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Design of QCA based Programmable Logic Array using decoder

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ABSTRACT

A novel cost effective design of Programmable Logic Array (PLA) is proposed by recursive use of XOR gate, which is used to design 2×4, 3×8 and 4×16 decoders. The 4×16 decoder is coupled with an OR-Array to implement the proposed PLA using Quantum-dot Cellular Automata (QCA). The design is made effective by substantially reducing QCA wire crossing and cell count. A comparative study shows the minimization of cell count and clock-cycle delay of the XOR and Decoders. The PLA is utilized to design an efficient and delay effective 2 bit full adder.

1. Introduction

Silicon technology is in a challenging phase due to its high power consumption and physical designing limits. Different alternative technologies are developing that might replace CMOS technology. Quantum Dot Cellular Automata (QCA) [1] is one of the notable paradigm shifts in the Nano-scale computational domain. Since its inception in 1993 by Lent et.al, QCA has proved its potential to be a sturdy alternative of CMOS technology. With experimental verification in 1997, the QCA devices with low power dissipation and high device density are presumed to provide around a THz processing speed, occupying few nanometres in area. With high speed switching capabilities, QCA layouts are collection of cells operated by the Columbic interactions. One of the major advantage of QCA is that it acts on the principle of electron polarization [2] as opposed to the transmission of current through devices, thus minimizes the energy consumption. In QCA paradigm the electrostatic influence on the neighbour cells is the key for information transfer. Furthermore room temperature operability of QCA which has been one of its major limitations is made possible in [3].

Each QCA cells are made of four quantum dots situated at four different corners of a square. Extra electrons reside diagonally apart from each other at maximum distance because of Columbic repulsion. The positions of the dots with additional electrons define the polarization (p) state of the cell. A binary 0 and binary 1 is encoded by $p=-1$ and $p=+1$ respectively as depicted in Fig. 1(a). The QCA wire is shown in Fig. 1(b) [1–17]. A QCA cell produces a complementary polarization at the cell, placed diagonally to it. Implementation of this knowledge leads to the foundation of QCA inverters which is shown in Fig. 1(e) [18–22]. Electrostatic interaction properties between the neighbour cells generate the realization of Majority gate in QCA as depicted in Fig. 1(c). The output cell then reflects the information as provoked by the driver cell. Therefore, the majority function Y for three inputs A, B, C can be suggested as: $M(A,B,C)=AB+BC+CA$. The polarization state of a cell can be measured as the effective energy produced through the Columbic interactions with its neighbour cells which reside in the radius of effect [23]. The wire crossing in QCA can be performed in two ways namely co-planar crossings and multi-layered crossings [24–27,33] as shown in Fig. 1(d). It is predicted that the coplanar coupling is to some extent weaker than it would have been in a normal wire [5]. The stability in coplanar crossover is less compared to multilayer type crossover [6,7]. But implementation of multilayer crossing in QCA is a challenging issue [4]. This is because of the fact that QCA cells have been fabricated only in single layer [28]. A number of variations in coplanar crossing have been

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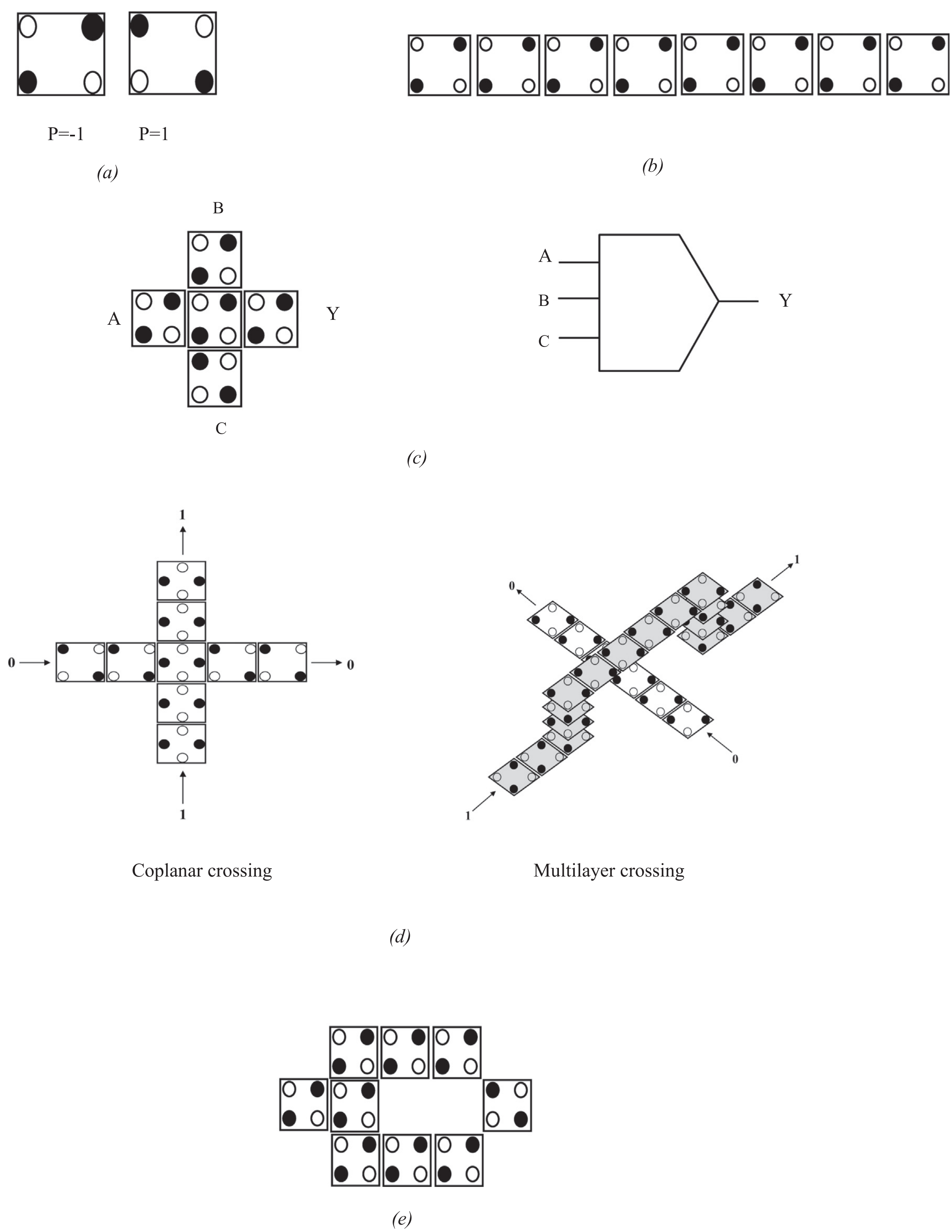

Fig. 1. (a) QCA Cell Polarization. (b) QCA Wire. (c) QCA Majority Voter. (d) QCA Crossover. (e) QCA Inverter.

proposed [6] in order to improve its efficiency. In the proposed design of XOR and Decoders multilayer design have been used but with minimized wire crossing. Thus this proposed design is more efficient and stable then traditional QCA coplanar designs.

Programmable Logic Array (PLA) is a reconfigurable system level architecture. In a PLA the programmable memory device and logic gates are arranged in an array form. The circuit functions of it can be reconfigured even after the fabrication. The advantage of PLA is that a single device can be used to perform various operations. Crossovers in QCA are of important consideration. Basically there are two types of crossovers namely multilayer and coplanar. Though multilayered crossover is difficult to fabricate, [4] the stability of coplanar crossover is less compared to the multilayered crossover [5–7]. The XOR gate and Decoders have been designed using multilayer design with reduced number of crossovers. Furthermore as only 90° cells are used the stability of the circuit is no way hampered. The complexity and performance of QCA circuits [8–10] are evaluated based on certain parameters as cell count, area, latency, stability of output, etc. A strong attempt is made to derive an optimized design of XOR and Decoders. While getting