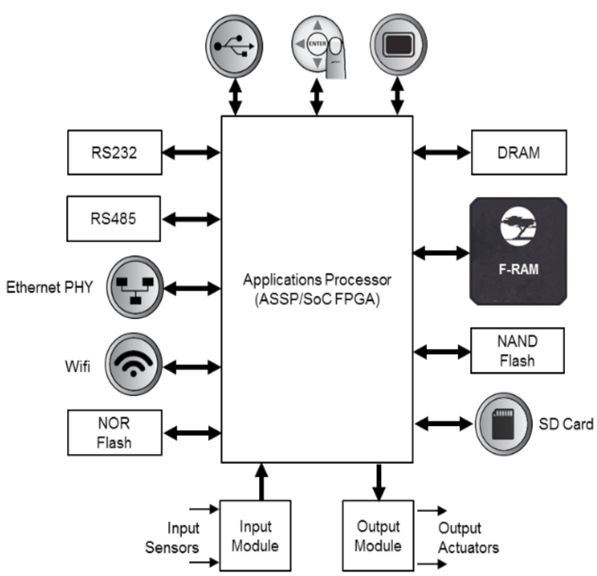
Industry 4.0 Data Logging Memory Reimagined

As Industry 4.0 is developed and deployed, factories will be smarter and more connected. Machines in smart factories will predict, then prevent failures before they occur using real-time data from connected sensor nodes. Accumulated data will refine the predictive analytics to continuously improve the process. These advancements will enhance operational efficiency and reduce downtime, ensuring product quality while reducing costs.

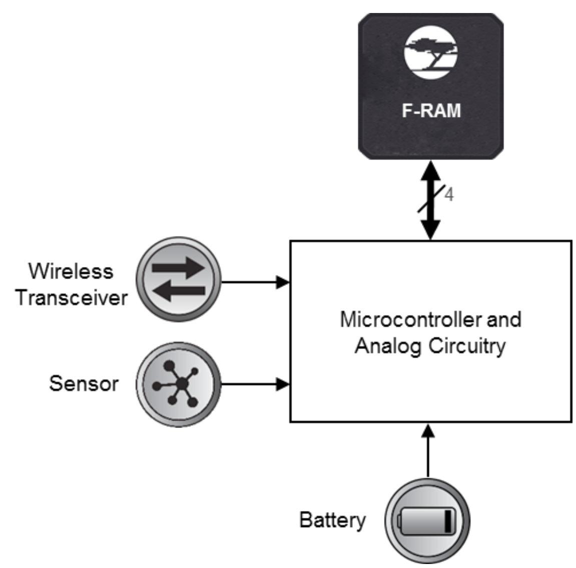
Industry 4.0 enhancements are enabled by gathering real-time data through networks of connected sensors. Therefore, logging data continuously and reliably is critical, with the amount of recorded data set to explode. To meet the challenges of next-generation industrial systems, high-performance nonvolatile memories must ensure 'zero data at risk', work reliably in harsh operating conditions, support long-term and guaranteed backup while operating at high speed with low power consumption. Achieving these features may seem impossible with a single memory technology, but Cypress' Ferroelectric RAM meets the challenge.

Industrial Data Logging Challenges

Industrial control systems in segments including factory automation, energy management, process controls and test measurement, require nonvolatile data-logging memories to ensure reliable, stable operation. Sensors collect, store, and process data from various input types to feed information to the control systems. The challenges and unique requirements of industrial control systems and sensor nodes can be described with two examples.



Programmable Logic Controller (PLC) Block Diagram



IoT Sensor Node Block Diagram

The Programmable Logic Controller (PLC) is a common example of an industrial control system. In a PLC, real-time system data, captured by the nonvolatile data-logging memory, can detect and correct failures. It also captures the last system state if power loss occurs, to ensure that the PLC and all connected machines restart in a safe mode when power is restored. Without this capability, there is potential risk to other machines and to human safety in the immediate surroundings.

IoT sensor nodes capture critical data. They may send the data up the system hierarchy or they may store and compute at the "edge of the network." These sensors have challenging requirements, including small form factors, low power consumption, long life and high reliability while operating in harsh environments. F-RAM is the ideal choice for these applications as it offers virtually unlimited read/write endurance (100-trillion cycles) and the industry's most energy efficient nonvolatile memory technology.

Benefits of F-RAM for Industrial 4.0 Data Logging Applications

F-RAM is the industry's most energy efficient nonvolatile memory, consuming 200× less energy than serial EEPROM and 3,000× less energy than NOR Flash. F-RAM provides unmatched data-reliability by offering read/write endurance of 100-trillion (10^{14}) cycles. Floating gate technologies including Flash and EEPROM wear out in as few as 10^6 cycles so they cannot support frequent system data-capture, resulting in system failure when they wear out. F-RAM further improves data-reliability since it can retain data securely for 100 years without any power backup, unlike battery-backed SRAMs. Finally, F-RAM ensures 'zero data at risk' for industrial systems by instantly storing data to the nonvolatile memory cells on system power loss. Competing technologies, including EEPROM, typically have a page-write delay of 5-10 milliseconds, so critical last-moment data is at risk.

Ferroelectric Technology Overview

The ferroelectric property is a phenomena observed in a class of materials such as Lead Zirconate Titanate (PZT). PZT has a perovskite crystal structure (Figure 1). The cation in the center has two equal and stable low-energy states. These states determine the position of the cation. If an electric field is applied in the proper direction, the cation will move in the direction of the field.

Applying an electric field across the crystal causes the low-energy state or position to be aligned in the direction of the field and, conversely, the high-energy state in the opposite position. The applied field will, therefore, cause the cation to move from the high-energy state to the low-energy state. This transition produces energy in the form of a charge generally referred to as switch charge (Qs). Therefore, applying an alternating electric field across the crystal will cause the cation to move from the top of the crystal to the bottom and back again. Each transition will produce a charge, Qs.

A common misconception is that ferroelectric crystals are ferromagnetic or have similar properties. The term "ferroelectric" refers to the similarity of the graph of the charge plotted as a function of the voltage to the hysteresis loop (BH curve) of ferromagnetic materials (Figure 2). Ferroelectric materials switch in an electric field and are not affected by magnetic fields.

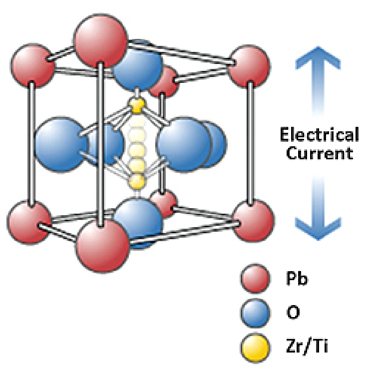


Figure 1. Ferroelectric PZT Perovskite Crystal

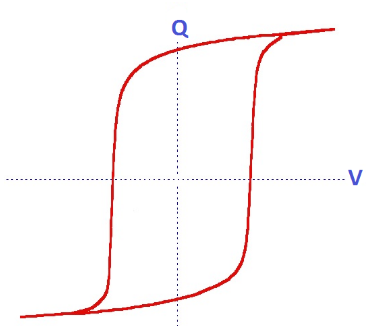


Figure 2. Ferroelectric Hysteresis Loop

The ferroelectric material has two states, the cation at the top, which is referred to as “up polarization”, and the cation at the bottom, which is referred to as “down polarization,” as shown in Figure 3. Therefore, with a viable sensing scheme, a binary memory can be produced.

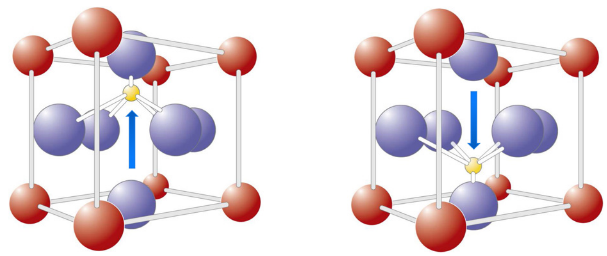


Figure 3. Two Polarization States

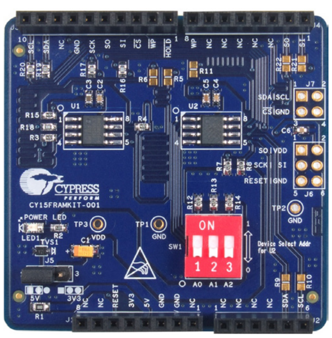
The F-RAM Family from Cypress

Cypress F-RAM (Ferroelectric RAM) combines nonvolatile data storage with the high performance of RAM. It provides fast writes at full interface speed and does not have any write delays and data is instantly nonvolatile. Traditional nonvolatile memories have delays of 5 or more milliseconds before data becomes nonvolatile. If power is disrupted, pending data is lost unless the system has extra capacitance or batteries to keep the system on until data is stored. Power consumption is as low as 300 µA active and 6 µA standby. Because of fast write speeds, it stays active for short periods of time, yielding very low energy consumption. Serial F-RAM offers a pin-to-pin and footprint compatible EEPROM replacement.

Key Features:

- 4Kb to 4Mb densities
- Serial QSPI, DSPI, SPI, and I^2C interface options
- Low power, instant data capture on power loss
- 100-trillion read/write cycle endurance
- No batteries required to store data on power loss; RoHS compliant
- Radiation and magnetic field tolerant

An Arduino compatible development kit (part #: CY15FRAMKIT-001) is an easy-to-use platform to get started.



Serial F-RAM™ Development Kit
(Part #: CY15FRAMKIT-001)

Summary

F-RAM combines ultra-low-power operation with high-speed interfaces, unlimited read/write cycle endurance and instant non-volatility. It is the ideal mission-critical data-logging memory for smart factories of tomorrow.

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