Sensing Circuits for Resistive Memory

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A nascent class of memory cells based on magnetic- and glass-based materials display resistive characteristics. The variation of the resistance with some applied electrical stimulus must be sensed and interfaced with standard CMOS electronics.

Figure 1 shows a glass-based memory cell called a programmable resistance RAM (PRRAM) element. When the voltage V_{cell} is negative silver molecules are pulled down into the glass and can cause of short between the two layers of metal. As seen in Fig. 1 the cell can be thought of as either a large resistance, say 1 Megaohm, or as a small resistance, say 10 kohms. Figure 2 shows how the cell goes from the programmed state to the erased state while Fig. 3 shows going from the erased state to the programmed state. The key thing to notice when sensing the PRRAM cell is that the voltage across the cell must be less than 0.25 V. However, more desirable is to minimize the voltage across the cell when sensing. This increases the retention time, increases the cell's lifetime and makes process shifts in the actual switching voltage irrelevant.

Figure 4 shows the basic magnetic RAM (MRAM) sandwich. The bottom layer in the sandwich is a pinned (meaning the magnetization is fixed) layer while the top layer's magnetization is switched by running a current over the top of the layer. A change in resistance between the two layers is in the range of 20%. The actual magnitude of the resistance is highly dependent on the thickness of the tunnel barrier. The benefit of the MRAM element over the PRRAM element is the fact that MRAM can serve as a memory without an access device, Fig. 5.

Precision Sensing

Figure 6 shows a cartoon indicating the traditional method of sensing. A bucket is filled with water to some level. The actual signal we are trying to measure is the water running out of the bucket. One guy, in the cartoon, is trying to precisely set the rate of current flowing out of the bucket. The other guy is timing to see how long it will take for the bucket to empty. This technique relies on precisely regulating the flow of current out of the bucket. The circuit equivalent of this technique is seen in Fig. 7. The op-amp tries to precisely set the current through the unknown resistor (either 800k or 1 MEG) while holding the potential across the sneak resistance (the 40k) at zero volts (and hence the name equipotential). Offsets, noise, and op-amp gain make this scheme challenging to implement.

Sensing using Signal Processing

Figure 8 shows a cartoon indicating how we would sense using signal processing (here averaging). Again, the bucket is draining. However, we will make no attempt to regulate the flow of water out of the bucket. Rather, we will add a cup of water, when needed, to hold the water level in the bucket at a constant value. The first thing to notice in our scheme is that we can sense indefinitely because our bucket never drains. To understand this technique in detail let's consider and example.

Suppose we add a 10 oz cup of water, if needed, every 10 seconds to the bucket. If the rate the bucket is draining is 0.3 oz per second (3 oz every 10 seconds) and we arbitrarily want the water in the bucket to remain at 100 oz then roughly every 30 seconds we have to add a cup of water to the bucket. The average amount of water we add to the bucket is then 10 oz/30 seconds or 0.3 oz a second. If the water level is going to, on average, be constant then the water we add has to precisely match the water lost from the bucket.

The final question then becomes how do we average the number of cups of water added to the bucket over a period of time in the actual circuitry? The answer is that we use a simple counter counting the number of pulses indicating when a current is added to a capacitor to compensate for losses from the signal current.

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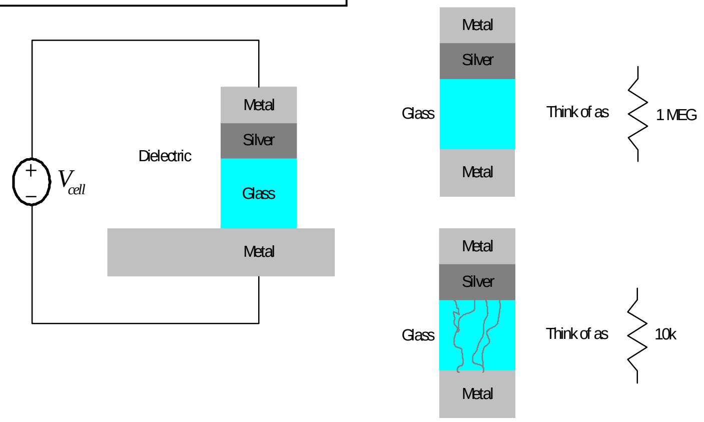

Figure 1 – PRRAM Cell

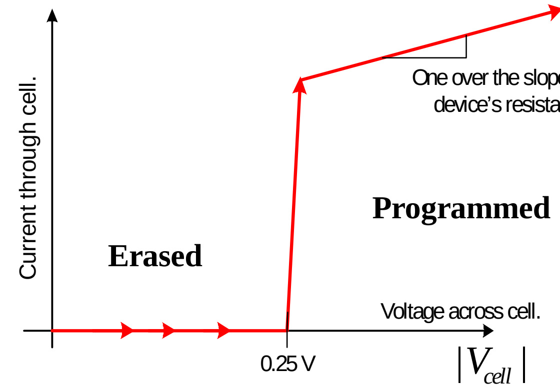

Figure 2 – Programming the PRRAM Cell

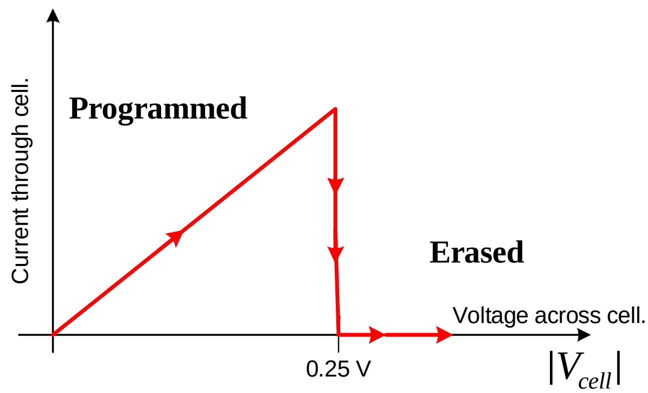

Figure 3 – Erasing the PRRAM Cell

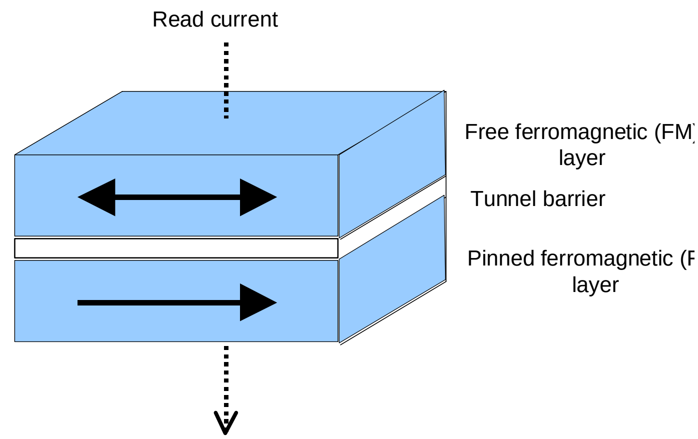

Figure 4 – Basic MRAM element

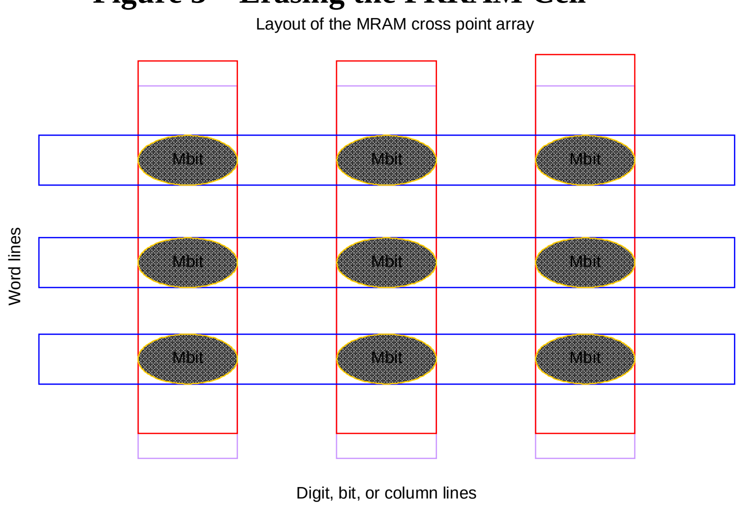

Figure 5 – Layout of an MRAM array

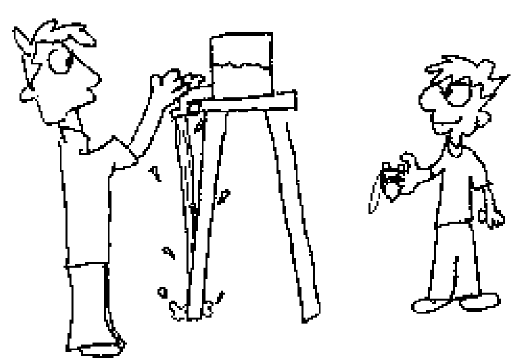

Figure 6 – Cartoon showing precision sensing

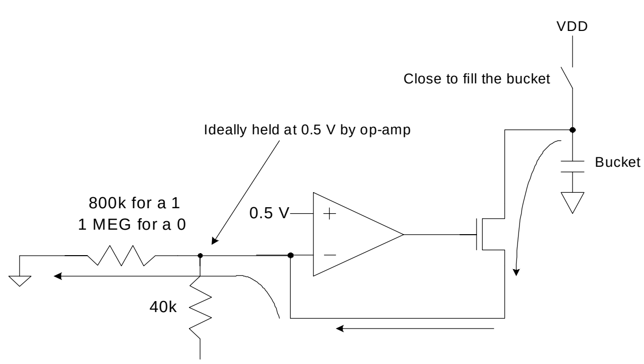

Figure 7 – The equipotential sensing scheme

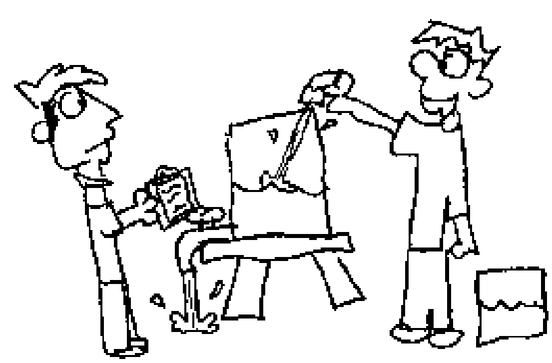

Figure 8 – Cartoon showing signal processing