RAMTRON
International Corporation

Performance and Energy Comparison of F-RAM and EEPROM Devices

System Analysis

In order to quantify the overall impact that low-energy F-RAM has on the energy consumption of practical systems, a simple data collection system will be considered. The system consists of a sensor, a low power microcontroller and a nonvolatile memory. The microcontroller includes an internal A/D converter. The purpose of the system is to periodically measure the voltage generated by the sensor and write the data into nonvolatile memory for later retrieval. The measurement period for this analysis ranges between 10 milliseconds and 10 seconds. By allowing the microcontroller to spend more time in sleep mode and less time writing to the memory, use of F-RAM results in significant energy savings across a wide range of measurement periods.

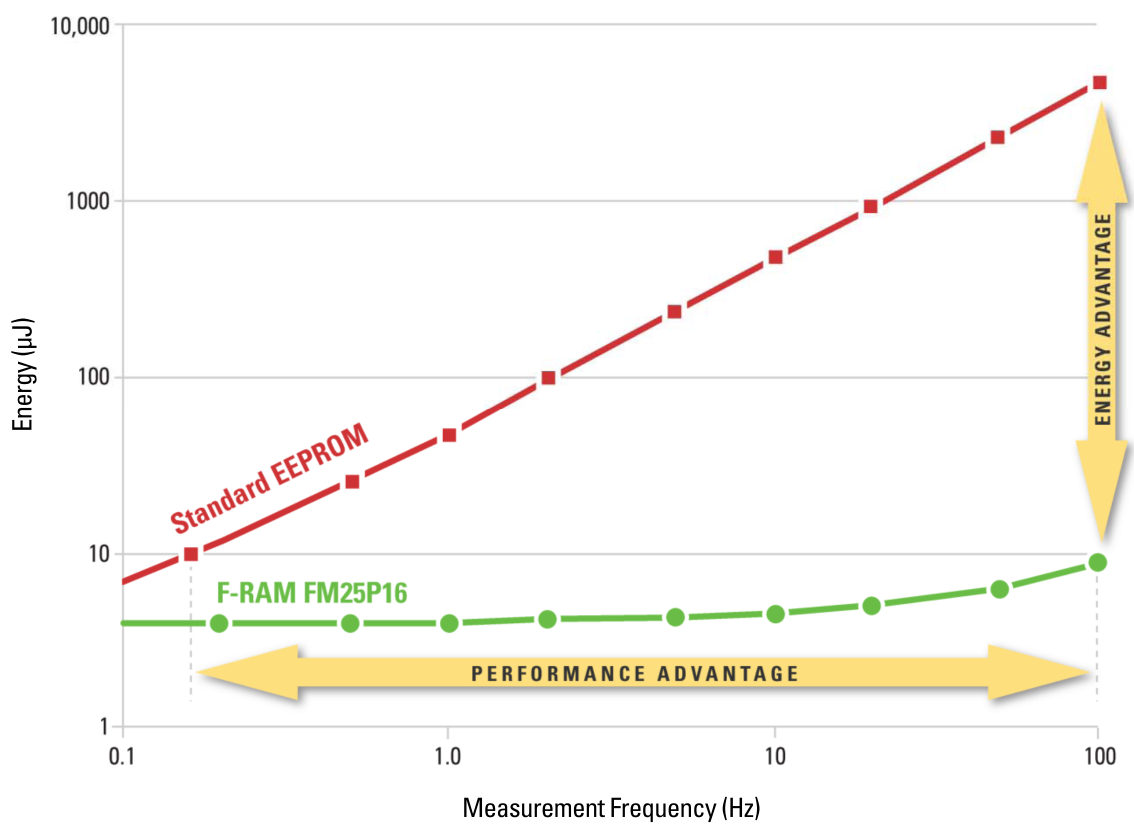
The following table shows the comparison for voltage measurements taken every 100ms. The low write current and the fast write time of F-RAM dramatically lowers the energy consumed by the nonvolatile memory during a write by a factor of over 35,000. The actual energy savings of the system are lower because of the microcontroller contribution to the active current and the standby contribution of both the microcontroller and the memory. Even after all system current sources are fully considered, the use of Ramtron Low Energy Memory FM25P16 reduces the system current by two orders of magnitude compared to the same system implemented using EEPROM. The chart below (Table 1) plots system power as a function of loop time. A logarithmic scale is used to allow the EEPROM and F-RAM to be compared on the same graph.

Table 1: System Power as a Function of Loop Time

Parameter	FM25P16	EEPROM	Calculation
Supply Voltage (V)	1.8	1.8	V
Loop time (s)	0.1	0.1	tL
Active micro current at 1MHz (µA)	180	180	IA1
Micro wakeup time (µs)	5	5	tW1
Wakeup Charge (µC)	0.0009	0.0009	QWU = IA1 * tW1
A/D Measurement current (µA)	180	180	IA2
A/D Measurement time (µs)	100	100	tAD
A/D Measurement charge (µC)	0.02	0.02	QAD = IA2 * tAD
Active write current at 1MHz (µA)	22	5000	INV
Memory write time at 1MHz (µs)	32	5032	tNV

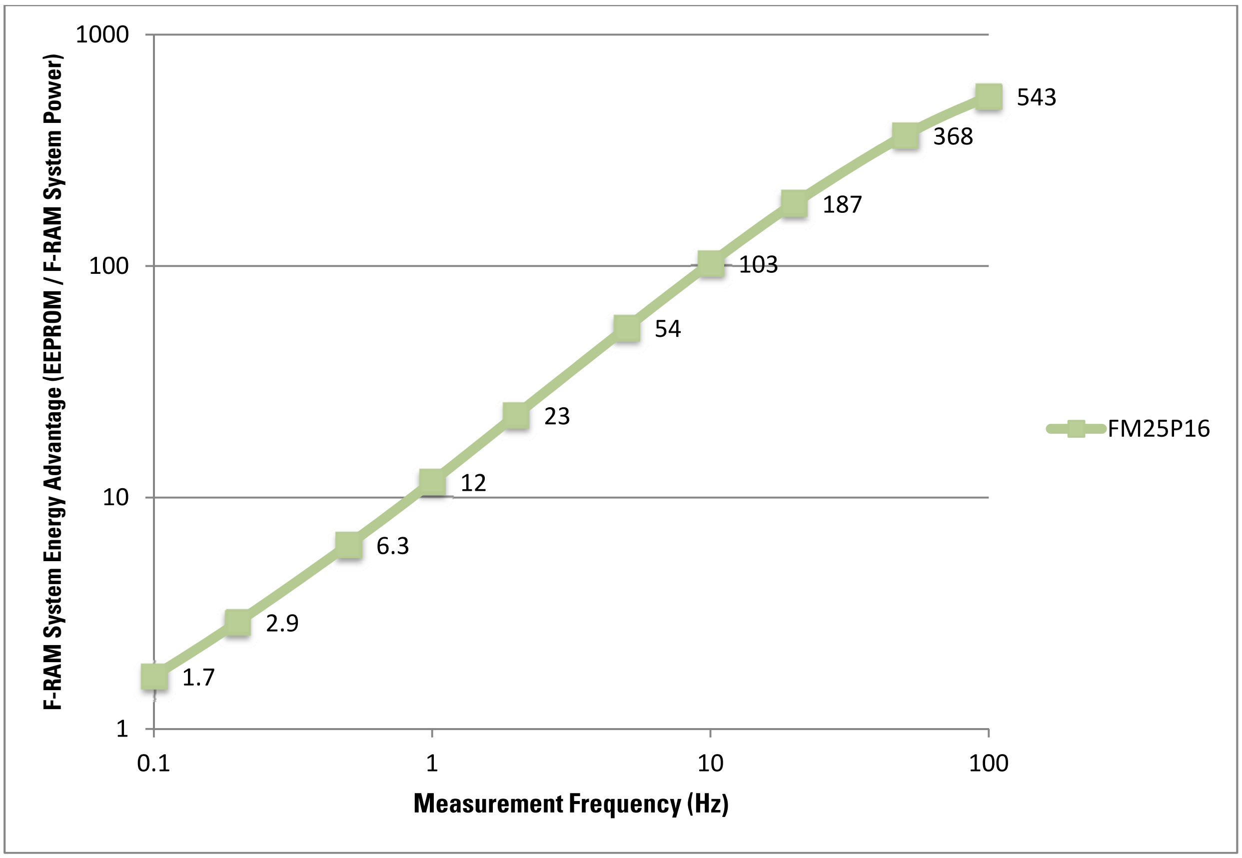
Parameter	FM25P16	EEPROM	Calculation
Memory Write Charge (µC)	0.006	26.07	QNV = (INV + IA1) * tNV
Total Active Charge (µC)	0.025	26.08	QACT = QWU + QAD + QNV
Micro Standby Current (µA)	1.10	1.10	IS1
Memory Standby Current (µA)	1.20	0.20	IS2
Write Time (µs)	137	5137	tWRITE = tW1 + tAD + tNV
Standby Time (µs)	99863	94863	tSTBY = tL - tWRITE
Standby Charge (µC)	0.23	0.12	QSTDBY = tSTBY * (IS1 + IS2)
Total Charge (µC)	0.26	26.21	QTOT = QACT + QSTDBY
Total Energy (µJ)	**0.46**	**47.17**	E = QTOT * V
Power (µW)	**4.59**	**472**	P = E / tL
F-RAM Energy Advantage	**103**		EEPROM / F-RAM System Power

Figure 1: System Power Comparison: F-RAM and EEPROM

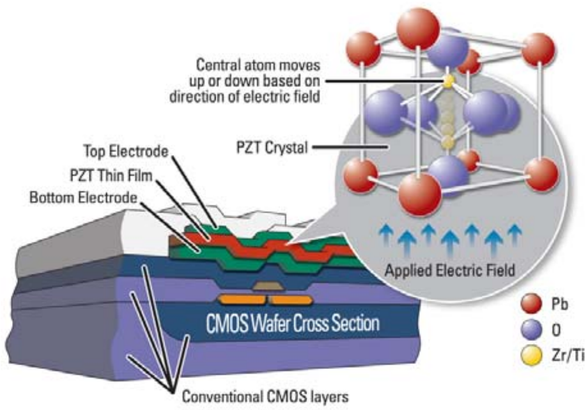


For a given measurement rate, F-RAM offers a significant energy advantage over EEPROM. For battery powered sensor nodes, the energy reduction results in less frequent battery changes. In some cases, it can eliminate the need for battery changes altogether. For a given power budget, F-RAM allows measurements to be taken significantly more often. This benefit is most noticeable in sensor nodes that are powered by harvested energy. In such systems, use of nonvolatile memory is required because the power supply may be intermittent, and F-RAM offers a drastic performance advantage. In Figure 1, the graph illustrates that a system power budget of 10μW that writes to EEPROM limits the measurement rate to once every 10 seconds, while writes to F-RAM allow the same measurements to happen every 10 milliseconds. This is a performance advantage of 1,000. F-RAM enables a wide variety of practical systems to log data more frequently and reduce the system energy consumption at the same time. Figure 2 shows the power advantage of F-RAM over EEPROM at different measurement frequencies.

Figure 2: F-RAM Energy Advantage over EEPROM



About F-RAM Memory



Established semiconductor memories are divided into two categories: volatile and nonvolatile. Volatile memory includes static random access memory (SRAM) and dynamic random access memory (DRAM), among others. RAM type devices are easy to use, offer high performance, but they share a common vulnerability — stored memory is lost when the power supply is removed.

Conversely, nonvolatile F-RAM has similar performance to RAM devices but retains its data when power is shut off or interrupted. Each memory cell contains a thin ferroelectric film of lead zirconate titanate [$Pb(Zr,Ti)O_3$], commonly referred to as PZT. The crystal has two stable states. When an electric field is applied, the zirconium (Zr) or titanium (Ti) atom changes position. The read circuit detects the polarity of the atom as a difference in voltage, which determines the 0 or 1. Each orientation remains in place even after the electric field is removed, preserving the data within the memory without the need for periodic refresh.

F-RAM combines the best of RAM and ROM into a single package that outperforms other nonvolatile memories with its distinct properties — including remarkable fast writes and high endurance and low power.

For More Information

Consult the following resources to learn more about how F-RAM semiconductor products could be used as to improve your next system design.

- To contact a local authorized sales representative, visit www.ramtron.com/sales/buy-now.aspx
- Call Customer Service at 719-481-7181 or email info@ramtron.com
- For more detailed information on F-RAM Low Energy Memory visit www.ramtron.com/go/LowEnergyMemory

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Ramtron International Corporation, headquartered in Colorado Springs, Colorado, is a fabless semiconductor company that designs, develops and markets specialized semiconductor memory and integrated semiconductor solutions used in a wide range of product applications and markets worldwide. For more information, visit www.ramtron.com or contact us at Ramtron International Corporation, 1850 Ramtron Drive, Colorado Springs, CO 80921.

