Area Efficient Layout Design of Multiply Complements Logic (MCL) Gate using QCA Technology

Sharmin Farzana[1], Ali Newaz Bahar[2] and Syeda Sharmin Islam[3]

[1] Mawlana Bhashani Science and Technology University

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Abstract
Quantum dot Cellular Automata (QCA) is one of now popular technology for its highly scalable feature and ultra low power consumption that made its one of the promising alternatives to CMOS technology. This paper present a new layout design of Multiply Complements Logic (MCL) gate based on QCA inverter (INV), QCA wire and QCA majority voter (MV) gates. To verify and simulate the proposed gate QCA Designer and Microwindlite tools are employed. The simulation result confirmed the correctness of the proposed circuits and comparison shows the area efficiency of QCA over CMOS technology. This proposed design layout has a promising future in constructing ultra low power exhausting information processing system and can stimulate higher digital applications in QCA.

Index terms— QCA inverter (INV), QCA wire, QCA majority voter (MV) gate, QCA Designer and MICROWIND.

1 Introduction

anotechnology provides new possibilities for computing due to the unique properties that arise at such reduced feature sizes. Among this new devices, Quantum-dot Cellular Automata (QCA) [1,2] relies on new physical phenomena (such as Coulombic interactions), and innovative techniques that radically depart from a CMOS-based model. QCA not only gives a solution at nano-scale, but it also offers a new method of computation and information [3,4]. Consider the processing features of QCA technology, the basic element is cell that can be used as an information processing unit (perform logical operation), while others (i.e. wires) are used for information transfer and communication. In information processing reversible logic circuit made a great attention in recent years. It is addressed that the reversible logic gates are promising computing paradigm with applications in emerging technologies such as quantum computing, quantum dot cellular automata, optical computing, etc. [5][6][7][8]. In Quantum computing we found there are many proposals on Reversible Logic Gate (RLG) design like Feynman Gate [9], Toffili Gate [10], Fredkin Gate [11], NFT Gate [12] but very few of them are being designed in QCA [13,14].

Author ? ? ?: Department of Information and Communication Technology, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh. e-mail: sharmin.sf@gmail.com, bahar_mitdu@yahoo.com II.

2 Materials and Methods

The QCA cell is the basic building block of QCA. Four quantum dots that consist of a QCA arranged in a square pattern. These quantum-dots are sites in which electrons are able to tunnel between them but cannot leave the cell. The basic cell constructed from four quantum dots with two mobile electrons which can move to different quantum dots by means of electron tunneling. Columbic repulsion will cause the electrons to always occupy diagonally opposite dots.

The two stable polarization of electrons P= +1.00 and P= -1.00 of a QCA cell represents logic '1' and logic '0' respectively, shown in figure 1. QCA wires can be either made up of 90 0 cells or 45 0 cells. 45 0 cells are used for coplanar wire crossings (Figure **??**). In case of Inverter, if place two cells at 45 0 with respect to each other they interact inversely. An array of QCA cells acts as a wire and is able to transmit information from one end to another, i.e., all the cells in the wire will switch their polarizations to follow that of the input or driver cell. P = -1 P = +1 Quantum dot Electron (a) (b)

3 Mcl Gate

In this section describe the 3 × 3 MCL (Multiply Complements Logic) Gate. Reversible Logic gate is defined as input vector and output vector must be with one to one correspondences. The MCL gate maps the inputs A, B, C to P= (B+C)?, Q= (A+B)?, R=A. Table **??** represents the truth table of this gate and figure 5 shows the QCA block diagram of MCL gate. QCA Designer [16,17] is the product of an ongoing effort to create a rapid and accurate simulation and layout tools for quantum-dot cellular automata (QCA). Figure 6 shows the simulated gate design of MCL gate, where A, B, C and P, Q, R are the input and output cell respectively. ii. CMOS simulation For design and simulation the MCL gate in CMOS we used PC tools MICROWIND [18]. This tool is very user-friendly to design and find out the covered area of any logic gate.

4 Table 1 : Truth Table of the MCL gate

A B C P=B'C' Q=A'B' R=A 0 0 0 1 1 0 0 0 1 0 1 0 0 1 0 0 0 0 0 1 1 1 0 0 1 0 0 1 0 1 1 0 1 0 0 1 1 1 0 0 1 1 1 1 1 1 1 A B C

5 Result Comparison

In this section show that, designed MCL gate in QCA, how much area efficient than CMOS. Here show the comparisons that have calculated area using QCA Designer and MICROWIND [18]. Table 2 shows the designing parameter Figure 9 shows the covered area comparison between CMOS technology and QCA technology. For this comparison different designing technology are employed in MICROWIND.

6 Conclusions

QCA is one of the emerging nano-technologies in computing paradigm which is capable to design highly saleable logic device also suitable for implementing reversible logic gates. This paper presented an area efficient layout design of Multiply Complements Logic (MCL) gate in QCA which is 118 times smaller in size than 45 nm CMOS technology. The simulation has done using QCA Designer and MICROWIND. [1]

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Figure 1: Figure 1 :

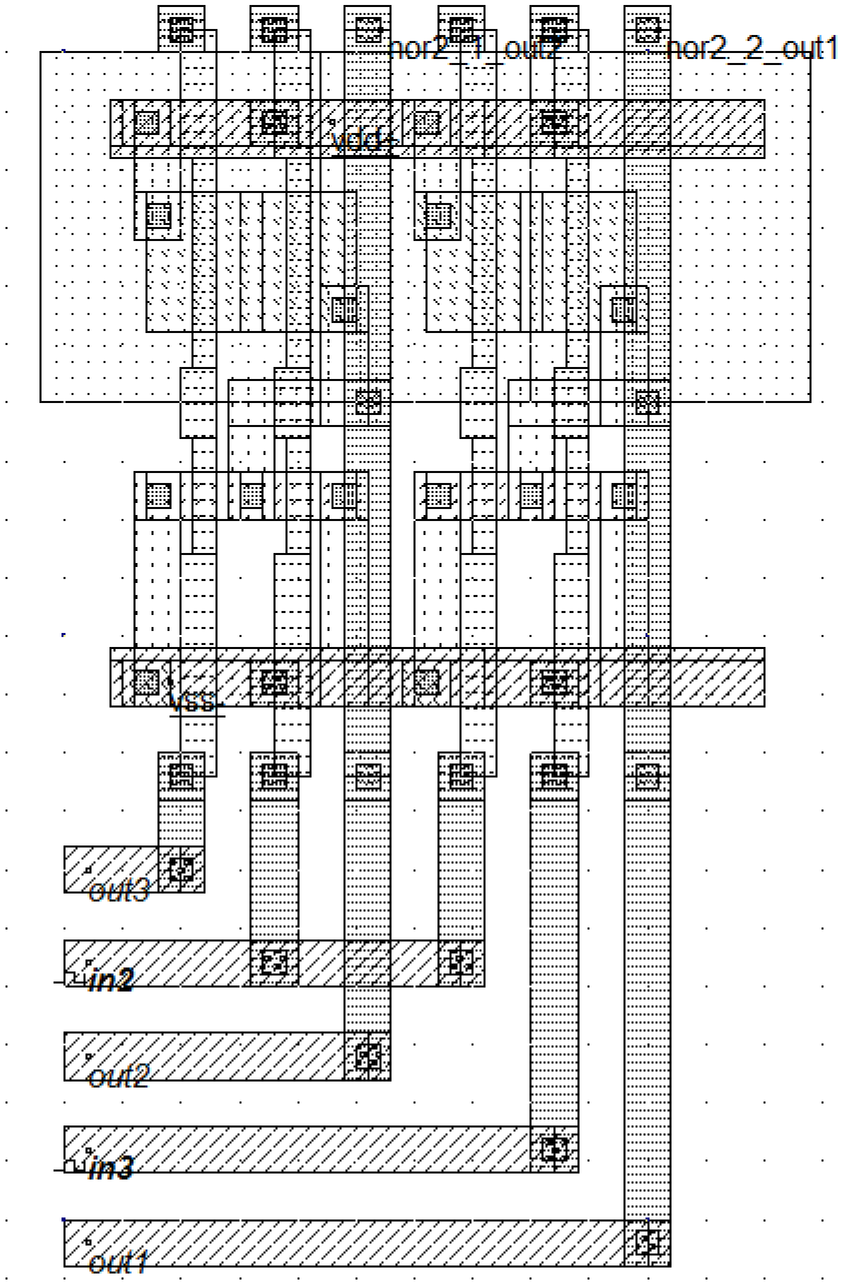

Figure 2:

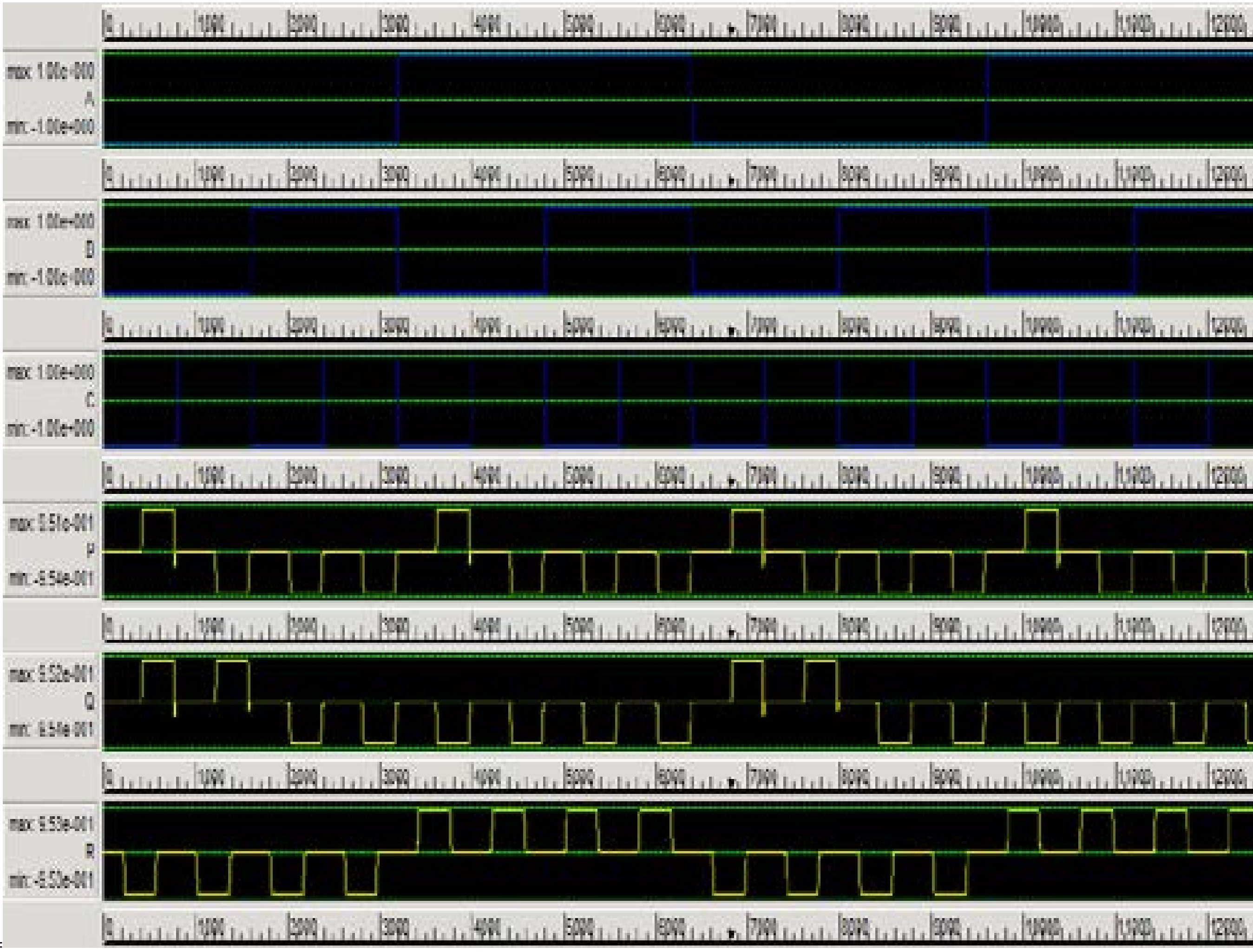

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Figure 3: Figure 2 :Figure 3 :Figure 4 :

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	CMOS technology	
Parameters		MCL Gate
Number of cells		24
Number of Majority Voter gate		2
Time delay (clock cycle)		0.5
Covered area (size) in QCA (µm 2)		0.038
Covered area (size) in CMOS (µm 2)		4.5
Improvement (in times)		118.42 times

18 17.8 Covered area
16
14
2) 12
Covered area (µm 6 8 10 8.7 4.5
4
2
0 0.038
90 nm 65 nm 45 nm QCA
Used Technology

Figure 4: Table 2 :

[Quantumdot Cellular Automata (QCA). International Journal of Computer Science Engineering (IJCSE)] , *Quantumdot Cellular Automata (QCA). International Journal of Computer Science Engineering (IJCSE)* 2 (06) p. .

[Bahar et al. ()] , A N Bahar , S Waheed , M A Uddin , M A Habib . 2013. (Double Feynman Gate (F2G) in)

[Haghparast and Navi ()] 'A novel fault tolerant reversible gate for nanotechnology based systems'. M Haghparast , K Navi . *American Journal of Applied Sciences* 2008. 5 (5) p. 519.

[Bahar et al. ()] 'A Novel Presentation of Toffoli Gate in Quantum-dot Cellular Automata (QCA)'. A N Bahar , M Habib , N K Biswas . *International Journal of Computer Applications* 2013. 82 (10) p. .

[Baker ()] R J Baker . *CMOS: circuit design, layout, and simulation*, 2011. John Wiley & Sons. 18.

[Lent et al. ()] 'Bistable saturation in coupled quantum dots for quantum cellular automata'. C S Lent , P D Tougaw , W Porod . *Applied Physics Letters* 1993. 62 (7) p. .

[Fredkin and Toffoli ()] *Conservative logic*, E Fredkin , T Toffoli . 2002. London: Springer. p. .

[Amlani et al. ()] *Demonstration of a six-dot*, I Amlani , A O Orlov , G L Snider , C S Lent , G H Bernstein . 1998.

[Walus and Jullien ()] 'Design tools for an emerging SoC technology: quantum-dot cellular automata'. K Walus , G A Jullien . *Proceedings of the IEEE* 2006. 94 (6) p. .

[Imre et al. ()] 'Majority logic gate for magnetic quantum-dot cellular automata'. A Imre , G Csaba , L Ji , A Orlov , G H Bernstein , W Porod . *Science* 2006. (5758) p. .

[Walus et al. ()] 'QCADesigner: A rapid design and simulation tool for quantum-dot cellular automata'. K Walus , T J Dysart , G A Jullien , R A Budiman . *IEEE Transactions on* 2004. 3 (1) p. . (Nanotechnology)

[Lent et al. (1994)] 'Quantum cellular automata: the physics of computing with arrays of quantum dot molecules'. C S Lent , P D Tougaw , W Porod . *Physics and Computation, 1994. PhysComp'94, Proceedings., Workshop on*, 1994. November. IEEE. p. .

[Feynman ()] *Quantum mechanical computers. Foundations of physics*, R P Feynman . 1986. 16 p. .

[Vedral et al. ()] 'Quantum networks for elementary arithmetic operations'. V Vedral , A Barenco , A Ekert . *Physical Review A* 1996. 54 (1) p. 147.

[Orlov et al. ()] 'Realization of a functional cell for quantum-dot cellular automata'. A O Orlov , I Amlani , G H Bernstein , C S Lent , G L Snider . *Science* 1997. 277 (5328) p. .

[References Références Referencias] *References Références Referencias*,

[Toffoli ()] *Reversible computing*, T Toffoli . 1980. Berlin Heidelberg: Springer. p. .

[Al-Rabadi ()] *Reversible logic synthesis: From fundamentals to quantum computing*, A N Al-Rabadi . 2004. Springer.

[Thapliyal and Ranganathan ()] 'Reversible logic-based concurrently testable latches for molecular QCA'. H Thapliyal , N Ranganathan . *IEEE Transactions on* 2010. 9 (1) p. . (Nanotechnology)

[Thapliyal and Ranganathan (2008)] 'Testable reversible latches for molecular QCA'. H Thapliyal , N Ranganathan . *Nanotechnology, 2008. NANO'08. 8th IEEE Conference on*, 2008. August. IEEE. p. .