An Optimal Design of Multiplexer Based Conservative Gate in Quantum-Dot Cellular Automata

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***Abstract*—Nanotechnology based on Quantum-dot Cellular Automata (QCA) is one of the potential alternative technology to CMOS. The design of conservative circuits received significant attention due to error detecting and energy conservation. In this paper, multiplexer based conservative gate (MX-CQCA) is presented. The property of the gate is similar to the Fredkin gate, but MX-CQCA is a conservative gate.**

Keywords-Quantum-dot cellular automata; multiplexer; conservative gate; MX-CQCA.

I. INTRODUCTION

The transistor based complementary metal-oxide-semiconductor (CMOS) technology is reaching its limited point in developing process due to high power consumption, limited physical density and high current leakage. Quantum-dot cellular automata (QCA) is one of the promising nano technologies that has attracted researchers to investigate its reliability constraints. QCA also offers new type of information computation. The basic element of this technology is QCA cell. It is square shape structure that contains four quantum dots positioned at the corners and two free electrons. Electrons can move to any quantum dot in the cell through electron tunneling due to coulombic interaction between them. In that case, polarizations -1 and +1 are encoded as logic binary "0" and "1", respectively [1][2]. QCA standard wire which propagates a logic value can be constructed by placing QCA cells side by side as shown in Fig. 1(a). Moreover, there is an inverter chain that can be constructed using rotated cells, as shown Fig. 1(b). Wire crossing in QCA is usually realized with two ways. Coplanar wire crossing is achieved using inverter chain. Second type of wire crossing is multilayer crossing that uses crossover bridge, like CMOS technology [3].

Fundamental gates of QCA circuits are inverter and majority gates. Any QCA circuits can be built using these gates. Majority gate consists of three inputs and one output as illustrated in Fig. 1(c) and (1). The three-input majority

$$M(A, B, C) = AB + BC + AC; \qquad (1)$$

gate performs logic OR operation or logic AND operation by fixing polarization one of the input cells to $P = +1$ or

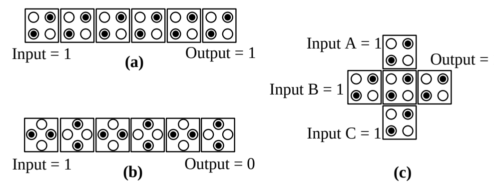

Figure 1. (a) QCA wire, (b) inverter chain, (c) QCA majority gate.

$P = -1$, respectively. The inverter is implemented by placing two cells diagonally.

Timing and synchronization of QCA is accomplished by cascaded clocking of four phases. QCA clocking is for providing with power to all part of QCA circuits and regular computation throughout the circuit. The tunneling barrier between two dots of the cell starts to rise in the switch phase. By taking a certain polarization, the cell stores current situation during hold phase. Cell polarization is reduced and eventually lost through release and relax phases [4].

Some defects may occur while positioning cells to surface in QCA circuits. They are divided three major categories: cell misalignment, cell omission and rotation cell defects. In the first category, the defected cell is not properly lined up to its neighboring cells. Sometimes misalignment cells have no effect on functionality of the circuit, but sometimes it may cause the circuit to have unexpected output. Cell omission occur when a cell is missing in its position and becoming defective. A third type of defects occurs when cells are rotated to the other cells [5].

In this paper, multiplexer based conservative logic gate is presented. It can be used to design any majority logic and multiplexer logic based testable nonreversible circuits.

II. RELATED WORK

Conservative logic is a comprehensive model of computation, which explicitly reflects the fundamental principle of thermodynamics. It is multiple-output logic element that the number of 1s (binary 1) at the inputs is equal to its corresponding outputs. Conservative logic network can be reversible if one-to-one mapping is maintained between inputs and outputs. If one-to-one mapping is not preserved, it will be irreversible in nature. There is popular conservative gate called Fredkin gate that has three inputs and three outputs and also it is universal gate in nature.

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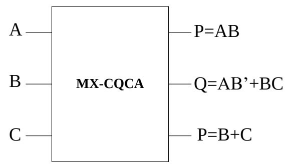

Figure 2. Schematic of MX-CQCA.

Recently, a multiplexer based conservative gate MX-CQCA is proposed, as shown in Fig. 2 [6]. Design of this gate in QCA requires five majority gates and four clocking phases. Conceptually, the target of this work is to improve MX-CQCA conservative gate in terms of complexity, occupied area and delay factors. In the gate, 13-standart functions are represented and these functions are widely used in QCA.

III. DESIGN METHODOLOGY

Commonly conservative gates use to design inverter chain. The existing conservative MX-CQCA gate also has been designed using coplanar wire-crossing. The proposed block diagram is illustrated that one QCA multiplexer and two conventional majority gates are built in the diagram, as shown Fig. 3. R and P outputs are implemented by constructing QCA logic OR and logic AND, respectively.

Construction of 2-1 multiplexer (2-1 MUX) is built based on gate level QCA multiplexer which was proposed in [7]. This structure has achieved significant improvements in terms of complexity and occupied area, as shown in Fig. 4. Moreover, the expected result is correctly simulated without delay. The gate level MUX is more suitable in several conservative structures. Hence, we also will realize this design in our proposed conservative gate for significant achievement.

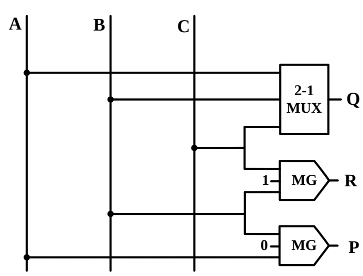

Figure 3. Block diagram of MX-CQCA.

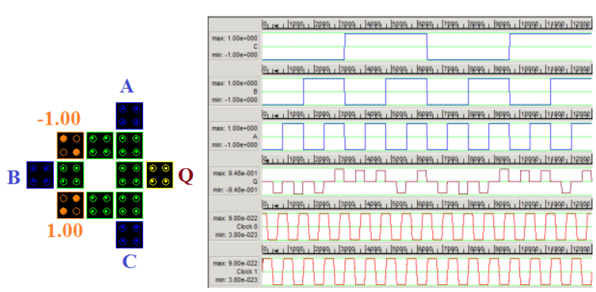

Figure 4. QCA design of MUX.

IV. PROPOSED DESIGN

Based on proposed block diagram, we have designed MX-CQCA conservative circuit in Fig. 5. It is coplanar structure and consists of 128 QCA cells. Occupied total area of the circuit is approximately equal to $(S = 0.1\ \mu m^2)$ as well as the output is generated after three clock phases.

The proposed design and previous design [6] have been compared in terms of complexity, area and latency. An improvement of the proposed gate has achieved 41% less cells, 86% less area and also better latency in comparison.

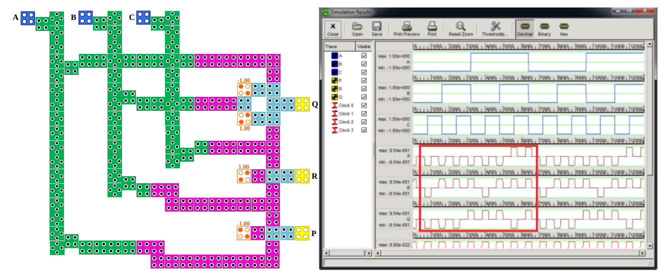

Figure 5. Proposed MX-CQCA design.

V. CONCLUSIONS

In this paper, MUX based conservative gate has been proposed. The sequential circuits can be implemented using this gate. The layout and functionality have been done using QCADesigner tool version 2.0.3 and all features work well. It can be used in testable circuits, as well as in reversible ALU designs.

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