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Advanced FRAM memory

Mike Alwais and Craig Taylor discuss the significance of FRAM technology

Rapid electrification worldwide has made data collection a common requirement in most electronic systems. Today's designers of electric power meters and data collection systems face complex demands as the push toward more sophisticated utility distribution management grows. Nonvolatile, Ferroelectric Random Access Memory (FRAM) offers three distinct benefits to these designers, creating an electronic power meter with the memory technology to capture data quickly and continually, never wear out and consume a very low level of power.

First, FRAM is capable of collecting data for an unlimited period without wearing out. In an electric meter, FRAM can be written every second or minute for the life of the meter. No other nonvolatile memory offers this capability. Less advanced designs for digital meters must rely on writing the data when power is failing because other memory products wear out very quickly if they are written too often.

Ramtron offers FRAM devices with industry standard two-wire interfaces from 4Kb to 512Kb that are ideal for electric meters. The FM24C04 4Kb and FM24C16 16Kb devices are commonly used in low-cost residential meters, while the FM24C64 64Kb, FM24C256 256Kb and FM24C512 512Kb devices are suitable for advanced three-phase commercial and industrial meters. These products are of sufficient bandwidth for metering applications and are easily integrated because of their small package outline (eight-pin SOIC or DFN).

In addition to their high endurance, FRAM products operate with very low power consumption. The technology is capable of producing devices with standby current of less than one µa and active current below 100µa. The low power allows integration without a significant increase in the power budget.

The third benefit of Ramtron's FRAM memories is speed. The underlying technology is based on RAM, like SRAM, rather than ROM, like EEPROM and Flash. RAM devices are much faster for reading and writing, where write speed can be less then 200 nanosecond (ns). For example, Ramtron's FM22L16 is a 256Kx16 nonvolatile RAM that requires no battery backup. It reads and writes with a 55 ns access time. This device is ideal for many types of data collection and storage applications.

Why FRAM?

FRAM technology is a preferred memory solution for data collection. Several hundred customers are already using FRAM in production systems today; making it the most widely used advanced memory technology available.

All current production memory technologies use stored or trapped charge to capture data. Ferroelectric memory technology stores state and is, therefore, nonvolatile. Ferroelectric materials have two unique properties:

- They change state in an electric field. If an electric field is applied across a ferroelectric crystal that is properly oriented, the crystal structure changes. If the field is removed, the crystal is stable in the new orientation
- A switching crystal produces a significant charge.

The ferroelectric material commonly used in memories is PZT (Lead Zirconate Titanate). The figure below shows the two stable states of the crystal.

The ferroelectric material changes state in an electric field and is not affected by magnetic fields. The memory cell consists of a transistor and a capacitor. The dielectric in the capacitor is the ferroelectric material.

The memory cell control requires a voltage to be applied across the ferroelectric material.

The transistor is a switch that connects the bit line to the capacitor (N-channel device means V+ applied to the word line turns the transistor on). The cell capacitance (Ccell) is shared with the bit line capacitance (Cbit).

External commands/control signals are decoded and the internal memory cell control signals are generated .

The plate line and word line are driven high. This causes the electric field to be in the direction of the plate line. If the orientation is a shown on the left in the ferroelectric material will switch. As previously mentioned, the switched material produces a charge spike. Since CV=Q, the switched capacitance is greater than the unswitched capacitance.

For a typical cell, the switched capacitance is approximately 2.5x the unswitched capacitance. A typical cell has a switched capacitance of 250 ff (femtofarad) and a bit line capacitance of one pf (picofarad). Given a bit to cell ratio of 4:1 for a 3V device, there will be approximately 600 mV on the bit line for a switched capacitor and approximately 300mV for an unswitched capacitor. A sensing amplifier easily resolves this and the sense amp drives the bit line to the rail (V+ for a switched device and 0V for an unswitched device).

After the data is sent to the output the original state must be restored. Driving the plate line low reverses the field and restores the state. The cycle time is not dependent on the time it takes to switch the ferroelectric material (nearly instantaneous) it is dominated by the capacitance that must be driven (tRC).

Battery-backed SRAM is often used in applications requiring fast write times. FRAM is an alternative for applications where the battery is not desirable (environmental issues, maintenance problems and more). BBSRAM has a cycle time equal to the access time and, therefore, when considering FRAM as an alternative, the restore delay must be addressed. Relative difference is shown between FRAM and SRAM timing. Modern complex control systems for applications like factory automation are becoming increasingly programmable and can adapt to changing conditions automatically or an operator can adjust them over a network. These systems can have a significant amount of state information that changes or could potentially change often. If the state is distributed amongst various subsystems, it may be desirableto recover from a power failure gracefully.

A simple technique is to use one of Ramtron's serial FRAM devices (small outline) and a comparator. Figure seven is an example of a circuit that can be used as a state saving solution. The comparator will trigger an interrupt voltage determined by the resistor divider. There can be significant time before the regulator drops out. A FRAM device with a serial peripheral interface (SPI), for example, is used as the storage device.

There are FRAM devices available, which can be clocked at 16 MHz. In this example, if it takes 4 ms for the power supply to decay sufficiently such that the regulator drops out, 64Kbits (8Kbytes) can be written. The data can be used to restore the system parameters on power up.

Preferred meter memory technology

Ramtron's FRAM devices are designed into millions of smart meters worldwide, including the world's largest advanced metering management (AMM) project in Italy, Ampy Automation's Pay As You Go utility meters in the United States, Schlumberger's low-cost prepayment electricity meter in South Africa and several top meter manufacturers in China.

FRAM is used as nonvolatile storage for data such as meter identity, customers' remaining credit and operational data. FRAM was chosen by Schlumberger for its ability to write data at full speed, avoiding the complexity of a write-back pipeline to be managed at power down, and for its write cycle endurance, which allows data to be written at frequent intervals. Ampy's Pay As You Go utility metering system incorporates a two-way communication capability that offers enhanced functionality, including Automatic Meter Reading (AMR), on-line inquiries, remote connect/disconnect and complex rate structures. The meters also enable customers to exercise more control over their energy consumption, leading to cost savings and more efficient energy distribution. FRAM's unique performance characteristics are ideally suited for Ampy's advanced utility meters since they require much higher data collection rates than meters of the past.

Six of China's largest utility meter manufacturers have selected FRAM for use in a variety of single- and triple-phase multi-rate digital power meters for its high-reliability features, including superior write endurance. FRAM is ideal for the emerging class of digital utility meters that enhance energy distribution and management. Among the companies designing FRAM into their metering products are Hangzhou Holley Group, Jiangsu Linyang Electronics, Hunan Weisheng Electronics, Shenzhen Longdian, Hangzhou Hualong Electronics and Henan Star Instrument.

Mike Alwais is Vice President, Ramtron International Corporation. For more informationlog on to www.ramtron.com/framinfo@ramtron.com