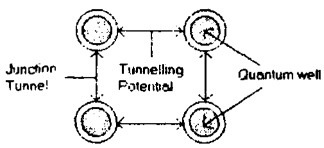
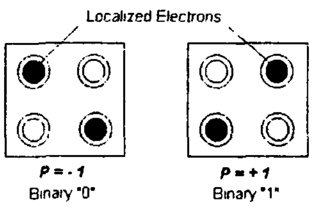
XOR DESIGN AT NANOSCALE WITH QUANTUM-DOT CELLULAR AUTOMATA

S Roy*, S Mahinder#, A R Khudabukhsh#
*Assistant Professor, Dept. of Computer Science & Engineering,
#Final Year, B.Tech, Dept. of Computer Science & Engineering.

The CMOS technology of VLSI design is fast approaching its fundamental limit. It is anticipated that further reduction in size of the devices will prompt quantum mechanical effects to come into play and thereby hinder proper functioning of the fabricated devices. In this scenario, researchers are looking for an appropriate nanotechnology for future generation ICs.



(a) Structure of a QCA cell

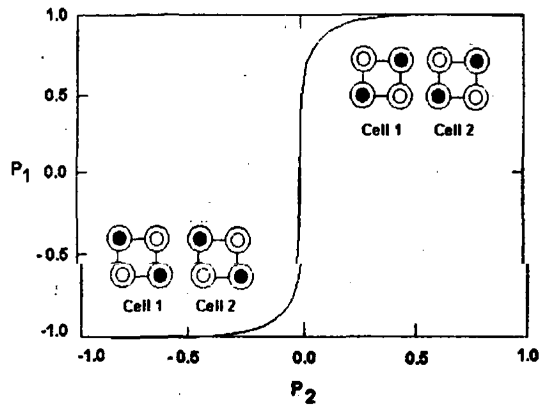


(b) Representing a binary digit with the help of two different polarizations of the localized electrons

Fig. 1. QCA cell and its binary logic

Quantum-dot cellular automata (QCA) is a promising nanotechnology that is envisaged as a viable alternative to the current CMOS technology of VLSI design. It is expected that such a technology will be able to achieve a density of 10^{12} devices/cm^2 and operate at THz frequencies.

QCA offers a new paradigm of information processing and transformation. In terms of feature size, it is projected that a QCA cell of a few nanometer size can be fabricated through molecular implementation by self assembly process.



The cell response function of two adjacent QCA cells

Fig.2. Interaction of two adjacent QCA cells

A QCA is an array of nanostructures called the quantum-dots. A quantum-dot is a region where a charge may be quantum mechanically localized. It acts as a well, in the sense that once an electron, or a hole, is trapped inside the dot, it can not escape from it due to lack of the required energy. A QCA cell consists of four of such dots, positioned at the four corners of a square. Fig.1 depicts the structure of a quantum-dot cell and the technique of representing one bit of information with the help of such a cell. Each cell contains two extra electrons. The electrons can quantum mechanically tunnel among the dots but can not go out of the cell. However, they are subject to Coulombic interaction among themselves so that they are forced to settle into the opposite corner positions. This corresponds to two opposite polarization $P = -1$ and $P = +1$, thus representing the logic values of "0" and "1" respectively. Although QCA is still in the research stages, it has been experimentally verified.

An array of QCA cells interact with each other, as depicted in Fig. 2 and carry information through them.

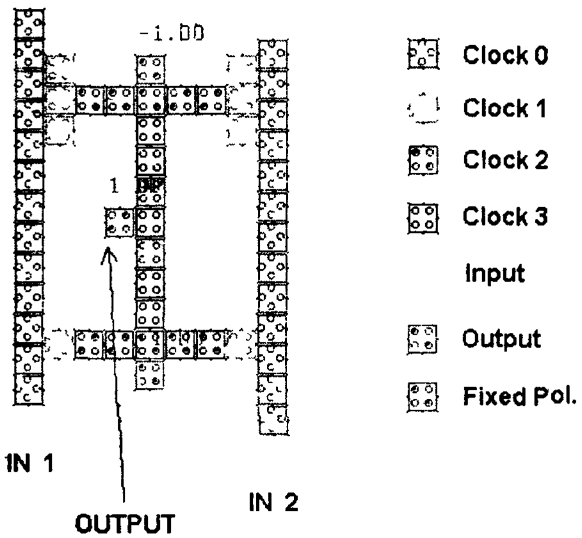


Fig. 3. The proposed design of XOR gate with QCA

This paper presents a novel design of an XOR gate with QCA. The proposed design is developed in the QCADesigner environment. The XOR gate has been implemented following the expression AB'+BA'. As we needed both the original and the complemented form of the input, two kinds of junctions have been employed. Three more conventional gates, viz., two AND gates and one OR gate are used to get the desired output. The flow of information through the proposed XOR gate is controlled by four clock signals each shifted in phase by 90 degrees. Two diagonal wires have been used in this design. A diagonal wire has the property of toggling the information every adjacent cell. The final design is shown in Fig. 3. Simulation result shows that the proposed design carries out the desired function assuming that intercellular interaction is electrostatically coupled and waveform overlap between cells is nonexistent.

Acknowledgement :

This research was partially supported by AICTE sponsored R&D project No. F.NO./8020/ RID/R&D - 142.2001-02.

** This paper was presented by Sri Sayanytan Mahinder, B.Tech., Final Year, C.S.E., Kalyani Govt. Engg. College in International Conference on Nanoelectronics, Japan, in January 2005.