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A Novel Controllable Inverter and Adder/Subtractor in Quantum-Dot Cellular Automata Using Cell Interaction Based XOR Gate

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Abstract. A promising nanotechnology, quantum-dot cellular automata (QCA), offers a new method for implementing digital systems at a nano-scale with significant improvements. In this paper, a novel three-input XOR gate that is based on a cell-interaction design is proposed. It can be used as a multifunctional gate by fixing one of the structure's inputs, which allows two-input XOR or XNOR gates to be easily implemented. By utilizing the three-input XOR gate, a coplanar compact full adder is created. Additionally, this paper focuses on an 8-bit adder/subtractor design using QCA. Novel design for an 8-bit adder and 8-bit controllable inverter are also proposed. The functionality and performance of the designs are demonstrated using the QCADesigner tool and by comparison with other existing designs. Moreover, a comprehensive power dissipation analysis is also conducted by QCAPro simulator.

Keywords: Nanotechnology, Quantum-dot cellular automata, Adder/subtractor, Controllable inverter, XOR gate.

1. Introduction

As a replacement to complementary metal-oxide-semiconductor (CMOS) technology, quantum-dot cellular automata (QCA) are considered prospective nanotechnology for high-performance integrated circuits. This technology is based on classic cellular automata with a quantum mechanics feature, namely, that quantum dots are used as the positions for electrons. The positions of the electrons in the dots reflect the logic states. QCA have huge potential advantages for implementing nano-scale circuits with high-speed operation and are also more attractive due to their low power dissipation features [1].

In accordance with the QCA physical fabrication methods, four implementation types have been proposed: metal-dot, semiconductor, molecular and magnetic QCA. The concept of QCA was demonstrated using relatively large metal islands (approximately one micrometer). Most experimental studies have been performed with semiconductor QCA. The cellular, square-shaped structure which includes four quantum dots and two excess electrons is manufactured from semi-conductive materials using a GaAs/AlGaAs hetero-structure with a high-mobility two-dimensional electron gas below the surface. This process could be a possible fabrication method for QCA devices. However, an ultra-small size would not be provided with this process. Molecular QCA an alternative technology to CMOS and has several advantages over the metal-island and semiconductor QCA implementations. Molecular QCA is expected to provide nano-scale (1 *nm*) cell size, high switching speeds (*THz*) and room-temperature operation. Studies of the fabrication methods for molecular QCA are under investigation [2-5].

Although many previous studies have been proposed, existing studies have focused only on reducing the number of cells and delay time using majority gate and inverter. However, this study proposes a novel XOR gate using cell interaction, and proposes adder and subtractor based on it. In this study, we focused on designing a QCA based 8-bit adder/subtractor that would serve as the main part of an arithmetic and logic unit (ALU) in a processor. This study presents a novel design of a three-input exclusive OR(XOR) gate with low complexity. The proposed structure has multi-functional XOR properties. It can be easily converted to a two-input XOR or XNOR gate with the same complexity. Using the proposed three-input XOR gate, a one-bit full adder is designed. The proposed one-bit full adder can be used to make four-, eight- … bit ripple-carry adders with a minimum cell count and area. An 8-bit controllable inverter design is also proposed using QCA.