Multivalued Ferroelectric Associative Memory Design

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Abstract: This talk provides an introduction to Content Addressable Memories (CAM), Ferroelectric memories, and Multiple-Valued Ferroelectric Content-Addressable Memories (MVFCAM). Circuit simulation results are presented for two architectures of MVFCAM.

What is an associative memory?

An associative memory, or a Content Addressable Memory (CAM), searches for data by content rather than by address [1-4]. Thus, a CAM is different from a conventional address-based RAM which searches for data at a particular address. One application of CAMs is in an electronic spelling checker, where the CAM is searched to locate a word with a specific spelling. If there is at least one word in the CAM with a matched spelling, the search is successful.

A search by content can be performed in a word-serial or a bit-serial approach. In a word-serial approach, the words in CAM are compared sequentially against the input word for a possible match. Assuming a CAM with w words, a word-serial approach requires w comparison steps to complete a search. In a bit-serial approach, the most significant bit of each word in CAM is compared simultaneously against the most significant bit of the input word. In the next steps, bits of less significance are compared sequentially against the corresponding bits of the input word. Assuming a CAM with n-bit words, a bit-serial search approach requires n comparison steps to complete a search. As a result, in a CAM with w n-bit words, a bit-serial approach is advantageous in terms of the search speed if $n \ll w$.

Why 'multilevel' CAM?

In a bit-serial approach, an m-level data storage can ideally increase both the search speed and the CAM density by a factor of ($\log_2 m$). The speed or the density is usually compromised to some extent for a less complex design.

What is a ferroelectric capacitor?

A ferroelectric capacitor is physically distinguished from a regular capacitor by substituting the dielectric with a ferroelectric material [5-6]. A ferroelectric capacitor is capable of storing one bit of data in the form of electric polarization. A positive or negative voltage pulse brings the capacitor to its positive or negative polarization state, respectively. The capacitor retains its polarization state without a power supply.

A ferroelectric capacitor constitutes the core of a storage cell in a Ferroelectric Random Access Memory (FRAM).

What is a multilevel FCAM?

Ferroelectric capacitors are used as the storage elements in the recently proposed CAM architectures [2] to implement a Multiple-Valued Ferroelectric CAM (MVFCAM). A 4-level parallel-access FCAM, for example, is capable of storing 4-level data, and searching for data that is less than, greater than, or equal to the input data. Moreover, the search is twice as fast as a search in a binary FCAM. The proposed architectures are also write programmable in real time; a feature that is absent in most nonvolatile CAMs.

References:

[1] K. J. Schultz and P. Glenn Gulak, “Architectures for large-capacity CAMs”, INTEGRATION, the VLSI Journal, Vol. 18, pp. 151-171, June 1995.

[2] Ali Sheikholeslami, P. Glenn Gulak, and Takahiro Hanyu, “A multiple-valued ferroelectric content-addressable memory”, Proc. of the 26th Int. Symp. on MVL, pp. 74-79, Spain, May 1996.

[3] Takahiro Hanyu, Manabu Arakaki, and Michitaka Kameyama, “2-transistor-cell 4-valued universal-literal CAM for a cellular logic image processor”, ISSCC Dig. of Tech. Papers, pp. 46-47, 1997.

[4] T. Hanyu, S. Aragaki, and T. Higuchi, “Functionally separated, multiple-valued content addressable memory and its applications”, IEE Proc. Circuits Devices Syst., Vol. 142, No. 3, pp. 165-172, June 1995.

[5] Ali Sheikholeslami and P. Glenn Gulak, “Transient Modeling of ferroelectric capacitors for nonvolatile memories”, IEEE Trans. on UFFC, Vol. 43, No. 3, pp. 450-456, May 1996.

[6] Ali Sheikholeslami and P. Glenn Gulak, “A survey of behavioral modeling of ferroelectric capacitors”, to be appeared in IEEE Trans. on UFFC, July 1997.