ARTICLE IN PRESS

Microprocessors and Microsystems xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Microprocessors and Microsystems

journal homepage: www.elsevier.com/locate/micpro

A novel rising Edge Triggered Resettable D flip-flop using five input majority gate

Saeid Zoka[a], Mohammad Gholami[b,*]

[a] Faculty of Computer Engineering, University College of Rouzbahan, Sari, Iran
[b] Faculty of Engineering and Technology, University of Mazandaran, Babolsar, Iran

ARTICLE INFO

Keywords:
Quantum cellular automata
D flip-flop
Edge triggered
QCADesigner
Clocking zones

ABSTRACT

Quantum Dot Cellular Automata (QCA) provides a new structure for designing digital circuits with smaller size and less power consumption. This technology is a new method to implement digital circuits in the future. This paper presents a new rising edge triggered D flip-flop structure with reset capability. Simulation of the circuit in QCADesigner software confirms the correct operation of the circuit. Finally, several common structures without reset ability are compared with the proposed structure and the results are indicated in the comparison table. The designed D flip-flop uses 95 cells for implementation and will function properly in one period of time.

1. Introduction

Nanotechnology is a discipline of applied science and technology that covers a wide range of topics. Its main issue is the controlling of materials or devices with dimensions less than one micrometer. In fact, nanotechnology is the understanding and application of new properties of materials and systems in this dimension, which have new physical effects mainly influenced by the dominance of quantum properties on classical features. Quantum cellular automata is a nano sized structure that identifies information at the location of electrons, and forms an automaton using electrostatics between the bars [1]. The basic element in this technology is a cell consisting of four quantum dots and two electrons. Using this cell, basic elements of this technology are made and used to implement different circuits. These are due to the importance of the design of high-efficiency hybrid and sequential circuits in any binary systems.

Flip-flops are among the most important types of sequential circuits and are widely used in digital circuits. Quantum cellular automata has many characteristics for implementing flip-flop circuits that are less common in previous technology. These features include higher speed, very low power and design coherence, which offers new possibilities for researchers of this field. D-flipflops have received the most attention by many designers due to various usages in building memory cells. There are two general approaches to designing these types of flip-flops based on their inherent capability. The first one is line-based method in which the process of storing data happens through a quantum cellular automata wire and changing the direction of flow in the clocking zone. Several instances of this design are provided in [2,3]. This method requires more cells for designing and also increases the complexity of the circuit, but the use of this method will reduce the delay. The second is ring-based method which performs the storage bit operation of a data bit by rotating a bit in a ring that includes four clocking zones. This method is delineated in [4–7]. Since ring-based memory cells apply less hardware load on the system, most researchers focus on ring-based designs.

Another requirement for designing digital circuits, which has always been the focus of researchers, is designing reset-enabled sequential circuits. These circuits, which are most often arranged alongside the circuit, play an important role. Selectable counters and memory are two examples of important circuits that require resettable memory blocks. In most traditional designs, reset inputs are not considered for these types of flip-flops. This paper introduces a new and optimal design for D-flipflops that has the rising edge triggered reset ability. The design is compared with several examples of existing designs that do not contain reset inputs in terms of design and occupied space and the delay of diffusion and complexity. In the following sections, the provided structures are simulated and verified by QCADesigner software.

The rest of the paper is organized as follow: Section 2 gives a brief review of QCA preliminaries structures. In Section 3, a new Edge Triggered Resettable D-Flip Flop Structure is proposed. Section 4 addresses QCA implementation, simulation results and discussions. Section 5 concludes this paper.

2. QCA preliminaries

Quantum Cellular Automata was first introduced in 1993 by

* Corresponding author.
E-mail address: m.gholami@umz.ac.ir (M. Gholami).

https://doi.org/10.1016/j.micpro.2018.06.006
Received 1 October 2017; Received in revised form 25 April 2018; Accepted 13 June 2018

Please cite this article as: Zoka, S., Microprocessors and Microsystems (2018), https://doi.org/10.1016/j.micpro.2018.06.006

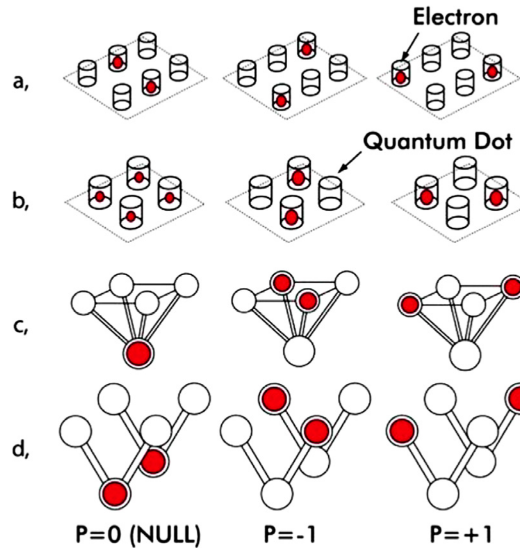

Fig. 1. Geometric arrangement used to implement quantum cellular automata cells in (a) Six-point plate arrangement. (b) Four-point plate arrangement used in semi-conductor implementations and metal-island. (c) The first demonstration of the molecular implementation of quantum cellular automata in 3D form The second molecular demonstration of quantum cellular automata. (d) Molecular QCA cells are created using three-dimensional geometries [1].

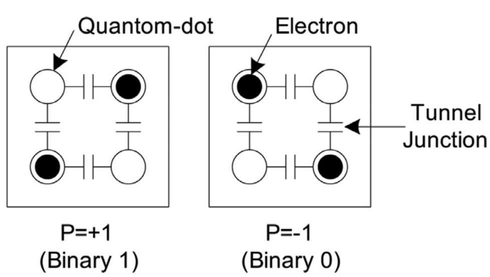

Fig. 2. 90-degree cell structure of quantum cellular automata with two possible polarization.

Professor Lent at the University of Notre Dame. The processing of information in a quantum cellular automata takes place based on a Columbic interaction between the same cells of the quantum cellular automata. Each of these cells, as shown in Fig. 1, consists of four to six electron locations (quantum dots) that are connected to each other through tunneling connections. The quantum dot is referred to a place that the electron can occupy. Fig. 1 geometrically shows the types of standard cells present in a quantum cellular automaton. Each cell of the quantum cellular automaton has two electrons, and since electrons electrostatically repulse each other, these two electrons tend to be placed at the existing diameter points. In other words, it is only in two arrangements that electrons have the least energy. In a six-point quantum cellular automata, null mode is created by placing electrons in the midpoints, and in four-point quantum cellular automata, it is defined by the superposition of mechanical quantum of two polarities and the distribution of the load between the four quantum dots. If the potential boundaries that separate the quantum dots are low, electrons can tunnel between the points, but it should be noted that they are not able to leave the cell [8].

2.1. Cells and wire in quantum cellular automata technology

In a quantum cellular automata, as shown in Fig. 2, binary information is indicated in the location of the electrons in such a way that one of the two arrangements with the polarization $P = -1$ is considered as the logical zero and the other with the polarization $P = +1$ as a logical one. This binary feature of the quantum cellular automata cell provides a natural bridge to digital electronics. These concepts also apply to the 45-degree rotation of quantum cellular automata cells [9].

Two methods are commonly used in quantum cellular automata technology. The first method, which is considered as the standard wiring method in the quantum cellular automata technology, is the combination of an array of quantum cells. As shown in Fig. 3, when the input signal is applied, the polarization of the input cell is transferred to the adjacent cells due to electron repulsion, and due to this, the input signal is transmitted to the output. Another mode of wiring in a quantum cellular automaton is using 45° cells, so that the cells are arranged side by side with the polarization of $+1$ and -1, thus the input signal is transmitted to the cell, and the input signal is seen on the other side of the wire. This kind of wiring is called the inverter chain [10].

2.2. Clocking

In the architecture of quantum cellular automata, binary information is placed in the arrangement of loads within quantum cells, and cells do not need external power except for automata clocks. Each of the electrons are placed inside a cavity of energy that, by decreasing and increasing the energy, can provide a clock for a quantum cellular automata circuit. Generally, there are two types of clocking in the quantum cellular automata technology: one-dimensional and two-dimensional. Basic computational operations in quantum cellular automata are done by one-dimensional clocking in four phases. Adding the clocking functionality to the circuits makes them more controllable, so that by actually adding the clocking function, the cells are effectively stored in a clocking area with definite polarization. As shown in Fig. 4, each of the four phases of the clocking cycle has a phase difference of 90-degrees. Since clocking is stated in four stages, so four clocking regions should be defined in each quantum cellular automata and this increases parallelization functionality of the circuit. Each of the four stages are defined as follows [11]:

Switching: Potential barriers inside the dot gradually increase, so the electrons in the dots can be influenced by adjacent cells.
Holding: At this stage, the energy boundaries become large, and thus the electrons cannot influence the electrons of the adjacent cells.

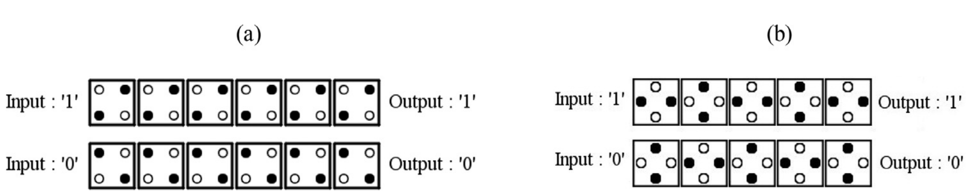

Fig. 3. Wiring in QCA. (a) Wiring with 90-degree cell. (b) Wiring with 45-degree cell.