Data-Logging Memory Challenges in the 21st Century

Douglas Mitchell, MPS Product Marketing Engineer

As factory automation systems become more intelligent they will move data acquisition, storage and processing out to the edge of the network, enabling real-time machine controls and management. Factories will be smarter and more connected. These “edge nodes” will predict, then prevent failures before they occur using real-time sensor data, then higher-level predictive analytics will refine processes to continuously improve operational efficiency and reduce downtime, ensuring product quality while reducing costs. Enabling networks of connected sensors will create an explosion of input data requiring continuous, reliable logging to support critical data processing and decision making.

Emerging assisted and autonomous driving systems are also placing increased demands on processing and data storage applications. Advanced Driver-Assistance Systems (ADAS) require reliable capture of camera-, ultrasonic-, radar-, and LIDAR-sensor data, ensuring proper operation and guaranteeing complete, high-fidelity data capture in case of a power loss. All of this while operating in a harsh, sometimes uncontrolled automotive environment.

To meet the challenges of next-generation industrial and automotive systems, high-performance nonvolatile memories must ensure that no data is at risk, must work reliably in harsh environments, and must support long-term and guaranteed backup—all while operating at high speed with low power consumption.

There is one nonvolatile memory technology with more than 25 years of operational history capable of meeting these extreme challenges. That proven technology is Ferroelectric RAM (F-RAM).

Ferroelectric Technology Overview

The ferroelectric property is a phenomenon 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.

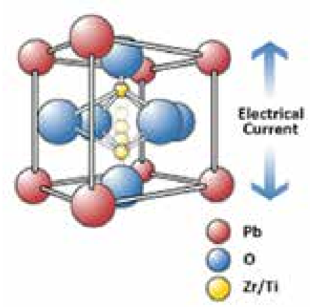
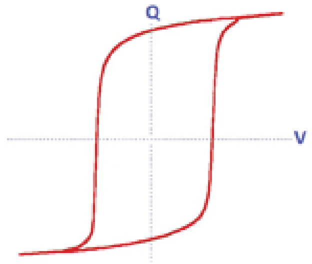


Figure 1. Ferroelectric PZT Perovskite Crystal

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 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. With a viable sensing scheme, a binary memory can be produced.



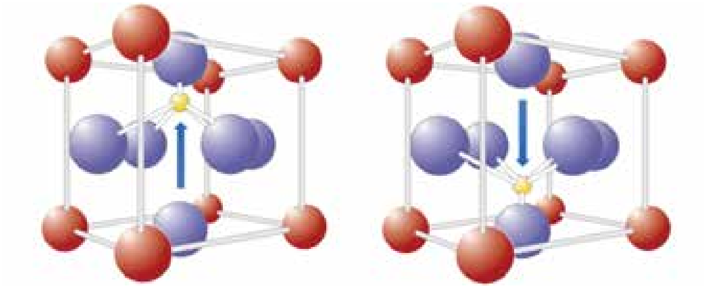


Figure 3. Two Polarization States

F-RAM Benefits

Traditional writable nonvolatile memories derived from floating gate technologies use charge pumps to develop high voltages on-chip (10V or more) to force carriers through the gate oxide. Therefore, there are long write delays, high write power, and the write operation is destructive to the memory cell. Floating gate devices are incapable of supporting writes that exceed 10^6 accesses.

To put this in perspective, a data recorder using an EEPROM to record data at 1 sample/s would wear out in less than 12 days. In comparison, the 3-V F-RAM products offer virtually unlimited endurance (10^{14} accesses).

Additionally, F-RAM is far superior to floating-gate devices in both write speed and power consumption. For a typical serial EEPROM with a clock rate of 20 MHz, it would take 5 ms to write 256 bits (32-byte page buffer) and 1,283.6 ms to write to the entire 64 Kb. For an equivalent F-RAM, it takes only 14 µs for 256 bits and 3.25 ms to write to the entire 64 Kb. In addition, it requires 3,900 µJ to write 64 Kb for the EEPROM, compared with 17 µJ to write 64 Kb to an F-RAM—a difference of more than 229 times.

F-RAM for Data-Logging Applications

F-RAM is the industry's most energy efficient nonvolatile memory, consuming 200x less energy than serial EEPROM and 3,000x less energy than NOR Flash. F-RAM provides unmatched data reliability by offering read/write endurance of 100-trillion (10^{14}) cycles compared to 1 million (10^6) cycles for the typical EEPROM. 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.

Data-Logging Examples

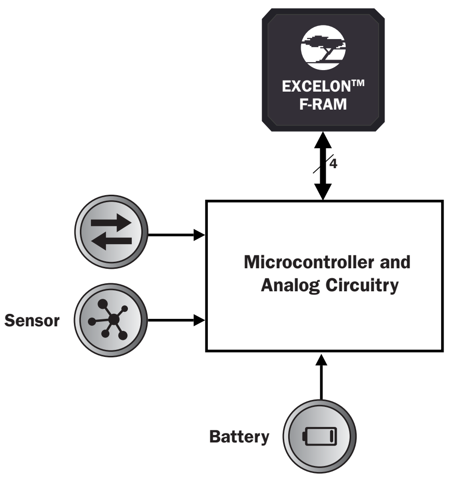


Figure 4: IoT Sensor Node Block Diagram

One key application for F-RAM data logging is in an IoT sensor, as shown in Figure 4. An IoT sensor captures and stores data, then wirelessly transmits it to cloud storage. Power is often supplied from small batteries or capacitors charged by solar panels or alternative sources. The limited energy budget requires the system to be optimized for low power operation.

Wireless transmission is the most power consuming task in IoT sensors. Storing the sensor data locally and transmitting in bulk can significantly improve the data sample size and the sampling interval without compromising the quality of wireless data transmission. This can help improve the power usage and quality of services (QoS) in energy harvested or small battery based IoT nodes.

Low-power F-RAMs, used as local storage, play a pivotal role in these architectures due to faster writes with instant nonvolatility, low power modes and virtually infinite endurance.

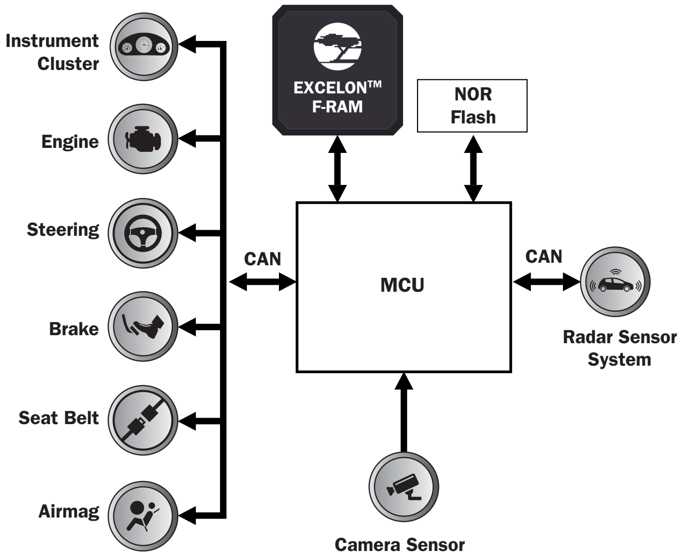


Figure 5: ADAS Block Diagram

Another critical data-logging application for F-RAMs is in automotive ADAS systems (shown in Figure 5). Conventional Flash-based event data recorders (EDRs) buffer camera image data into external RAM or in the Flash memory's volatile buffer memory, then periodically back up that data into nonvolatile Flash. In the event of a crash, these systems risk losing the last moment of critical system data due to power failure. This risk is mitigated when using F-RAMs by enabling instant nonvolatile writes.

ADAS EDRs also take advantage of F-RAM's virtually infinite endurance by continuously writing data into a circular buffer, then benefit from NoDelay™ writes, guaranteeing last image data capture if power is lost in a crash. No external power backup, such as a battery or super cap, is required to complete the store operation.

F-RAM's inherent data store capabilities ensure complete data fidelity recovery to perform after-crash data forensics.

Cypress Semiconductor Corporation
198 Champion Court, San Jose CA 95134
phone +1 408.943.2600 fax +1 408.943.6848
toll free +1 800.858.1810 (U.S. only) Press "1" to reach your local sales representative

002-24171 **

CYPRESS
EMBEDDED IN TOMORROW™