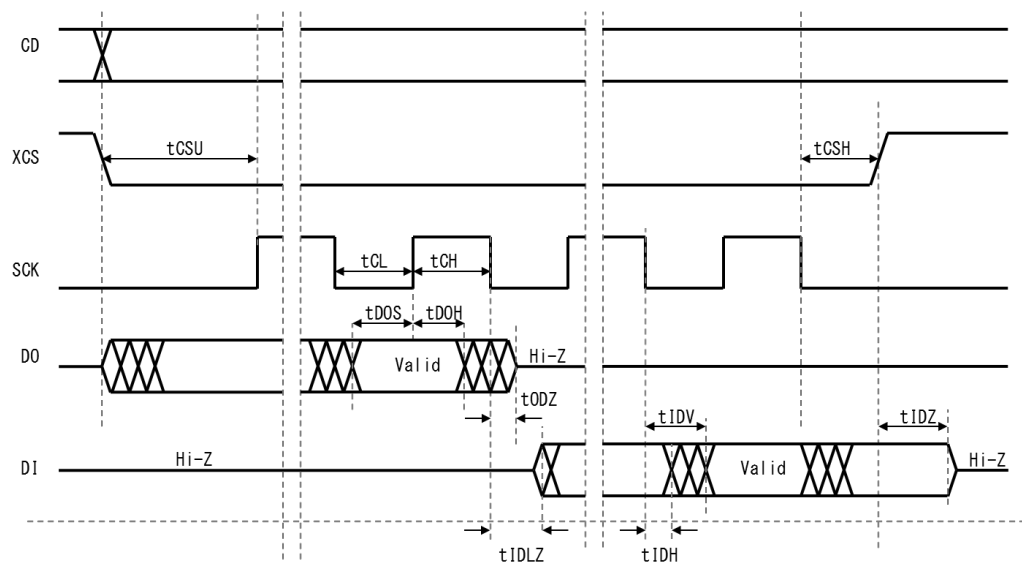


Figure 8.5.2.2 - SPI master timing(MuxDio=1)

■ 8.6 Key Matrix scan Characteristics

■ 8.6.1 DC Characteristics

Table 8.6.1 - DC Characteristics

Parameter	Symbol	Value			Unit	Condition
		MIN	TYP	MAX		
Input leakage current	ILI	—	—	±1	μA	"L" Input ※1
		—	12	—	μA	"L" Input ※1
Output leakage current	ILO	—	—	±1	μA	"Hi-Z" ※2
Power output voltage	VDOUT18	1.65	—	1.95	V	※3
"H" level Input voltage	VIH	VDOUT18×0.7	—	VDOUT18+0.5	V	※1
"L" level Input voltage	VIL	−0.5	—	VDOUT18×0.3	V	※1
"H" level Output voltage	VOH	VDOUT18 − 0.5	—	VDOUT18	V	IOH = −10μA ※2
Pull-down resistance	RIN	—	150	—	kΩ	※1

※1 : KR[0:7] Pin ※2 : KC[0:15]Pin ※3 : VDOUT18Pin

■ 8.6.2 AC Characteristics

Table 8.6.2 - AC Characteristics

Parameter	Symbol	Value			Unit	Related Pin
		MIN	TYP	MAX		
"H" level output period of KC Pin	tOKH	—	256	—	μs	refer to 7.3.1

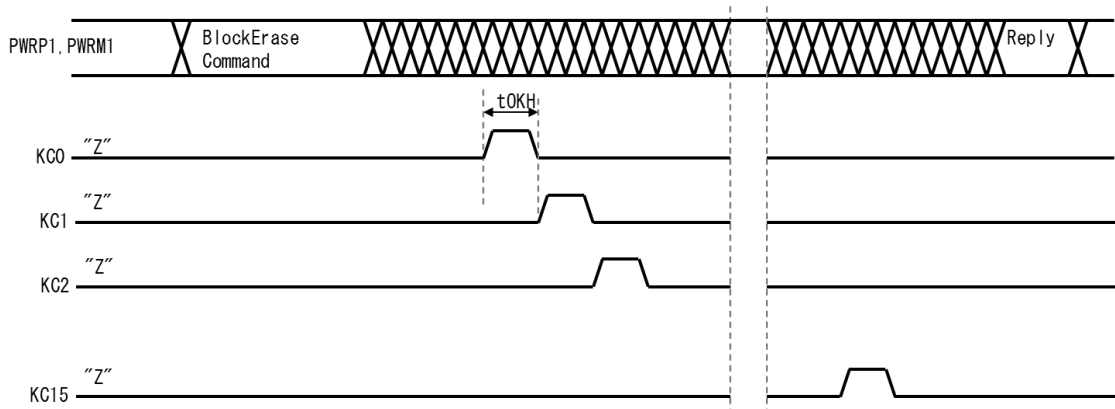


Figure 8.6.2 -Key Matrix scan timing

■ 8.7 GPIO Characteristics

■ 8.7.1 DC Characteristics

Table 8.7.1 - DC Characteristics

Parameter	Symbol	Value			Unit	Conditions
		MIN	TYP	MAX		
Input leakage current	ILI	—	—	±1	μA	※1
Output leakage current	ILO	—	—	±1	μA	"Hi-Z" output ※2
"H" level Input voltage	VIH	VDIO×0.7	—	VDIO+0.5	V	※1, ※3
"L" level Input voltage	VIL	−0.5	—	VDIO×0.3	V	※1, ※3
"H" level Output voltage	VOH	VDIO−0.5	—	VDIO	V	IOH = -0.5mA ※2, ※3
"L" level Output voltage	VOL	0	—	0.4	V	IOL = 0.5mA ※2

※1 : INT Pin ※2 : COM[2:0] Pin ※3 : VDIO voltage is provided by VDOUT3.

■ 8.7.2 AC Characteristics

Table 8.7.2 - AC Characteristics

Parameter	Symbol	Value			Unit	Related Pin
		MIN	TYP	MAX		
COM output update time	tOCV	—	—	1	ms	COM[2:0]
INT input setup time	tIIS	0	—	—		INT ※1
INT input hold time	tIIH	—	—	T1	ms	INT ※1

※1:INT information is read out at the input timing described in Table 8.7.2 and Figure 8.7.2.2. T1 is the T1 time specified in EPC standard.

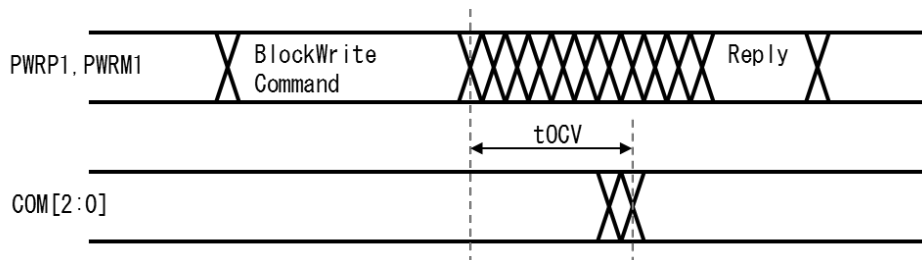


Figure 8.7.2.1 - GPIO timing (COM output)

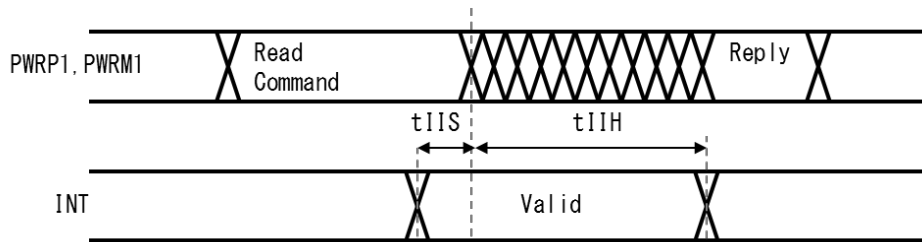


Figure 8.7.2.2 - GPIO timing (INT input)

■ 9 Ordering Information

Part Number	Shipping Method	Wafer thickness
MB97R8110-WF	Wafer	725 μm $\pm 20 \mu\text{m}$
MB97R8110-DI15	Sawn wafer	150 μm $\pm 2.54 \mu\text{m}$
MB97R8110-CHIP15	Chip (in Waffle pack)	150 μm $\pm 2.54 \mu\text{m}$

RAMXEED LIMITED

Shin-Yokohama Chuo Building, 2-100-45 Shin-Yokohama,
Kohoku-ku, Yokohama, Kanagawa 222-0033, Japan
<https://ramxeed.com/>

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