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Spec No: 001-87566

Spec Title: COMPARISON OF WIRELESS F-RAM VS. EEPROM WRITE SPEEDS - AN602

Sunset Owner: HARSHA MEDU (MEDU)

Replaced by: NONE

AN602

Comparison of Wireless F-RAM vs. EEPROM Write Speeds

Author: Harsha Medu
Associated Project: No
Associated Part Family: WM72016
Software Version: None
Related Application Notes: None

This application note describes the write speeds of Cypress's WM72016 family of wireless F-RAM memory products and compares them with the write speeds of EEPROM-based technologies.

Introduction

This application note describes the write speeds of Cypress's wireless memory products and compares them to EEPROM-based technologies. Cypress's WM72016 family of wireless memory products is named MaxArias. This application note discusses the advantages and benefits of F-RAM, focusing primarily on the faster write times.

EPC Class 1 Generation 2 Standard

Cypress's MaxArias products utilize the EPC Class 1 Gen 2 protocol for wireless access. This technology was developed primarily for use in RFID systems. Gen 2, or EPC Class 1 Generation 2, defines the physical and logical requirements for a passive-backscatter, Interrogator Talks First (ITF), RFID system operating in the 860 MHz ~ 960 MHz frequency range. The system is comprised of Interrogators (also known as Readers) and Tags (also known as transponders). The earlier EPC, Transponder standards were known as Class 0 and Class 1. EPC Class 1 Gen 2 represents a major step in standardization, performance, security, data retention ability, and quality.

F-RAM Technology

F-RAM (Ferroelectric Random Access Memory) is a nonvolatile memory that uses a ferroelectric film for storing data. F-RAM is impervious to magnetic fields and has high tolerance to gamma radiation. Possessing characteristics of both ROM and RAM devices, F-RAM features high-speed access, high endurance, low power consumption, nonvolatility, and excellent tamper resistance. It is therefore ideal for use in smart cards, where high security and low power consumption is important, vehicle tracking, and in cellular phones and other devices.

EEPROM Technology

EEPROM (Electrically Erasable Programmable Read-Only Memory) is a user-modifiable read-only memory that can be erased and reprogrammed (written to) repeatedly through a stored electrical charge. EEPROM cells are comprised of two transistors. The storage transistor consists of a floating gate that stores an electrical charge. In addition, there is an "access" transistor which is used during erase operations and also needs to be charged to store bit information. Both of these operations require a charge pump to create an elevated internal voltage to add or remove the charge to the transistor's floating gate. When the charge pump has fully ramped up, there is an additional "Soak Time" the memory undergoes to ensure the integrity of the write process. These processes have the adverse effect of requiring additional time and power compared to F-RAM technology. In addition, there is a wearout mechanism at work in which the hot electron effect traps the charge indefinitely. When this occurs, EEPROM bits are permanently stuck and cannot be reset.

Advantages of F-RAM over EEPROM

F-RAM has the following fundamental advantages:

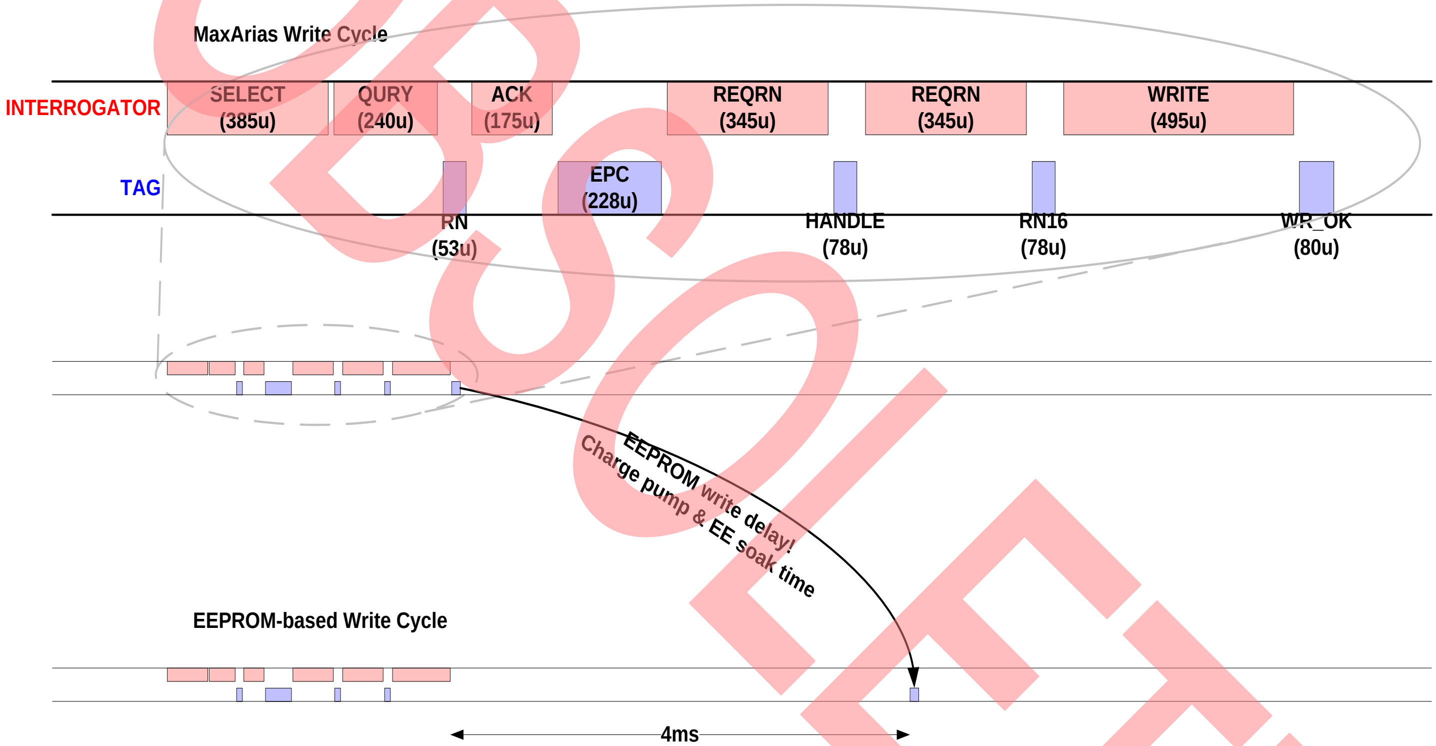
- Faster write times
- No charge pump required. The charge pump used in EEPROMs is relatively power hungry and it takes some time to ramp up to the proper voltage to perform a WRITE or ERASE cycle.
- No Soak Times for F-RAM. The soak time is the duration when the data is communicated to the RFIC until it is written to the EEPROM.
- Lower power consumption.
- 100 Million times greater rewrite capability (1E14 vs 1E6).
- Symmetrical read and write sensitivities.

Time Lapse

Figure 1 compares a typical Gen 2 write command sent from an RFID interrogator and the time required to write to a single word (16-bits) in the user memory for both F-RAM and EEPROMs. Figure 1 shows how the F-RAM successfully writes a single word immediately and is limited by the Gen 2 protocol. EEPROMs require 4 ms of additional time to complete the write cycle. This longer write duration is due to the delay in developing the elevated voltage by the charge pump and soak times required to move the electrical charge into or out of the floating gates.

Note Typical Soak Times for EEPROMs range anywhere from 4 ms to 10 ms, depending on the EEPROM manufacturer and IC version. In this application note, a 4 ms soak time is used to calculate the write times for comparative purposes.

Figure 1. Comparison of MaxArias to EEPROM Write Cycle



Working Stored Address

To better utilize F-RAM's fast write capability, Cypress's MaxArias products have been designed to use an optional Working Stored Address Register contained in the MaxArias' user memory. The Working Stored Address feature allows automating the storage of large blocks of user data, such as logging or tracking information. This feature provides the RFID interrogator with the ability to use a standard Gen 2 WRITE command using a designated address of 0x3FFF (0xFF7F EBV-formatted) as a redirect pointer (Address Pointer) to use the contents of the Working Stored Address register. This is referred to as an unaddressed write (UNADDR_WRITE). The Working Stored Address is a USER memory address pointer used to address the first available user- memory address (16-bit data word). The Working Stored Address Register is a read/write register located in the address 0x003 in the USER memory. It is used to only address the USER memory and cannot be utilized to address other memory banks such as the EPC, Access Passwords, Kill Passwords, or the TID. This Working Stored Address eliminates the need for an RFID reader to survey the user memory contents of the MaxArias Integrated Circuit (IC) to locate a vacant address to write data. MaxArias does this automatically, further reducing write times. This also has the added advantage of reducing the Bit Error Rate (BER) by eliminating one communication sequence from MaxArias back to the reader to convey its available memory contents.

Table 1 shows the memory structure of a MaxArias IC. The memory structure illustrates the Working Stored Address Register contained in the address 0x003, available User Memory Bank, and the Working Stored Address Pointer residing in the location 0x3FFF.

Table 1. Memory Structure

Working Stored Address Pointer	Gen-2 Memory Bank	Gen-2 Address	Memory Description	
Address Pointer Cannot be Used for These Memory Addresses	RESERVED	0x000 - 0X003	RESERVED - passwords	USER MEMORY UNAVAILABLE
	EPC	0x000 - 0x009	EPC	
	SERVICE	0x00A	RESERVED	
	SERVICE	0x00B	RESERVED	
	TID	0x000 - 0x003	TID	
	USER	0x000	RESERVED	
	USER	0x001	RFU	
	USER	0x002	Control/Status Register	
	USER	0x003	**Working Stored Address Register: 0x007**	
	USER	0x004	Interrupt Generation	
	USER	0x005	Interrupt Generation	
Address Pointer Will Point to one of These Available User Memory Addresses	USER	0x006	**START USER Memory**	AVAILABLE USER MEMORY
	USER	0x007		
	USER	0x008		
	USER	.	.	
	USER	.	.	
	USER	.	.	
	USER	0x3E7	**USER Memory - END**	

The Working Stored Address can be utilized for a single unaddressed write to a single word or to write multiple blocks of words during a single write command cycle from the interrogator. Up to 127 words can be written to at one time without the need to resend a write command again at the beginning of every word. This is another feature of Cypress's F-RAM technology that expedites the write process.

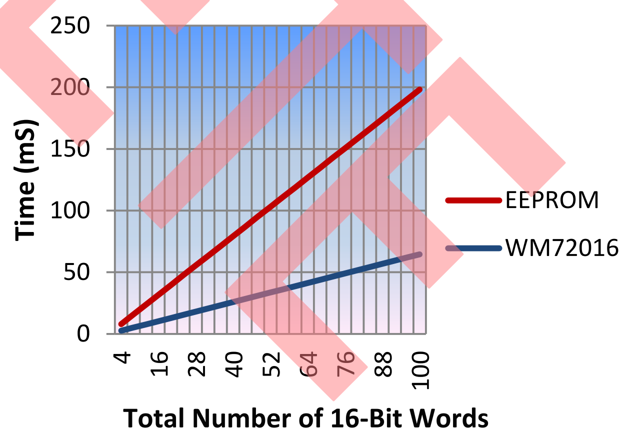
Figure 2 shows the write times required for both F-RAM and EEPROMs when writing in 4-Word blocks (1 word is 16 bits of data). A 4-Word block write was chosen because most Gen-2 readers on the market are only capable of writing in 4-Word increments making this a much more realistic comparison for the two technologies. The data shown in Figure 2 assumes the following configuration:

- TARI: 6.25 us. (Reader to Tag Link Frequency)
- Tag to Reader Link Frequency: 640 Kbps
- EEPROM Soak Time: 4 ms

This essentially means that the system is configured to operate at the maximum data rate in both directions, Tag-to-Reader and Reader-to-Tag. A 4 ms Soak Time is also one of the shortest for the current EEPROMs in the marketplace. Even with this relatively short Soak Time, Figure 2 shows that F-RAM is still able to write at much faster speeds.

If Figure 2 were expanded to show the write times to fill the entire user memory (250 Words) of a typical 16-Kbit EEPROM, it would require 1.3 seconds compared to 0.65 seconds for F-RAM.

Figure 2. WM72016 vs. EEPROM Write Speed for 4-Word Blocks

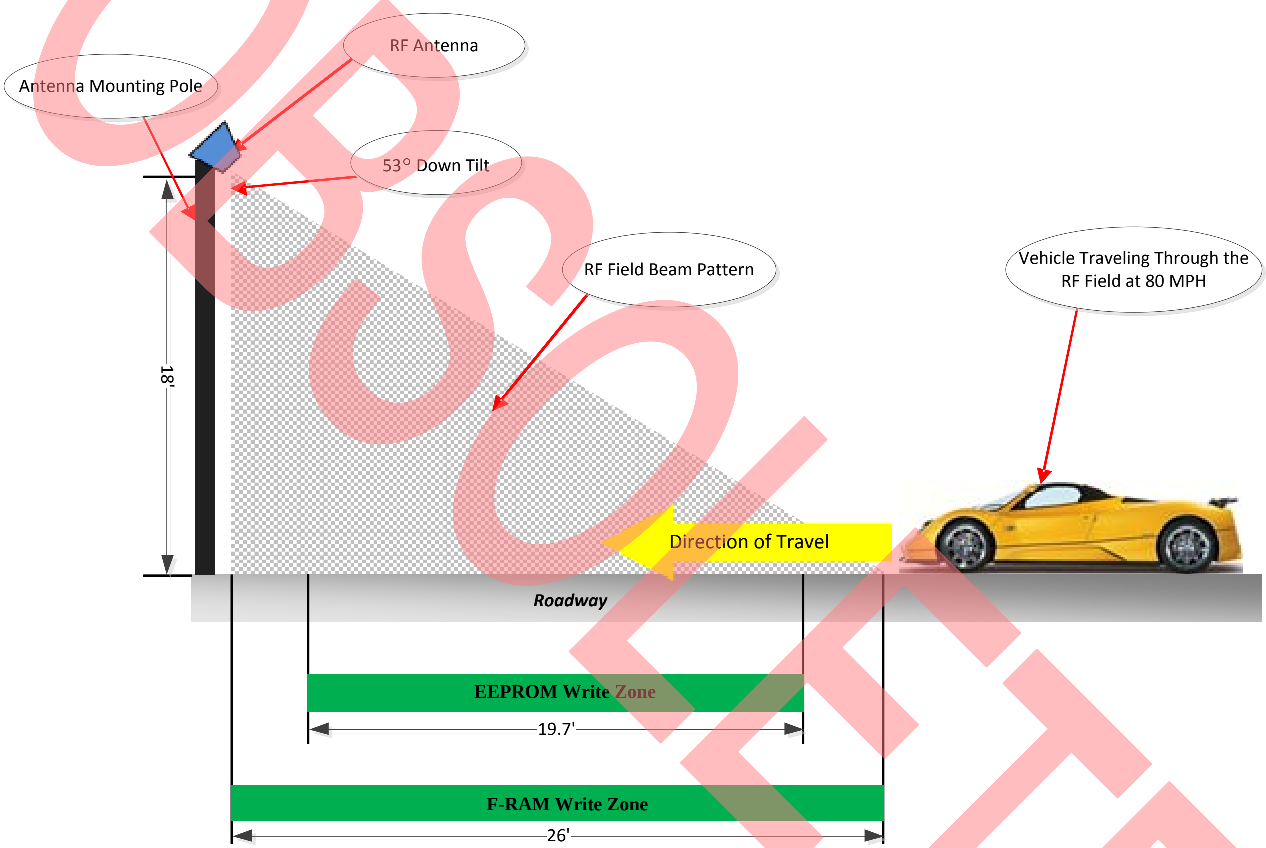


Furthermore, if the data was written using single 16-bit words and not in 64-bit increments, F-RAM would need just 1.3 seconds to write 1000 words while EEPROM would take 9.3 seconds.

Vehicle Tracking Application

Figure 3 shows a vehicle traveling through an RF field ("Write Zone") at a velocity of 80 mph (129 km/hr). This is a typical configuration for vehicle tracking applications such as Automated Vehicle Identification (AVI) and Electronic Vehicle Registration (EVR) with the RFID transponder adhered to the center of the vehicle's windshield. Figure 3 shows a transmitting antenna mounted 18' (5.4 meters) above the roadway with the antenna having a 53 ° down tilt fanning the RF into the vehicle as it travels though the RF field. This antenna configuration optimizes the RF field and maximizes the duration at which a transponder resides in the write zone.

Figure 3. Vehicle Traveling in RF Field at 80 mph



One assumption that must be made here is that the F-RAM and EEPROM RFIC's have the same read sensitivity (SR). If this assumption is established, it is important to note that the transponder containing F-RAM will start writing data sooner as it enters the RF field and continue the write sequence longer as the vehicle exits the field. In other words, the write zone for F-RAM will be larger than for EEPROMs given the same read sensitivity. This is due to the difference in the inherent characteristics of F-RAM and EEPROM that adversely compromise the EEPOM technology over F-RAM technology.

As mentioned before, most EEPROMs on the market exhibit an additional 4 ms to 10 ms delay at the beginning of every write cycle due to the charge pump/soak time required to reach the proper voltage in the capacitor to store data. For a vehicle travelling at a velocity of 80 mph (as the one shown in Figure 3), a 4 ms delay in the write cycle causes the EEPROM to start storing data at about 0.47' (14.3 cm) later into the write zone compared to F-RAM technology. For EEPROMs with longer charge/soak times, this will result in longer write time delays and shorter write zones.

Moreover, the internal circuitry of EEPROMs require an additional 20% (this is an approximation based on datasheets for some prominent EEPROMs such as Alien's Higgs-4 and Impinj's Monza-4) of extra power to activate the charge pump which generates the relatively high voltage levels required to store the data. For example, the datasheet for an EEPROM may state that the sensitivity of the RFIC is -19 dBm. This typically refers to the sensitivity for the read process (SR), which requires less power because data is simply being read with none of the bits

changing state. The write process sensitivity (SW), on the other hand, drops down to about -15.2 dBm. This reduction in write sensitivity of about 3.8 dBm reduces the write zone for an EEPROM by an additional 2.9' at both the entry and exit point of the respective write zones. The power density of the RF field is stronger towards the middle of the field and less potent as one move away from the bore-site of antenna. Consequently, EEPROMs will not start writing at the same entry and exits points given the same sensitivity due to the longer charge pump time and additional power required by EEPROMS.

These inherent characteristics cause the write zones for EEPROMs to be smaller than the F-RAM by about 25%. For older EEPROM versions such as Alien's Higgs-3 and Impinj's Monza-3, these read and write power discrepancy are even more pronounced. For example, both Alien's Higg's-3 and Impinj's Monza-3 require about 40% more energy for writing data compared to simply reading it. This reduces the write zone even more significantly.

Figure 3 shows the corresponding F-RAM and EEPROM write zones for a vehicle tracking application. Figure 3 shows the two write zones as 19.7' (6.0 meters) for EEPROMs and 26' (7.9 meters) for F-RAM. Based on these write zones, this vehicle will take approximately 22.2 ms to enter and completely pass thorough the interrogation zone for F-RAM and 16.8 ms for EEPROMs. At this velocity, F-RAM can successfully write to approximately 17.8 bytes of data, while EEPROMs can write up to a maximum of only 5.2 bytes of data.

Summary

This application note compares the write speeds of the Cypress wireless F-RAM memory, WM72016, with the write speeds of EEPROM-based technologies, and clearly shows that wireless F-RAM is much faster than EEPROM-based technology.

Document History

Document Title: Comparison of Wireless F-RAM vs. EEPROM Write Speeds - AN602

Document Number: 001-87566

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	4039506	MEDU	06/25/2013	New Spec.
*A	4315234	MEDU	03/20/2014	Obsolete document.

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