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Tohoku University
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Spintronics-based logic LSI for text search by Tohoku University and NEC reduces power consumption to 1% or less of conventional systems

- Superior power efficiency of spintronics-based logic integrated circuit technology confirmed. -

Tohoku University and NEC Corporation (NEC; TSE 6701) have developed a prototype chip for text search systems using spintronics-based logic integrated circuit technology (Note 1). Early testing of the new prototype chip has demonstrated that the power consumption required for text search has been reduced to only 1 % or less when compared to conventional systems.

Text search processing currently requires a great amount of power to transfer data between the DRAM and CPU within a server. Yet, using just a logic-in-memory structure (Note 2) to eliminate the data transfer process simply increases standby power. The latest spintronics-based logic integrated circuit for text search that Tohoku University and NEC's joint research team developed takes on a logic-in-memory structure but is nonvolatile, and thus requires no standby power. By setting up a structure that supplies power only to necessary circuit blocks for the text search processing, the circuit can run search with a minimal amount of power. This allows a significant reduction in power consumption for text search processing.

With the recent advent of cloud computing and big data usage, the use and scale of computer systems continues to expand, which poses a challenge for the reduction of power consumption.

Tohoku University and NEC address this issue by developing zero standby power and other optimal methods for saving power in computer systems through the application of spintronics-based logic integrated circuit technology.

Features of the recently developed logic integrated circuit for text search include the following:

1. Development and use of multi-functional CAM cells

The team developed and used new multi-functional CAM cells ~~(Note 2~~Note 3) for text-search logic LSI.

In a text search, the computer looks into character strings of index data in DRAM, where all the index data is loaded from a hard-disk in advance, to find ones that match a search text. CAM-based search systems can complete the search for a large amount of index data through a single operation, which eliminates power consumption for data transfer between the DRAM and CPU that is conducted in a conventional text search system, and enables high-speed search processing. However CAM-based systems need to run a search operation with all index data on the CAM chips, regardless of the length of the index text data.

When searching for short lengths of text within a large amount of index data, the newly developed multi-functional CAM is able to avoid searching for long index texts. This is accomplished by setting up combinations (patterns) of input signals that represent long texts. This enables circuits to detect when a long text is input, and to avoid any further unnecessary operations. The circuit also sets up patterns that

avoid searching for (will not run CAM cells for) empty spaces within index data that has no characters. These two patterns allow circuits to cut power consumption by reducing the processing required for a text search.

Logic integrated circuits that use this multi-functional CAM cell for text search will only run circuits that are necessary. This, in combination with its nonvolatile characteristics, reduces standby power and significantly reduces overall power consumption.

2. 1Mb prototype chip fabrication and demonstration

The prototype chip has been fabricated and demonstrated using a 90 nm CMOS circuit (Note 4) and a perpendicular MTJ (Note 5) device. It can store character strings up to 1 Mb in volume, which stores 4,000 index words of up to 32 letters. The prototype chip conducted search operations consuming just 25.7 mW of power with almost zero standby power.

This reduced power consumption to 1% or less of conventional search processing methods using DRAM and CPU. In the future, gigabit-level spintronics-based logic LSIs for text search systems are expected to help enable the commercialization of these technologies.

Tohoku University and NEC present their latest findings on June 13 at the 2013 Symposium on VLSI Circuits, an international meeting on semiconductor circuit technology held in Kyoto from June 11-14.

Part of these findings were obtained through the Cabinet Office's Funding Program for World-Leading Innovative R&D on Science and Technology

(Subject Title: “Research and Development into Energy Efficient Spintronics Logic Integrated Circuits”; directed by Professor Hideo Ohno of Tohoku University) (Note 6).

Note 1: Spintronics-based logic integrated circuit technology uses intrinsic characteristics of electrons – negative charge and minute spin (Note 1b) magnetics – to reverse the magnet’s N/S poles according to the direction of electric current in order to memorize calculation results. The technology allows all circuits on the logic integrated circuit to be nonvolatile. Since nonvolatile circuits are effective in achieving less power consumption in ICT equipment and systems, Tohoku University and NEC have applied this spintronics technology to develop prototypes including an all-purpose integrated circuit (TCAM, Note 1c) and an image processor, and run verification tests on these prototypes (Note 1d).

Note 1b: “Spin” is one of the properties of electrons (an elementary particle with negative electric charge) that makes them behave like tiny magnets.

Note 1c: TCAM (ternary content-addressable memory) refers to a ternary state of stored data with a two-bit memory circuit within the cell in order to give it a masking feature to achieve flexible searching.

Note 1d: http://jpn.nec.com/press/201302/20130219_02.html

Note 2: Logic-in-memory is an architecture that locates memory and logic circuits near poles to shorten wiring distance and thereby cut delays in data transfer and use minimum power. It is also called logic-embedded memory.

Note 3: CAM (content-addressable memory) is the collective name for search-use hardware that can detect matches between search data and an extensive amount of stored data.

Note 4: CMOS circuit: A circuit structured by combining transistors of N and P channel types

Note 5: MTJ: magnetic tunnel junction

Note 6: The Funding Program for World-Leading Innovative R&D on Science and Technology is a national project with the goal of improving Japan’s international competitiveness by selecting core researchers in cutting-edge technologies and then pursuing research and development centered on these core researchers.

Press Contact:

Tohoku University
Center for Spintronics Integrated Systems
Yutaka Kadowaki
+81-22-217-6116
yut-kado@riec.tohoku.ac.jp

NEC Corporation
Corporate Communications Division
Joseph Jasper
+81-3-3798-6511
j-jasper@ax.jp.nec.com