FRAM-embedded RFID LSI for 13.56MHz MB89R119B

Traceability management with "MB89R119B" improves the safety and reliability in the medical scene. The radiation hardness feature of FRAM enables "MB89R119B" to attach on the medical devices before the sterilization process.

Introduction

FUJITSU SEMICONDUCTOR has been developing FRAM (Ferroelectric Random Access Memory)-embedded RFID LSI for both HF (13.56MHz) and UHF (860 to 960MHz). As one of the most significant feature of FRAM, the radiation hardness has recently come into the spotlight especially in health care industry, since data stored in FRAM can survive gamma-ray sterilization.

"MB89R119B" introduced in this article is a RFID LSI for HF embedded with 256bytes FRAM. Since it has a smaller memory density than MB89R118C (featured in Vol.28 No.4 of this magazine), which is already distributed into the RFID market, it is recommended for customers who do not require large-density memory. Also high input capacitance specification is provided in order to achieve downsizing of tag with smaller number of antenna turns, which enables to attach RFID tags onto small medical devices.

Radiation Sterilization in the Medical Field

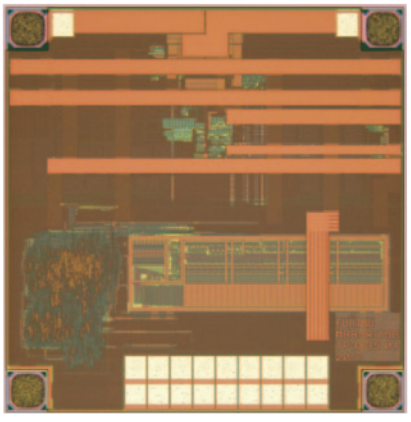
The sterilization of medical devices are differentiated depending on the case. The difference between the sterilization before shipment and the sterilization in the hospital is one of those examples.

The main targets of the sterilization in the hospital are the reused devices such as surgical instrument, and the devices are sterilized repeatedly. For the sterilization in the hospital, autoclave, EOG (Ethylene Oxide Gas), and H_2O_2 Plasma are widely used.

On the other hand, the single use medical devices are sterilized once before the shipment. In this case, EOG and radiation sterilization with gamma-ray or electron beam are widely used. Because the radiation sterilization is normally executed in the large facility, it is not used for the sterilization in the hospital. The most significant feature of radiation sterilization is strong transparency, which enables to sterilize the target objects after being packed in the box. And also this feature is quite effective to sterilize very thin tube for example, which EOG sterilization might be difficult to sterilize far inside.

In addition, the radiation sterilization is preferred compared with the EOG sterilization from the environment points of view, because EOG sterilization uses toxic gas and it tends to be restricted. Furthermore, the disposable devices tends to be increased from the medical safety points of view, and this tendency causes the demands of radiation sterilization on the

Photo 1 External View



plastic devices, which cannot be sterilized with autoclave because of its high temperature.

Together with these backgrounds, the traceability management of medical devices are strictly required and the traceability with RFID technology is now getting to attract interest in order to improve the medical safety and reliability. In this case, the radiation hardness of RFID tag itself should become important in order to trace objects from the production to the end of life.

Radiation Hardness of FRAM-embedded RFID

One of the reasons why RFID tag has not applied on medical devices that are sterilized with radiation is the fact that E^2PROM is widely used as the memory of RFID tags. In fact, the data stored in E^2PROM cannot survive under the 25kGy (kilogray: gray is the unit for absorbed dose) irradiation required for the sterilization of medical devices. Because of the data storage principle using electron charge, the electron stored in the memory capacitor is easily lost under the irradiation. In this case, the tags cannot be distinguished anymore because the unique ID (UID) of the tags are also erased.

On the other hand, the data stored in FRAM survives under the 50kGy irradiation which is enough for the sterilization of medical devices. The data storage principle of FRAM is the self polarization of ferro-electric materials, and the data is stored in the crystal structure level which cannot be affected by irradiation. Because of this strong radiation hardness, FRAM RFID products are already applied for the medical devices in the US.

Product Features

MB89R119B is a new FRAM- embedded RFID LSI for HF band, which is the same frequency products as MB89R118C embedded with 2Kbytes FRAM.This product consists of three parts: RF (Analog), Logic, and Memory. The communication specification is based on ISO/IEC15693, which defines protocols and commands for the vicinity type of passive RFID powered by RF.

The major difference between this product and MB89R118C is that this product has a small memory of 256bytes and that its memory configuration has 4bytes per block. Its specifications are easy to understand for customers who have conventionally used E^2PROM RFIDs. Furthermore, a 96pF model similar to MB89R118C has been prepared for input capacity to address the demands for tag miniaturization.

The main features of this product are as follows:

Embedded FRAM:
Memory density: 256bytes (user memory: 232bytes)
Memory configuration: 4bytes per block, 64 blocks

Data transmission:
Reader/writer ⇒ RFID tag:
(Modulation) ASK10/100%
(Data coding) 1 out of 4
RFID tag ⇒ reader/writer:
(Modulation) Single sub-carrier OOK
(Data encoding) Manchester

Anticollision:
ISO/IEC15693 compliant, Complete time slot with ASK 10% EOF and Break time slot with ASK 10% EOF

Commands:
ISO/IEC15693 command group
Fast Read/Write commands, Kill commands (custom)

Antenna input capacitance:
24 (±5%) pF or 96 (±10%) pF for small tags

Read/Write endurance: 10^{10} times

Table 1 Memory Configuration

Domain	Block number	Details	Data reading	Data writing
User area (232bytes)	00_H to 39_H	User area	✓	✓
System area (24bytes)	$3A_H$	RFU (Reserved for Future Use)	✓	—
	$3B_H$	UID1 (1 to 32-bit)	✓	—
	$3C_H$	UID2 (33 to 64-bit)	✓	—
	$3D_H$	EAS, AFI, DSFID, IC reference	✓	Limited access
	$3E_H$ to $3F_H$	Block security status	✓	—

Data retention: 10 years (70℃)

Product Specifications

Memory configuration

256bytes FRAM is embedded as internal memory, which consists of a 232bytes user area and a 24bytes system area. As shown in **Figure 1**, the user area consists of 58 blocks from "00H" to "39 H" and the system area consists of 6 blocks from "3A H" to "3F H." Each block stores 4bytes of data.

The block is the accessed unit when the data is read or written. The user area is defined as an area that can be accessed when the corresponding block address is specified. On the other hand, the system area is defined as an area that can be accessed only for a specific command. The system area records 64bits UID, which is unique to the chip, security status for individual block (whether locked or not), and so forth.

Data transmission

From Reader/Writer to RFID

The communication between Reader/Writer and RFID is based on the protocol defined in ISO/IEC15693. The data transmitted from Reader/Writer is modulated by ASK (Amplitude Shift Keying), and the modulation index is 10% and 100%.

The data coding of "MB89R119B" is "1 out of 4" coding, and "1 out of 256" coding is not implemented. As depicted in **Figure 1,** "1 out of 4" coding is the method which indicates the 2bits value "00B" to "11B" with 4 different pulse position respectively. The command transmitted from Reader/Writer is coded with "1 out of 4" coding and then modulated with ASK, the data rate of which is calculated as 26.48kbps.

From RFID to Reader/Writer

The data responded from RFID to Reader/Writer is modulated by OOK (On Off Keying), which is the load modulation with sub-carrier frequency. Although one or two sub-carriers is defined in ISO/IEC15693, MB89R119B supports only one sub-carrier.

Data "0" and "1" are coded by Manchester coding and the data rate is normally 26.48kbps (at high data rate) for standard commands. However, as shown in **Figures 2** and **3**, if the fast command (custom command) is executed for MB89R119B, the data rate becomes double (52.97kbps). This feature is particularly effective in reading operations for large amounts of data.

Anticollision

Anticollision is a key feature of RFID that enables the recognition of multiple tags within the RF fields, which is defined in ISO/IEC15693. The anticollision sequence is executed by

Figure 1 Data Coding Method

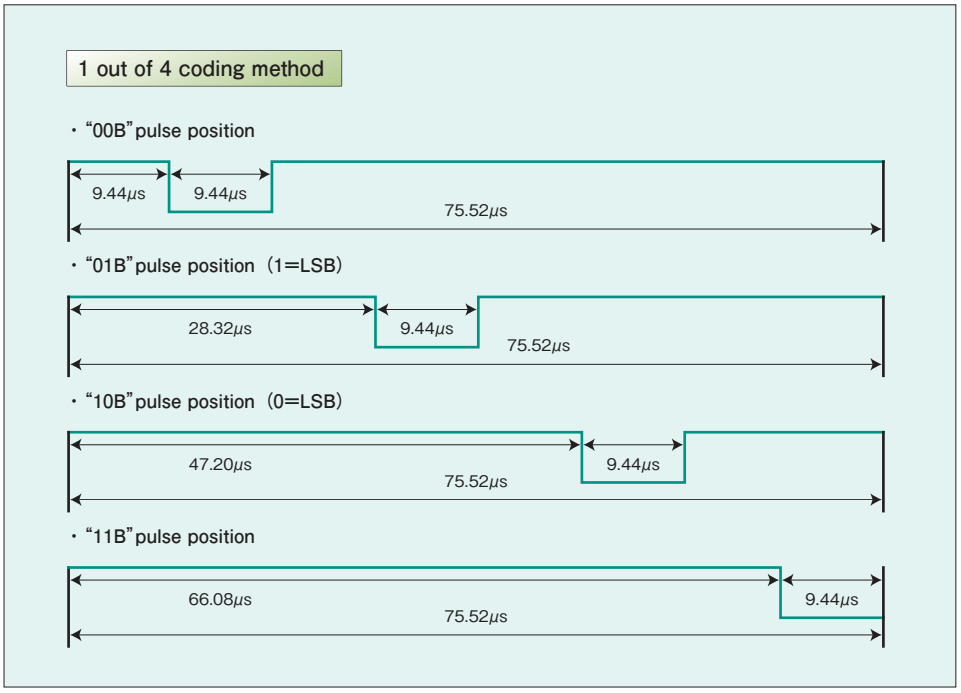


Figure 2 Signal Waveform of Load Modulation (Standard Command)

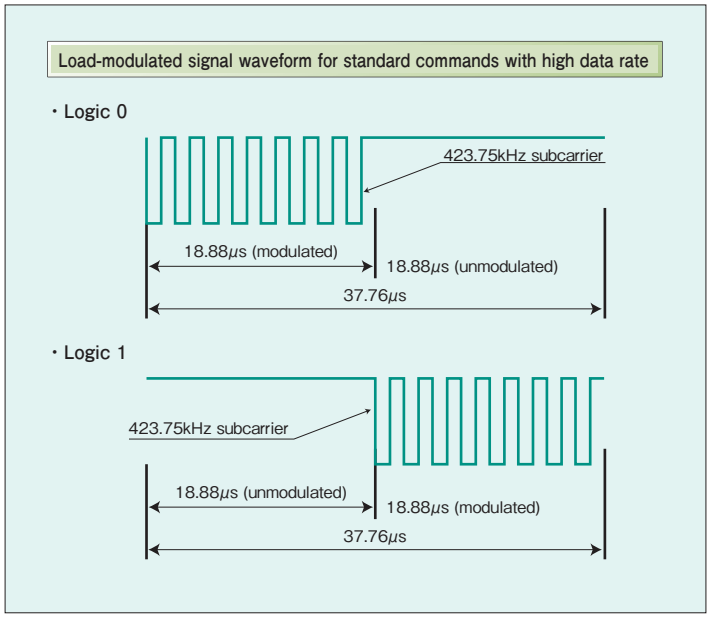
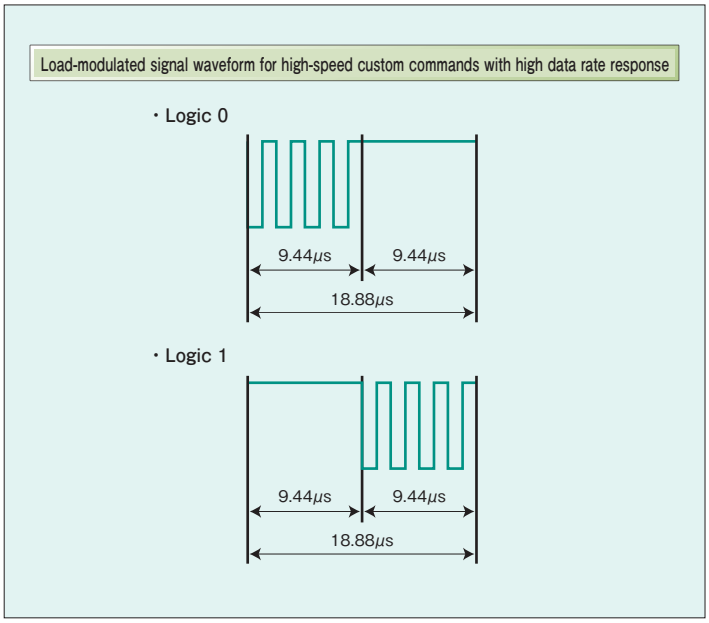


Figure 3 Signal Waveform of Load Modulation (High-speed Custom Command)



the Inventory command, which is described later, and UIDs of individual tags are identified by 16 slot signals (EOF signals) transmitted at fixed intervals following the command. If the number of tags in the RF fields is increased, more than two tags may respond to the same slot in which the collision is occurred. In this case, another Inventory command is transmitted for the tags, and 16 EOF signals follow in order to identify each of them.

This procedure is continued until all tags are identified. Therefore, in general, the required time for the whole procedure depends on the number of tags to be identified. EOF signal is modulated by ASK 10% or 100%, and the interval, which is the waiting time before sending a subsequent EOF slot, is specified in ISO/IEC15693. If the EOF is modulated with ASK10%, the interval is always the same (complete time slot) regardless of the response from the tag.

On the other hand, if it is modulated with ASK100%, the interval, during which no response is detected, is shortened (break time slot) and switches to the subsequent EOF slot quickly. MB89R119B supports 10%modulated EOF signals in addition to 10% signals, and can execute the anticollision sequence quickly.

Commands

MB89R119B supports all Mandatory commands and Optional commands specified by ISO/IEC15693, including read, write, and lock commands. In addition, as custom commands, FAST command enables to shorten the response time from tags, Kill command invalidates the tag, and EAS command supports anti-theft structure.

Table 2 shows all the commands supported by MB89R119B.

One of the advantages of FRAM-embedded RFID is fast writing compared to E^2PROM-embedded RFID, because E^2PROM requires internal high voltage when data is erased and written. For example, if it is assumed that the identical data is written into the memory, FRAM-embedded RFID can finish in less than half the execution time of E^2PROM-embedded RFID. Theoretically, MB89R119B enables the writing of 232bytes data into the memory in approximately 250ms.

Reading operation should not differ between E^2PROM and FRAM, but Fast commands (custom commands) can shorten the execution time with twofold the normal response rate. Theoretically, MB89R119B can read 232bytes data in 80ms, but practically it takes much longer because normally reader/writer does not have enough memory buffer to accept a huge amount of data.

Approach of FRAM RFID into the Medical Field

As the first exhibitor from semiconductor manufacturers, FUJITSU SEMICONDUCTOR participated in the exhibition of "INTERPHEX JAPAN," which is one of the world's leading pharmaceutical industry event at the end of June, and introduced the possible contribution of FRAM RFID into medical field.

The radiation hardness feature of FRAM protects the data stored in the memory from the radiation sterilization required for medical use, and enables FRAM RFID tags to attach on the disposable medical devices such as catheters, syringes, gauze, and specimen containers before sterilization. As a result, FRAM RFID makes it possible to support the safety and reliability of medical field, because FRAM RFID can manage the traceability of the devices from the production through logistics, stock in the hospital, and waste after being used.

Another possibility is RFID system used for the fluid management and the bio-processor, for which RFID tags are attached on disposable devices such as medical bags, tubes, filters, coupler, and so forth. In this case, RFID tag stores products specifications like dimension, flow rate, pH value, expiration date, and expects to be used for error detection when they're connected in order to improve the safety of use.

Furthermore, we intend to consider any possibilities of FRAM RFID as a key device for linking patient information with various medical data such as vital data monitoring, administration of medication, and some other personal health care records.

Because of the unique advantages of FRAM such as radiation hardness, fast writing, and high read/write endurance, FUJITSU SEMICONDUCTOR continues to develop FRAM RFID products not only for the medical applications but also for the applications on which E^2PROM RFID cannot achieve customer's requirement. *

Photo 2 FUJITSU SEMICONDUCTOR Booth at INTERPHEX JAPAN Exhibition

Table 2 List of Commands

Command code	Command name	Command type	Details
01	Inventory	Mandatory	Executes anticollision sequence and obtains the UID.
02	Stay Quiet	Mandatory	Transfers to Quiet state.
20	Read Single Block	Optional	Reads data from the specified 1 block in the user area/system area.
21	Write Single Block	Optional	Writes data in the specified 1 block in the user area/system area.
22	Lock Block	Optional	Locks (disables writing) the specified 1 block in the user area.
23	Read Multiple Blocks	Optional	Reads data from the specified consecutive blocks in the user area/system area (up to 64 blocks).
24	Write Multiple Blocks	Optional	Writes data in the specified 1 block or 2 blocks in the user area.
25	Select	Optional	Transfers to Select (selected communication) state.
26	Reset to Ready	Optional	Transfers to Ready (communication enabled) state.
27	Write AFI	Optional	Writes AFI (Application Family Identifier) data.
28	Lock AFI	Optional	Locks AFI (Application Family Identifier) data.
29	Write DSFID	Optional	Writes DSFID (Data Storage Format Identifier) data
2A	Lock DSFID	Optional	Locks DSFID (Data Storage Format Identifier) data.
2B	Get System Information	Optional	Reads the system information (UID, DSFID, AFI, number of bytes per block, number of blocks in the user area, and IC information) stored in the system area.
2C	Get Multiple Block Security Status	Optional	Reads the block security status stored in the system area.
A0	EAS	Custom	Command for antitheft detection. (Returns the response only when the EAS bit is set to "1.")
A1	Write EAS	Custom	Writes EAS data for anti-theft detection.
A6	Kill	Custom	Invalidates the tag.
B1	Fast Inventory	Custom	Inventory command with high-speed response.
C3	Fast Read Multiple Blocks	Custom	Read Multiple Blocks command with high-speed response.
C4	Fast Write Multiple Blocks	Custom	Write Multiple Blocks command with high-speed response.