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Universal shift register implementation using quantum dot cellular automata

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Abstract Quantum-dot Cellular Automata (QCA) demands to be a promising alternative of CMOS in ultra large scale circuit integration. Arithmetic and logic unit designs using QCA are of high research interest. A layout of four and eight bit universal shift register (USR) has been proposed. Initially QCA layouts of D flip-flop with clear and 4 to 1 multiplexer are designed, which are extended to design 4 and 8-bit parallel in parallel out (PIPO) shift register. Finally the PIPO is utilized to design 4-bit and 8-bit USR. By the comparative analysis it is observed that the proposed D Flip-flop achieved 40% clock delay improvement, whereas the modified layout of 4 to 1 multiplexer achieved 30% cell count reduction and 17% clock delay reduction from the previous works. This results in 31% reduction in cell count, 45% reduction in area and 55% reduction in clock cycle delay in 8 bit USR layout.

1. Introduction

In order to cope up with the Moore's law [1] the circuit sizes of present CMOS technology have been scaled down to about 20 nm [2] significant power dissipation and other short channel effects take place. Subsequently, further scaling becomes difficult as various quantum mechanical effects as well as high power consumption disrupt the circuit operations. Quantum-dot Cellular Automata (QCA) is one of the most promising alternatives of CMOS in designing nano scale computational units [3–8]. The main advantages of QCA are high speed up to terahertz frequency [1–3], extremely low power consumption, and high packing density.

QCA is a transistor less technology. It is based on the fundamental principle of quantum confinement [3,9–12]. One of the major challenges is the practical fabrication of QCA cell in room temperature, as because QCA cells are found to be operating only in cryogenic temperature. But very recently

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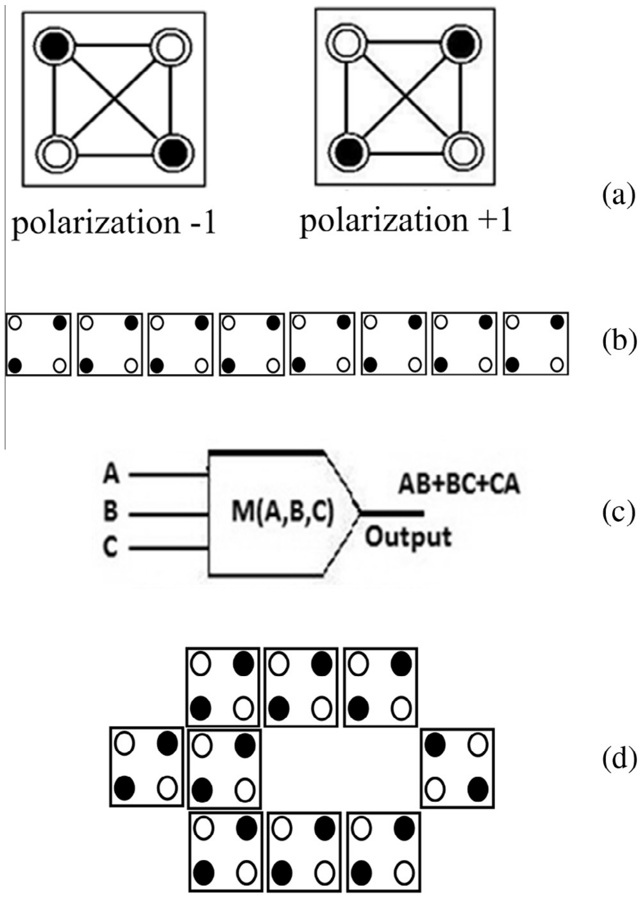

Figure 1 Basic circuits using Quantum dot Cellular Automata (QCA), (a) QCA Cell, (b) QCA wire, (c) three input majority voter, and (d) QCA inverter.

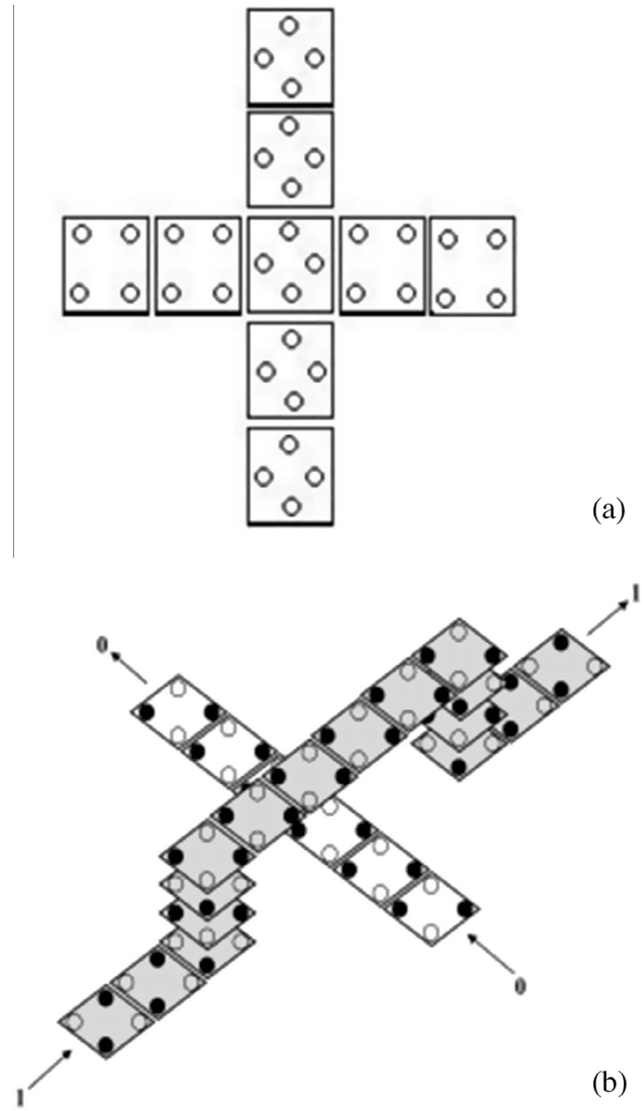

Figure 2 Different types of crossing in QCA circuits, (a) coplanar Crossing, and (b) multilayered crossover.

Dilabio and coworkers have been able to successfully fabricate electrostatic QCA cell in room temperature [9]. This breakthrough invention acts as a major motivation for room temperature fabrication of QCA. Data transfer and various computations in QCA, occur due to columbic interaction. So charge remains confined, which accounts for very low power dissipation. Further QCA technology is able to achieve operating speed up to Tera Hertz frequency. The QCA cells have been able to successfully fabricate in the experimental works [13–15]. One of the important works in QCA based combinational circuit is that proposed in [16]. Here the authors have proposed a novel 5 input majority voter circuit in QCA and designed XOR gate and 2 to 1 and 4 to 1 multiplexers utilizing the 5 input majority voter. As a result a significant area and cell count benefit have been achieved. Another interesting work is by Shamsabadi et al. in [17]. In these papers QCA based D flip flop is designed exploiting the inherent property of QCA clocking zones. The D flip flop layout is much more efficient in terms of cell count and delay.

In this paper layouts of 4 bit and 8 bit universal shift register are proposed in QCA technology. The designs and simulations are performed in QCA designer software tool. The proposed designs are not restricted to any specific QCA technology i.e. electrostatic or metallic as the layout can be designed in any of them, but as per the QCA designer specification it supports electrostatic QCA technology. We have proposed multiplexer based approach to design the shift register.

Table 1 Truth table of D flip flop.

Truth table	
D	Q
0	0
1	1

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