Modified binary comparator in quantum dot cellular automata using five input majority gate

[1] NALLAPARAJU SAIMYTREYI, Pg Scholar, Vlsi And Embedded System Design.
[2] R.SATHYA VENI, Asstasint professor, ECE Department.
[1, 2] Kakinada Institute of Engineering and Technology for Women

Abstract:

Quantum dot Cellular Automata (QCA) is a novel and potentially attractive technology for implementing computing architectures at the nanoscale. The basic Boolean primitive in QCA is the majority gate. By applying these items, the hardware requirements for a QCA design can be reduced and circuits can be simpler in level and gate counts. This paper proposes a new design approach oriented to the implementation of binary comparators in QCA. In this design a five input majority gate and a novel design for a QCA based comparator cell is designed. In ordinary form of QCA cells, a cell can take effect from three around sides (bottom, up and left) and out the result function from another side (right). Hence this form of cell is proper for three-input majority implementation. So, in this paper we designed a five input majority gate and implemented a QCA based comparator cell using it.

Keywords- QCA, three cube QCA cell, five-input majority gate, logical function, logical simplification.

I. Introduction

Quantum Cellular Automata (QCA) is a nanotechnology that has recently been recognized as one of the top six emerging technologies with potential applications in future computers. It has gained significant popularity in recent years. This is mainly due to rising interest in creating computing devices and implementing any logical function with that. The basic building block of QCA circuit is majority gate; hence, efficiently constructing QCA circuits using majority gates has attracted a lot of attentions. Several studies have reported that QCA can be used to design general purpose computational and memory circuits. QCA is expected to achieve high device density, very high clock frequency and extremely low power consumption.

In recent years the development of integrated circuits has been essentially based on scaling down that is, increasing the element density on the wafer. Scaling down of complementary metal oxide semiconductor CMOS circuits, however, has its limits. Above a certain element density various physical phenomena, including quantum effects, conspire to make transistor operation difficult if not impossible. If a new technology is to be created

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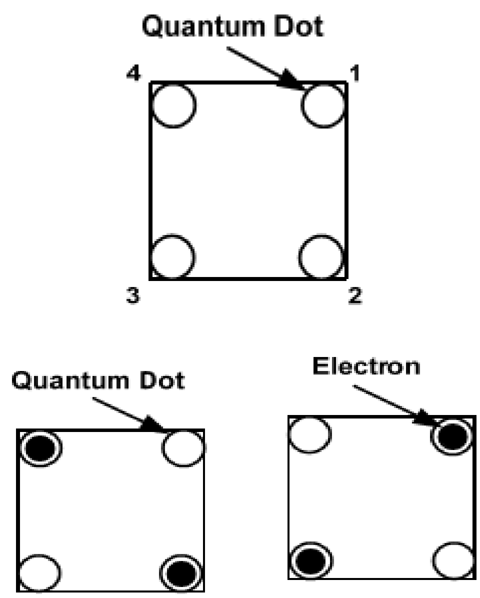
for devices of nanometer scale, new design principles are necessary. One promising approach is to move to a transistor less cellular architecture based on interacting quantum dots, quantum dot cellular automata QCA.

In this paper we propose another possible design for majority gates resulting in a novel scheme for QCA cells, to facilitate simplifying logical functions. By applying this form of majority gate, we can simplify logical functions and achieve improved results. For example a 1-bit QCA comparator is constructed only with three gates (two different forms of majority gates and only one inverter). In comparison to other existing implementation this method has demonstrated interesting results. Beside, some Boolean functions are expressed as examples and it has been shown, how our reduction method by applying new proposed item, decreases gate counts and levels. We will show and discuss that using of the proposed items can be efficient in designing majority gate based circuits.

Quantum cells

In ordinary form, QCA technology is based on the interaction of bi-stable QCA cells constructed from four quantum dots. A schematic of a basic cell is showed and the cell is charged with two free electrons, which are able to tunnel between adjacent dots. These electrons tend to occupy antipodal sites as a result of their mutual electrostatic repulsion. Thus, there exist two equivalent energetically minimal arrangements of the two electrons in the QCA cell. These two arrangements are denoted as cell polarization. And by using cell polarization to represent logic "1" and to represent logic "0" binary information is encoded in the charge configuration of the QCA cell.



Basic QCA cells

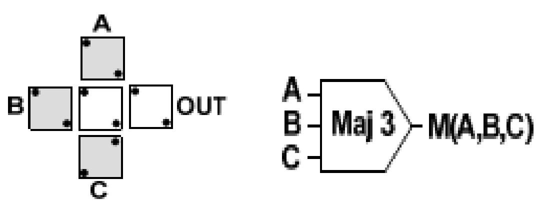
$$P \equiv \frac{(\rho_2 + \rho_4) - (\rho_1 + \rho_3)}{\rho_1 + \rho_2 + \rho_3 + \rho_4}$$

The cells exchange information by classical Columbic interaction. An input cell forced to a polarization drives the next cell into the same polarization, since this combination of states has minimum energy in the electric field between the charged particles in neighboring cells. Information is copied and propagated in a wire consisting of the cell automata. The available two cell types, which are orthogonal and have minimal interaction with each other, enabling the coplanar wire crossing, where the wires consist of different cell types and can operate independently on the same fabrication layer.

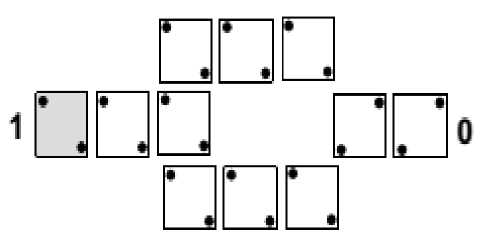
II.Literature Survey

Nano-electronic Circuits based on three-input Majority gates and Inverters:

Any QCA circuit can be efficiently built using only majority gates and inverters. Assuming the inputs are A, B and C, and the logic function of a majority gate.



QCA majority gate



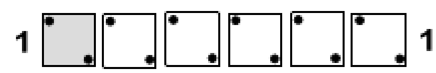
QCA inverter

M (A, B, C) =AB+BC+AC……….(1)

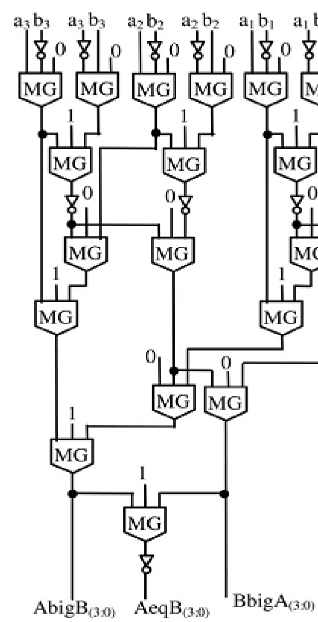
Each QCA majority gate in normal form requires only five QCA cells. Every QCA inverter gate can be implemented by 11 quantum cells. For generating an AND gate or an OR gate with majority we can fix the polarization of one input to a constant logic '0' or logic '1'. Hence, QCA circuit is based on majority gate-based circuits instead of AND/OR/Inverter gate-based circuits.

M (A, B, 0) =AB ……………..(2)

M (A, B, 1) =A+B…………….(3)



QCA wire



QCA based comparator using 3-input Majority Gate

Other important component in QCA designing is wire. In a QCA wire, the binary signal propagates from input to output because of the electrostatic interactions between cells. Since the polarization of each cell tends to align with that of its

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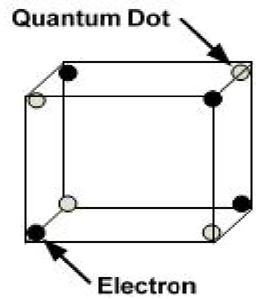
neighbors, a linear arrangement of standard cells can be used to transmit binary information from one point to another. In this wire, all of free cells align in the same direction as the driving cell (input cell), so the information contained in the state of the input is transmitted down the wire. Beside, the distance between dots and between cells is a key parameter giving Columbic effect in QCA application in conventional form.

III. Proposed Design

In ordinary form of QCA cells, a cell can take effect from three around sides (bottom, up and left) and out the result function from another side (right). Hence this form of cell is proper for three-input majority implementation, but for a five-input majority gate we need a different design of cells, that can affect from five sides and transmit its polarization from another side. Hence we need to have a new structure in QCA cells including five inputs and one output. A new scheme for QCA cells is presented here. In the proposed design a QCA cell is a structure comprised of eight quantum-dots arranged in a cube pattern. We propose this structure for compatibility with five pins majority gate.



Three cube QCA cell

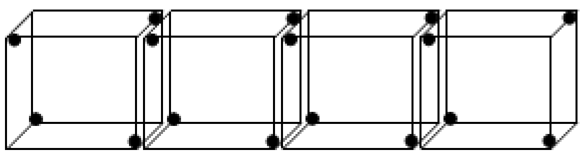
A five pins majority gate must have five inputs and one output. QCA uses the positions of electrons in quantum dots to represent binary values ‘0’ and ‘1’. Like ordinary form of QCA cells, in proposed form of QCA cells, an equation for cell polarization.

$$P \equiv \frac{(\rho_1 + \rho_3 + \rho_6 + \rho_8) - (\rho_2 + \rho_4 + \rho_5 + \rho_7)}{\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5 + \rho_6 + \rho_7 + \rho_8}$$

In this new form of QCA cell, we can have primitive components for designing every function only with QCA cells. These components are QCA wire, majority and inverter gates.

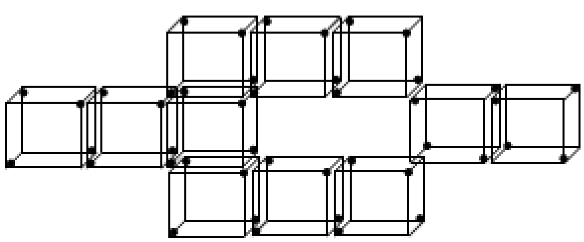
QCA wires:

In a QCA cell, QCA wires are adjacent QCA cells interact in an attempt to settle to a ground state determined by the current state of the inputs. Since the polarization of each cell tends to align with that of its neighbors. This is most clear in the case of the QCA wire. The polarization of the input cell is propagated down the wire, as a result of the system attempting to settle to a ground state. Any cells along the wire that are anti-polarized to the input would be at a higher energy level, and would soon settle to the correct ground state.



QCA inverter:

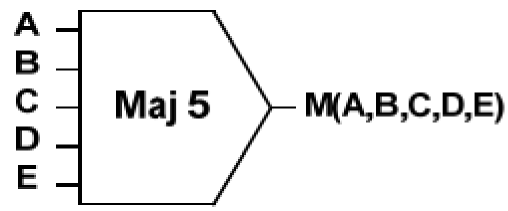
Two standard cells in a diagonal orientation are geometrically similar to two rotated cells in a horizontal orientation. For this reason, standard cells in a diagonal orientation tend to align in opposite polarization directions as in the inverter chain. Computation with QCA is accomplished by designing QCA layouts, which exhibit the desired interaction of states. Consider the arrangements, demonstrating the QCA implementation of an inverter. Similarly to ordinary QCA inverter, in this form we have 11 QCA cells.



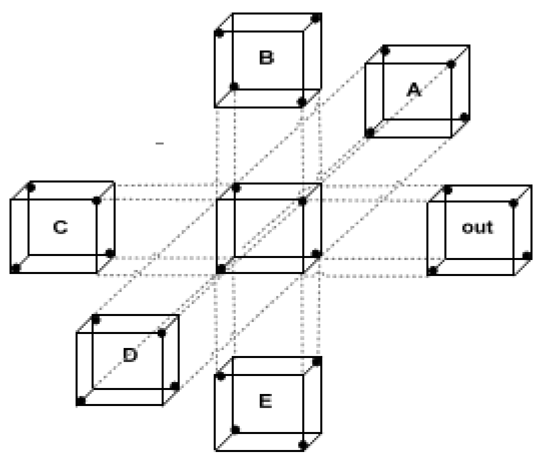
Five-input Majority gate:

Majority is a voter. In a new structure, a majority gate can be implemented using polarization of input cells are fixed and middle cell and out cell are free. Inputs from five around cells affect on the middle cell, and it determines polarization of the output cell. This structure makes majority decision. The majority voting logic function can be expressed in terms of fundamental Boolean operator.

M(A,B,C,D,E)=ABC+ABD+ABE+ACD+ACE+ ADE+BCD+BCE+BDE+CDE……….(4)



Schematic symbol for the majority gate



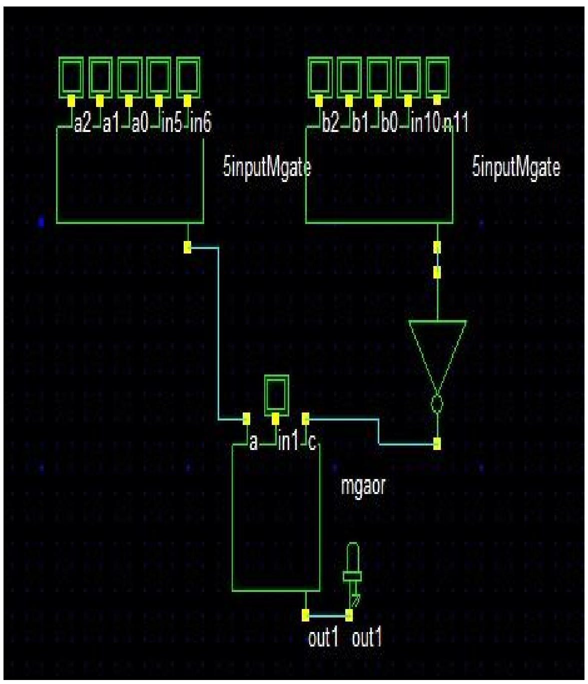
Majority of the five input neighbors

A schematic symbol of a five pins majority gate can implement a three-input AND gate and also a three-input OR gate using this majority gate.

M(A,B,C,0,0)= ABC………....(5)

M(A,B,C,1,1)= A+B+C…………(6)

In the previous technique we designed a 3-input majority gate based comparator which is very speed and efficient and now we implemented a 5-input based majority gate based comparator as shown in the above figure.



Five input Majority gate based Comparator

IV.Conclusion