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SYSTEMATIC REVIEW ON EFFICIENT NANO CIRCUIT STRUCTURES USING QCA TECHNOLOGY

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ABSTRACT:

The current is flowing towards scaling Complementary Metal Oxide Semiconductor (CMOS) VLSI circuits in response to the growing demand for low power and attractively fast devices. However, continued scaling of CMOS circuits is limited by quantum mechanical phenomena caused by scaling at the sub-micron and nano-level. Scientists are investigating novel characteristics of the nano regime that may provide an answer to this predicament. In this article, systematic review on efficient nano circuit structures using QCA technology has been discussed.

Keywords: Nano, Circuit, Structures, QCA, Technology.

INTRODUCTION:

The International Technological Roadmap for Semiconductors (ITRS) paper from 2005 provides a summary of potential technological solutions, including nanotechnology, to these issues. The quantum-dot cellular automata (QCA) introduced by Lent et al. (1993) is a nanostructure paradigm that uses arrays of connected quantum dots to accomplish Boolean logic functions. QCA's tiny spots, considered to be a useful, and minimum power device enable extensive compact.

SYSTEMATIC REVIEW OF LITERATURE:

Lamjed Touil et al. (2021) explored the fact that this study provides an optimized geometric greedy router (GGR) based on quantum dot cellular automata (QCA) technology. The network's spanning tree serves as the foundation for the GGR's suggested structure. With this kind of communication, an IP address is not necessary. It is compatible with a wide range of communication devices and only uses local information. In this paper, we first present the router's QCA architecture and then go over its main components. Thanks to its extremely low power consumption and fast processing speed, QCA technology is most likely to replace conventional circuits (CMOS). For the suggested design architecture, we have used the QCA clock-phase-based technique in order to take integration with other complex circuits into consideration. The QCA designer tool yielded findings that demonstrate the superiority of the given architecture over the current designs. The planned building exhibits a 30% decrease in occupied space. The QCA Pro tool analyses the proposed design's power dissipation rate and verifies its reliability. [1]

Quantum-dot cellular automata (QCA) technology is thought to be a potential substitute for circuit implementation in terms of energy efficiency, integration density, and switching frequency, according to Almatrood, Amjad, et al. (2021). The multiplexer (MUX) is a good option to use when creating QCA circuits. This study proposes two distinct topologies for energy-efficient 2×12×1 MUX designs. With approximate savings of 26% and 35% in power consumption, these MUXes outperform the best available design. Furthermore, these MUX structures achieve comparable or superior performance aspects like area and latency compared to the existing designs. These MUX structures can serve as the cornerstones of an energy-efficient QCA system, taking the place of majority-based structures. The suggested MUXes have good scalability and can be used in sophisticated QCA circuit designs that are energy-efficient. [2]

Enayati, M. et al. (2021) found that quantum-dot cellular automata (QCA) technology is a type of nanotechnology used to create computational circuits. Because of its low area and delay, it can be a useful technology for overcoming CMOS limitations at the nanoscale. A very quick memory that can complete searches in a flash is the Content-Addressable Memory (CAM). Because of this property, these memories are relatively widespread and have many uses, particularly in processors and network routing. In this work, we construct a unique loop-based circuit for the QCA memory unit, resulting in lower costs, areas, latency, and cell counts. Utilising 16 cells, 0.01 µm2 area, and 0.25 clock cycles, the developed QCA memory unit has a decrease of 33% in the number of cells, 50% in area, 50% in latency, and 75% in cost compared to previous works, according to the data acquired using the QCADesigner programme version 2.0.3. Furthermore, the memory unit is utilized to design an effective CAM circuit structure. The findings show that the CAM circuit's designed structure has 32 cells, an area of 0.03 µm2, and 0.75 clock cycles. Compared to earlier studies, it has 20% fewer cells, 25% less area, 40% less latency, and 75% less cost. [3]

Ali H. Majeed et al. (2021) explored that quantum-dot cellular automata (QCA) is a newly developed nano-electronic technology. Researchers are actively proposing QCA as a potential replacement for CMOS in the future due to its many advantageous properties, including its small size, high speed, and low energy consumption. Researchers have introduced numerous digital circuits in QCA technology, with the majority striving to provide the function with the best possible architecture in terms of area, number of cells, and power consumption. Researchers design the memory circuit, the primary component of a digital system, with the bare minimum of requirements in mind. This research presents a novel approach to the construction of two types of CAM cells. The suggested designs required one OR gate, one inverter, and two 2:1 multiplexers. In the first suggested design, the power consumption decreases by 53.3%, 35%, and 25.9% at (0.5 Ek, 1 Ek, and 1.5 Ek), while in the second design, it decreases by 53.2%, 31.9%, and 20.5% at the same energy levels. [4]

In order to extend the exponential Moore's law advancement of microelectronics at the nanoscale level, Divya Bhadoriya and Ashish Dubey (2021) investigated whether quantum-dot cellular automata (QCA) technology is a promising substitute technology for CMOS technology. Quantum-dot cellular automata (QCA) technology is anticipated to offer advantages for digital circuits. Quantum dot cellular automata, known as future representations of quantum reckoning, are created in a manner similar to the predicted cellular automata models that Von Neumann was familiar with. A multiplexer is a crucial component of digital circuits and a highly practical element of the majority of logical circuits. The fundamental components, or combinational circuits, are simulated in the earlier research on multiplexer designs. The findings show that, when compared to older QCA multiplexer architectures, the earlier designs performed better in terms of clock delay, circuit complexity, and area. As a result, the echoes reflect day-by-day improvements. It is difficult to analyse new approaches for designing new multiplexer circuits before we discover a few shortcomings in the earlier designs, and we are currently studying the majority of the fine multiplexer designs here. Previously, we created and effectively implemented a 2:1 multiplexer in the QCA with the assistance of majority voters. We strive to build multiplexer circuits that perform equally well compared to existing designs. The MUX is more durable and enjoys one layer and single-clock wire crossing, which requires only one type of cell. We are researching and attempting to create our own circuitry to solve problems; in order to achieve this, we are free to select from a variety of design approaches. Circuit simulation and comprehensive layout creation are accomplished with the QCADesigner software. We simulated the circuits using QCADesigner. [5]

Jadav Chandra Das and Debashis De (2020) researched that quantum-dot cellular automata (QCA) have been proposed as a potential substitute for complementary metal-oxide-semiconductor-based technology. Reversible computing should, ideally, help achieve zero power dissipation. This paper proposes a revolutionary QCA-based reversible priority encoder design. Toffoli and BJN gates serve as the design's fundamental building elements. The QCA designer simulator validates the suggested design. The simulation findings examine the performance of the reversible priority encoder. By using reversible logic, the suggested encoder reduces the amount of heat energy dissipation while simultaneously solving the issue of the messy code. Since reversible logic allows for zero information loss, the suggested reversible circuit may play a significant role in future wireless communication. Researchers investigated the power requirements of the suggested QCA circuits, indicating that QCA would be an ideal platform for implementing reversible circuits. Also mentioned is the connection to recently proposed work. [6]

Hani Alamdar et al. (2020) explored that electronic devices now confront basic hurdles in parameters like speed, frequency, and power consumption for CMOS technology circuits because it is not possible to further reduce the dimensions. Substituting quantum-dot cellular automata (QCA) technology for CMOS technology is one way to solve the problem. Researchers have conducted extensive studies on digital circuit design in QCA technology. In electrical and communication systems, one of the key components is the phase-frequency detector (PFD). This study presents a PFD structure in QCA technology for the first time. A D-fip-fop (D-FF) with reset capability based on a new inverter gate is employed in the suggested structure. In contrast to earlier inverters, the new inverter gate of this D-FF produces an output signal with a high degree of polarization. The suggested PFD is smaller than the PFD constructed with a typical inverter, with 199 cells, occupying an area of 0.22 μm2, and having a latency of two clock cycles. [7]

Syed Umira R. Qadri et al. (2019) investigated that quantum dot cellular automata are a novel technology that aids researchers in creating various digital circuits. However, digital architectures lack widespread acceptance. Consequently, the design of these digital circuits has become necessary to guarantee authenticity through various security components, like a multiplexer, which aids in secure message transfer as a cryptographic component to reserve a clock cycle or modify the channel separation track, among many other practical circuit designs. In quantum dot cellular automata, this study provides new and efficient structures of 2:1, 4:1, and 8:1 multiplexers without any cross-over, which is useful for data transfer. We compared the three presented multiplexers with some of the most recent structures in terms of cell count, cell area, speed, latency, complexity, and other factors. The comparisons show significant improvements. Additionally, the given multiplexer architectures are fully functional and resilient at high temperatures and frequencies, and they can be employed as a cryptographic element in secure message exchange, according to simulations conducted with the QCA Designer and QCA Pro software programmes. [8]

Harshitha S. et al. (2019) found that quantum-dot cellular automata (QCA) are an emerging technology used for nanoscale computation. It's a great substitute for traditional CMOS technology. For logical circuits, QCA offers us low energy consumption, high speed, quicker switching speed, and compact shapes. A scan flip-flop is used for device testing. Testing is an essential component of design verification. Processors use it for an integrated self-test. In contrast to earlier architectures, the goal of this research is to build an optimised scan flip-flop topology that requires less space and energy consumption. The number of cells, energy dissipation, and area occupied by the logical circuit are used to analyse the efficiency of the suggested structure. With a cell count of 32 and an energy dissipation of 0.0105 eV, the proposed scan flip flop is 20% and 29% more efficient than the earlier versions. For design and simulation, QCADesigner is a CAD tool. The cells have a separation distance of 2 nm and dimensions of 18 nm in height and 18 nm in width. The simulation tool makes use of bi-stable and coherence vector simulation engines. [9]

Md. Abdullah-Al-Shafi and Rahman Ziaur (2019) stated that one of the most prominent archetypes of field-coupled nanoscale devices is the quantum-dot cellular automaton (QCA). It is a minimally dissipated, non-von Neumann model for transistor-free logic in conventional nanocomputing. Restricted field connections between nanoscale constructions modules arranged in shapes are relied upon by field-coupled nanoscale models for practical evaluations. A few flexible charges create a lattice of connected dots to form a basic QCA device known as a cell. The charge arrangement starts a bit, and quantum charge channeling inside a squared cell allows device shifting. Higher switching speeds, room-temperature implementation, and extreme device thicknesses are approved by QCA operation. In this paper, we provide an innovative design of two widely used sequential circuits: the serial-in/serial-out (SISO) register and random access memory (RAM). Both systems have achieved notable improvements in scope, cell complexity, latency, and expense. Extensive performance evaluation and analysis validates the exceptional performance of the developed circuits relative to previous research in multiple domains. The exact functionality of the described architectures has been verified using the QCADesigner and QCAPro programmes. [10]

Zahid Shakee et al. (2017) stated that quantum dot cellular automata (QCA) is a developing technology that could provide an alternative to the VLSI industry's trend towards scaling down. Its advantages include improved switching speed, reduced power consumption, and its small size. Many advanced frameworks frequently use QCA as a component, positioning it as a strong competitor for future digital systems. As a result, researchers have implemented many logic functions based on QCA thus far. This study provides an effective XOR gate. The model demonstrates the design ability of combinational logic circuits. Research has proven that the suggested XOR gate can create logic circuits for QCA. In digital systems, the most basic component is the adder circuit. The suggested XOR gate is used to develop effective half-adder and half-subtractor circuits. We contrast the performance evolutions of the suggested XOR circuits with those of their traditional counterparts. Using the QCA Designer simulation programme version 2.0.3, the suggested designs' functionality and circuit operation have been verified. [11]

Abilash. B et al. (2015) found that the two main problems with circuit design are area and complexity. The number of transistors that can fit in a single die increases as they get smaller, improving the processing capacity of the chip. Transistors, however, are limited by their current size. One potential way around this physical limit is the quantum-dot cellular automata (QCA) technique. A fundamental part of QCA arithmetic circuits is the suggestion of using a Ripple Carry Adder (RCA) module. The adoption of so-called minority gates in addition to the more conventional majority voters was the primary methodological design advance over current state-of-the-art alternatives. QCA Designer 2.0.2 is used to create and simulate the suggested adder. According to simulation results, the suggested adder decreases area delay more effectively than earlier designs and surpasses all state-of-the-art competitors. [12]

Quantum-dot cellular automata (QCA) are a type of transistorless computing that uses the arrangement of charges between quantum dots to store binary data, as shown by Chabi, Amir Mokhtar, et al. (2014). The basic QCA logic primitives used to create a variety of QCA circuits are majority and inverter gates. Our work presents a novel method for creating effective QCA-based circuits by rearranging majority gates with three and five inputs to obtain Boolean expressions. While the exclusive-or and multiplexer are the most crucial basic logical circuits in digital systems, QCA technology offers the benefit of efficient single-layer structure design without the need for coplanar cross-over wiring. We develop simple and dense multiplexer and exclusive-or structures to demonstrate the effectiveness and utility of the suggested technique. Compared to earlier ideas, the suggested designs significantly improve in terms of space, complexity, latency, and gate count. The QCA designer tool has verified the correct logical functionalities of the provided structures. [13]

T. Mohammad Rafiq Beigh et al. (2013) explored that the quantum-dot cellular automaton (QCA) is a possible nano-electronic computational architecture of the future that stores binary information as the electronic charge configuration of a cell. It is a digital logic architecture that performs binary operations with single electrons arranged in arrays of quantum dots. QCA circuits are constructed using QCA cells, which serve as the basic building blocks. QCA architectures utilize QCA cells, which serve as fundamental building blocks for constructing basic gates and logic devices. This work assesses the performance of multiple QCA-based XOR gate implementations and suggests multiple innovative layouts with improved performance parameters. We discussed several QCA circuit design approaches for XOR gates. The traditional layouts currently documented in the literature have more crossovers and cells compared to these layouts. These design topologies serve particular purposes in circuit applications that rely on communication. They are very helpful in arithmetic processes, error detection and correction circuits, and phase detectors in digital circuits. There is also a comparison of several circuit designs provided. More intricate circuits can be realised with efficiency by utilising the suggested designs. We conducted the simulations in the current study using the QCA Designer tool. [14]

Quantum-dot cellular automata (QCA) are one of the few alternative computing platforms that Mohsen Hayati and Abbas Rezaei (2012) found have the potential to be a promising technology because they are smaller, faster, and consume less power than CMOS technology. An optimised full comparator is suggested in this letter for use in QCA. We compare the area, delay, and complexity of the suggested design to earlier efforts. Our design exhibits an improvement in cell count and area of 64% and 85%, respectively, above the best preceding whole comparator. Furthermore, we implemented it using a single clock cycle. The acquired data demonstrate that, in comparison to the earlier designs, our full comparator is more efficient in terms of cell count, complexity, area, and delay. Therefore, creating circuits based on QCAs is a straightforward use of this structure. [15]

Kunal Das and Debashis De (2011) investigated how the nanostructure of a basic computer is defined by quantum dot cellular automata (QCA). When designing high-speed computers, it serves as a substitute for CMOS technology. The fundamental logic of QCA is the logic state that measures the polarity of the electrons in the cell rather than the voltage level. Initially, developers constructed the Majority Voter (MV) when designing logic circuits. However, utilising MV alone made designing large logic circuits inefficient. There had been numerous suggestions for creating a QCA logic gate. This study focuses on several useful nanostructures, efficient design of the Nand-Nor Inverter (NNI), decreased size and design of and-Or Logic and AOI, as well as logic synthesis utilising proposed gates. We implement the NNI using 3 × 3 tile structures. We examine the QCA fault on the suggested gates and outline the acceptable level of defect tolerance. We outline the usefulness of the structures suggested in this study in QCA and discuss their potential application in creating ordinary functions. [16]

According to Singhal and Rahul (2011), the semiconductor industry appears to be approaching a point where difficulties related to power density and physical geometry may make device fabrication impractical. A novel nanotechnology called quantum-dot cellular automata (QCA) has promise for producing even more dense integrated circuits with low power consumption and high frequency capabilities. Instead of flowing to the electrons in a wire, QCA technology uses electrostatic interaction between the electrons to propagate the signal. A QCA cell, which encodes binary information using the relative positions of its electrons, is the fundamental component of QCA technology. One can use a QCA cell as logic or as a wire. An electric field, phase-shifted and produced on a layer other than the QCA cell layer, controls the directionality of the signal flow in QCA. We refer to this procedure as the clocking of QCA circuits. The semiconductor industry has greatly benefited from the logic realisation of regular structures like PLAs because of their easy logic mapping, behavioural predictability, and manufacturability. Regular structures in QCAs would provide a uniform QCA clocking structure in addition to these advantages. The clocking structure holds significance as the creators of QCA technology suggest fabricating it using CMOS technology. The design execution in detail and the comparative analysis of logic realisation utilising regular structures—that is, Shannon-Lattices and PLAs for QCAs—are presented in this thesis. As part of this research, a software programme was created that, given an input macro-cell library, automatically creates entire QCA-Shannon-Lattice and QCA-PLA layouts for single-output Boolean functions. Additionally, throughput and latency formulas for the new QCA-PLA and QCA-Shannon-Lattice design implementations were developed. Simulating the tool-generated layouts using QCADesigner confirmed the accuracy of the equations. A brief design trade-off analysis between the unstructured custom layout in QCA and the tool-generated regular structure implementation is shown for the full-adder circuit. [17]

S. Lakshmi Karthigai and G. Athisha (2010) discuss the many logical structure types based on quantum dot cellular automata (QCA) design. In nanotechnology, the QCA presents a novel paradigm for transistorless computing. Compared to transistor-based technology, it has the potential for attractive qualities, including faster speed, smaller size, and lower power consumption. By using the benefits of QCA, we may create intriguing computational architectures. The majority gate and the inverter are the two fundamental logic components of this technology. We use the fundamental components to create the additional logical structures. Instead of employing a 7-cell inverter, we have used a 2-cell inverter to create the logical structures here. Using this technique can lower the hardware requirements for a QCA design. The structures are designed and simulated using QCADesigner. A tool for designing and simulating quantum dot cellular automata is the QCA designer. Additionally, provided are the standard functions and their accompanying simplified majority expressions. [18]

Currently, researchers are investigating Quantum Cellular Automata (QCA) as a potential replacement for CMOS VLSI, as explored by Michael Thaddeus Niemier (2004). Researchers have examined some basic logical circuits and devices, but little to no work has been done on the architecture for systems of QCA devices. When taking into consideration systems of QCA devices, this work shows one of the earliest such initiatives. A team of researchers created a straightforward yet comprehensive processor dataflow solely in QCA. Moreover, methods for modelling circuits and designing floors have been created. The proposed dataflow potentially has smaller dimensions compared to the end of the CMOS curve, with remarkable size projections. Coverage includes size and power forecasts, real designs, floor planning strategies, simulation approaches, and fundamental QCA device physics. [19]

We propose a range of circuit designs for quantum dot cellular automata (QCA) that utilize the so-called coplanar crossover, based on Fabrizio Lombardi et al. (2004). The chart shows clear connection wire crossings, indicating the democratic majority of QCA. Longer voting and polling times achieve this. Rapid and accurate thermal efficiency comparisons are possible with BN simulators. Researchers illustrate numerous collinear transition designs (QCA) using nanotube integral pictures. [20]

CONCLUSION:

We looked at the history of QCA innovation. The process of constructing both combinational and sequential network designs is well documented. A large body of research has been dedicated to characterizing defects in various QCA components and evaluating the effects of these problems at the part of the circuit. The effects of flaws on QCA gates and inverters, as well as fault theories and methods for characterizing imperfections, are discussed. The difficulties of testing are discussed.

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