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HOW GREEN IS MY MEMORY 6

An engineers guide to F-RAM

By Duncan Bennett

FERROELECTRIC RANDOM ACCESS MEMORY (F-RAM) is a non-volatile memory. F-RAM has significant technical advantages that enable solutions not possible with other memory technology. The underlying molecular structure of an F-RAM memory cell is shown in figure 1. When an electric field is applied across the ferroelctric crystal, the central atom moves in the direction of the applied field.

The polarity of this atom remains when the electric field is removed, preserving the data within the memory without the need for periodic refresh.Understanding the three principle benefits of F-RAM enables an electronics engineer to acheive a more efficent and superior design:

- NoDelay Write: F-RAM writes so quickly that there is no need to wait for the write to complete. Typical write speed for F-RAM is around 55 nanoseconds as compared to the much slower 5 milliseconds write speed for EEPROM.
- Virtually Unlimited Endurance: F-RAM can withstand 1E14 (100-trillion) read/write cycles, making it virtually impossible to wear out.
- Low Power: F-RAM requires much less power to perform writes. For example, erasing and writing 64kbits of data in an F-RAM consumes 1/60th the power of that used by an EEPROM and 1/400th that used by a serial flash.

Duncan Bennett is FAE manager Europe at Ramtron.

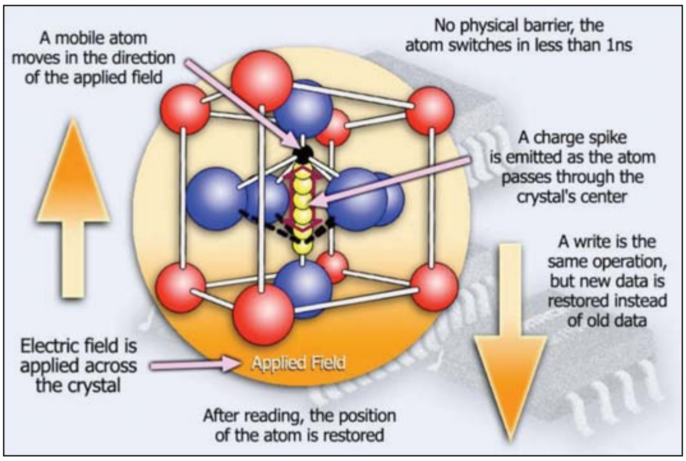

Fig 1: F-RAM properties in the presence of an electrical field.

Now that we've covered the basics, let's see how we can apply F-RAM technology to benefit your product features and time-to-market.

Using F-RAM is simple. Serial F-RAMs are compatible with serial EEPROMs and parallel F-RAMs are compatible with parallel SRAMs. Existing software will work with F-RAMs but most engineers chose to re-work the software. There are two significant software modules that may be employed with EEPROM or flash that are not needed for F-RAM. Removing this redundant code makes software faster to run, easier to debug, and consumes less code space. The first of these modules is the function necessary to wait for EEPROM or flash to complete the write operation. There is no point in polling the F-RAM to see if the write has completed (the write will have finished before you can check), but this feature is supported in case you don't want change your EEPROM software. The second module that is redundant with F-RAM is software that performs wear levelling. Wear levelling is a technique often used with flash or EEPROM to distribute memory writes to numerous locations so that the write cycle limit of any location is not exceeded. With F-RAM's virtually unlimited endurance this function is not necessary.

Now let us look at some example applications to see how the technology advantages of F-RAM have been used.

Automotive infotainment is becoming increasingly more sophisticated leading to a demand for more information to be stored. The stored data is current volume, sound source, filter settings (treble, bass, etc.), balance, user favorites, etc. These settings change with each different sound source (CD, DVD, navigation, radio, etc.). Why use F-RAM and not EEPROM for this data? All of this data must be stored upon power fail. The traditional EEPROM solution required a significant amount of capacitance to maintain power on the EEPROM and MCU after the main power supply fails. F-RAM eliminates the need for this capacitance, saving cost and space. Figure 2 compares the amounts of data that can be stored by F-RAM and EEPROM on power fail.

Figure 2 demonstrates a theoretical limit. In reality, the limitation is the micro-controller and the power fail circuit. The power fail circuit sets the amount of time the micro-controller has to store data. The earlier the power fail can be detected, the more time you have to store data, but this places greater demands on the voltage regulator to ensure that there are no dips in Vdd that could be interpreted as a power fail. If your microcontroller can work at a lower voltage, you have

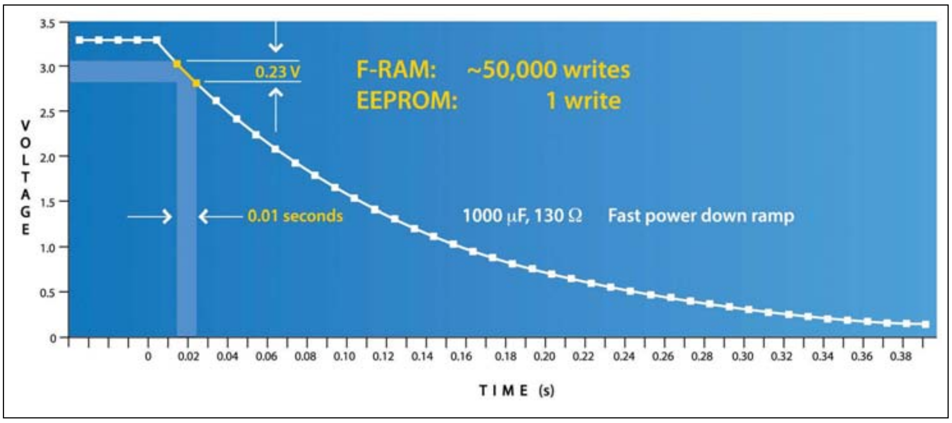

Fig 2: Data storage on power fail.

a longer period in which to capture data. In figure 2, it is assumed that the power fail circuit stops the microcontroller working at 2.8V. If it could continue down to the lower Vdd limit of the F-RAM (Vdd = 2V), you would have much longer to save data (70 mS in the example shown).

You should also consider how fast the microcontroller can collect data and write it. In the above example, the 50,000 writes occur in 10 mS, i.e. 1 write every 200nS. This data rate is only possible with a parallel interface which consumes a lot of the I/O of the microcontroller. With a fast SPI interface (40MHz) the I/O requirement is significantly reduced and the 10mS interval is enough time to write ~5 kbytes, still probably enough for most systems.

F-RAM technology offers an efficient alternative over EEPROM when writing data in applications prone to power failure. The endurance of F-RAM is so high and the write speed so fast that you could write data whenever it changes. This means that the data would already be present in the F-RAM when the power fails and there is no need to write any data during a power fail situation. This small step has a significant advantage; you don't need to have a reservoir capacitor in the system that keeps the power alive during power fail. These reservoir capacitors are necessary when

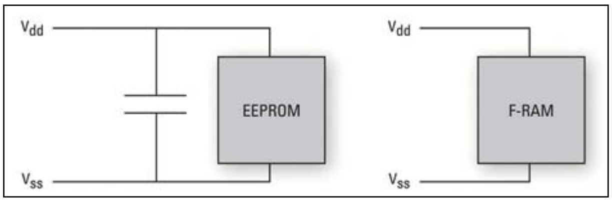

Fig 3: F-RAM eliminates the need for reservoir capacitors.