An Energy Efficient Binary Magnitude Comparator for Nanotechnology Applications

Divya Tripathi, Subodh Wairya

Abstract: Quantum-dot cellular automata (QCA) is inventive nanotechnology that suggest lesser size, lesser power consumption, with more rapid speeds and deliberated as a clarification to the scaling difficulties with CMOS technology. Physical bounds of CMOS for instance the effects of quantum and the limits of technologies like power dissipation obstruct the motion of microelectronics using consistent circuit scaling. In this paper, a 1-bit binary magnitude comparator circuit is proposed that takes down the count of QCA cells related to the previously reported design’s cell numbers. The proposed course of study involves just around 29 % of the total area as compared to the preceding design with the lesser speed and clocking cycle performance and energy dissipation also. QCA designerE tool is used for simulation and finding the parameters also. The projected magnitude comparator also compares the metrics result with some of the other preceding patterns.

Keywords: CMOS, QCA, cell, QCA designerE tool.

I. INTRODUCTION

A binary magnitude comparator is a digital circuitry that have two binary inputs and shows the similarity between them whether one input is greater than, less than or equal to the second input. A precise wide research and growth in the field device technology for the earlier numerous years prepared it probable for originators quickly and constantly decrease semiconductor device size and controlling current. QCA is a leading technology that works a nano-meter scale level to perform logic computation [1]. QCA technology, is committed on a perception that the placement of an electron promising by Coulomb repulsion, although in CMOS device, is a essential voltage for computation [2].

In MOS devices the gate tunneling current upturns with the forthcoming size going despondent to bottomless submicron device geometrical procedure. In several open fields, it is anticipated that these device technologies are coming near to its physical boundaries. Several physical phenomena that contain two discrete states used to define a logic variable in two effective logic states, for example, electron spin, etc. The contemporary effort displayed that QCA can attain high density, fast switching speediness and room temperature performances [1-3].

Magnitude Comparators are broadly applied in CPU and microcontrollers. Since a basketful studies has been designed

for comparator design [1] in QCA, the proposed design takes, the more depressed field area and high calculation speed as compared to reported designs. QCA designer tool was adapted to simulation and verification of outcome in the physical forefront [6]. QCA based designs are better in parameters of velocity (high), integrity (higher) and power consumption (low) and the power of highly parallel processing. In summation, few enhancement is realized in the primitives results based on QCA design -

• We put in a compact magnitude comparator circuit which is adapted lower area. The invention has been achieved by utilizing existing comparator design.

• We synthesize the blocks in QCA designer which work along the principle of Columbia interaction.

The accomplishment of this employment such as complexity, area, latency is fairly secure and suitable for nano-electronics application [7]. This work is systematized in the following sections: Section 2 deals the necessary background related to QCA technology to read. Part 3 provides existing work related to the comparator circuit and also dispenses with an preceeding work with its professionals and cons. Part 4 details the architecture, including the QCA design and the revelation of the consequences. Part 5 provides the comparative energy dissipation results based on preceeding work and section 6 their conclusion.

II. QCA CONCEPT

QCA is well-known on the four quantum dot in which full distance settles the two electrons [12]. A polarization framework in the cell is offered in Fig.1.a. The two polarizations are revealed as P=-1, i.e., binary ’0’ and P=+1, i.e., binary ‘1’. The activity of a cell is improved due to the columbic interface between cells. The two popular architecture in QCA is known as majority gate and inverter as shown in Fig.1b, 1c. The two identical logic information is transferred to two output node is shown in Fig.1.d. Generally QCA cells are collaborated by four phase clock. The four phase clock is unknown as a switch, hold, release and relaxes as offered in Fig. 1.f [8].The simple QCA cell structural design is shown in Fig.1.g.

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* Correspondence Author

Divya Tripathi*, Electronics & Communication Engineering, Lucknow, India. Email: divyattripathi.cest@gmail.com

Subodh Wairya, Electronics & Communication Engineering, Lucknow, India.
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At QCA, the elementary logic blocks are the not gate and the majority gate, where

\[ \text{Maj}(A, B, C) = AB + BC + CA \]  

(1)

Fig. 1. QCA Conception (a) Polarization (b) Majority Gate Circuit (c) Inverter QCA Cell (d) Fan-Out (e) Clocking (f) Research of cell (g) Cell design[9]

III. EXISTING WORK

A Existing QCA Comparator

Al-Shafil et al. [11] have established a QCA magnitude comparator design without wire-crossing, which is shown in Fig. 2. In this QCA comparator design 0.182 \( \mu \text{m}^2 \) area and 117 QCA cells used

Fig. 2 QCA layout of magnitude comparator design -1

Shinha Roy et al. [12] have planned a QCA magnitude comparator circuit based on layered-T OR and AND gates, which is shown in Fig. 3 (a) and (b)

This QCA multilayer comparator circuit utilized 0.039 \( \mu \text{m}^2 \) & 0.028 \( \mu \text{m}^2 \) area and 37 and 40 QCA cells respectively.

Fig. 3. QCA layout of magnitude comparator design-2

Ghosh et al. [16] have designed a QCA comparator circuit, which is publicized in Fig. 4. This QCA comparator design required 0.06 \( \mu \text{m}^2 \) area and 73 QCA cells.

Fig. 4. QCA layout of magnitude comparator design -3

Bhoi et al. [17] have planned a QCA 1 bit magnitude comparator circuit, which is presented in Fig. 5. This design utilized 220 QCA cells and 0.23 \( \mu \text{m}^2 \) area.

Fig. 5. QCA layout of magnitude comparator design -4

Akter et al. [18] projected a QCA comparator design by using TR and Feynman gates, which is shown in Fig. 6. This QCA comparator required 87 qca cells and 0.12 \( \mu \text{m}^2 \) area.

Fig. 6. QCA layout of magnitude comparator design -5

[Diagram of QCA layout]
Ahmadreza Shiri [20] suggested QCA magnitude comparator circuit based on XNOR gate having 38 cells and 0.30 μm² shown in fig. 7.

Fig. 6. QCA layout of magnitude comparator design - 5

Ahmadreza Shiri [20] suggested QCA magnitude comparator circuit based on XNOR gate having 38 cells and 0.30 μm² shown in fig. 7.

Fig. 7. QCA layout of magnitude comparator design - 6

**IV. PROPOSED WORK**

Comparator can be designated as a combinational circuit which compares the assessment of two binary numbers and explains if one of them is identical to, bigger than, or less than another number. If the binary numbers are A and B, then the outcome is detailed by

\[
\begin{align*}
A &= B &\rightarrow& AB + \overline{A}B \\
A &< B &\rightarrow& \overline{A}B \\
A &> B &\rightarrow& \overline{A}B
\end{align*}
\]

(2)

The proposed comparator contains 27 QCA cells and 0.04 μm² area.

The various designs of magnitude comparator comparison shown in Table-I which indicates that the proposed design in efficient and optimum in terms of number of cells and latency as compare to the preceding existing design.

![Fig. 8. Schematic Of 1-Bit Magnitude Comparator](image)

![Fig. 9. QCA Layout of Proposed 1 Bit Magnitude Comparator](image)

![Fig. 10. Simulation Result Of Proposed 1 Bit Comparator](image)
Table I - Comparison of various QCA Magnitude Comparator

<table>
<thead>
<tr>
<th>QCA Comparator</th>
<th>No. Of Cells</th>
<th>Area (in μm²)</th>
<th>Latency (Clocking Cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous 1-bit Comparator design-1 Fig.2</td>
<td>117</td>
<td>0.182</td>
<td>1.00</td>
</tr>
<tr>
<td>Previous 1-bit Comparator design-2 Fig.3</td>
<td>40</td>
<td>0.028</td>
<td>1.00</td>
</tr>
<tr>
<td>Previous 1-bit Comparator design-3 Fig.4</td>
<td>73</td>
<td>0.06</td>
<td>1.00</td>
</tr>
<tr>
<td>Previous 1-bit Comparator design-4 Fig.5</td>
<td>220</td>
<td>0.23</td>
<td>0.75</td>
</tr>
<tr>
<td>Previous 1-bit Comparator design-5 Fig.6</td>
<td>87</td>
<td>0.12</td>
<td>0.50</td>
</tr>
<tr>
<td>Previous 1-bit Comparator design-6 Fig.7</td>
<td>38</td>
<td>0.30</td>
<td>0.50</td>
</tr>
<tr>
<td>Proposed 1-bit Comparator Fig.10</td>
<td>27</td>
<td>0.04</td>
<td>0.25</td>
</tr>
</tbody>
</table>

During execution, each QCA cell depletes equal quantity of energy in per clock cycle. The energy dissipation by the full QCA design is estimated by the first certain power dissipation model [19]. QCAE Pro is used for prediction of energy dissipation in proposed QCA comparator design [20-21].
V. RESULTS AND COMPARISON

Table II: Energy dissipation in (eV) by the designed magnitude comparator

<table>
<thead>
<tr>
<th>Energy dissip. (Ev)</th>
<th>Sum_bath (S_b)</th>
<th>Avg_bath (A_b)</th>
<th>Sum_clk (S_c)</th>
<th>Avg_clk (A_c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_bath_total (E_{b})</td>
<td>1.67E-03</td>
<td>8.09E-04</td>
<td>-5.73</td>
<td></td>
</tr>
<tr>
<td>E_clk_total (E_{c})</td>
<td>2.13E-03</td>
<td>8.25E-04</td>
<td>-2.22E-04</td>
<td></td>
</tr>
<tr>
<td>E_Error_total (E_{e})</td>
<td>1.30E-03</td>
<td>1.58E-03</td>
<td>-1.31E-04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.82E-03</td>
<td>7.36E-04</td>
<td>-1.91E-04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.67E-03</td>
<td>8.09E-04</td>
<td>-1.73E-04</td>
<td>1.90E-02 (Err:.97e-003)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.73E-04 (Err:.79e-004)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.11E-02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.01E-03</td>
</tr>
</tbody>
</table>

Table III: Comparison of dissipated energy (eV) by the proposed and existing magnitude comparator designs

<table>
<thead>
<tr>
<th>Design</th>
<th>Sum_bath (S_b)</th>
<th>Avg_bath (A_b)</th>
<th>Sum_clk (S_c)</th>
<th>Avg_clk (A_c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous 1-bit Comparator</td>
<td>5.58e-002</td>
<td>5.07e-003</td>
<td>-3.02e-002</td>
<td>-2.74e-003</td>
</tr>
<tr>
<td>design-1 Fig.2</td>
<td>(Er:-5.73e-003)</td>
<td>(Err:-4.49e-004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous 1-bit Comparator</td>
<td>1.77e-002</td>
<td>1.61e-003</td>
<td>8.40e-003</td>
<td>7.64e-004</td>
</tr>
<tr>
<td>design-2 Fig.3</td>
<td>(Er:-1.67e-003)</td>
<td>(Err:-1.52e-004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous 1-bit Comparator</td>
<td>1.94e-002</td>
<td>1.77e-003</td>
<td>-7.83e-003</td>
<td>-7.11e-004</td>
</tr>
<tr>
<td>design-3 Fig.4</td>
<td>(Er:-1.68e-003)</td>
<td>(Err:-1.53e-004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous 1-bit Comparator</td>
<td>6.90e-002</td>
<td>6.27e-003</td>
<td>-2.71e-002</td>
<td>-2.47e-003</td>
</tr>
<tr>
<td>design-4 Fig.5</td>
<td>(Er:-5.38e-003)</td>
<td>(Err:-5.28e-004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous 1-bit Comparator</td>
<td>3.50e-002</td>
<td>3.18e-003</td>
<td>-1.44e-002</td>
<td>-1.31e-003</td>
</tr>
<tr>
<td>design-5 Fig.6</td>
<td>(Er:.318e-003)</td>
<td>(Err:.289e-004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous 1-bit Comparator</td>
<td>2.77e-002</td>
<td>2.52e-003</td>
<td>-8.34e-004</td>
<td>-7.58e-005</td>
</tr>
<tr>
<td>design-6 Fig.7</td>
<td>(Er:.282-003)</td>
<td>(Err:.257e-004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposed 1-bit Comparator</td>
<td>1.60e-002</td>
<td>1.53e-003</td>
<td>1.11e-002</td>
<td>1.01e-003</td>
</tr>
<tr>
<td>Fig.10</td>
<td>(Er:.97e-003)</td>
<td>(Err:1.97e-004)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An extension of QCA Designer 2.0.3 is QCA designer E of Konrad Walus [21]. It gives an idea of the energy depleting power of QCA logic circuits. It works on after simulation and shown the total and average energy dissipation which is summarized in table -2 and table- 3. In the table $E_{th}$ is used to complete energy transmissions to the bath of all cells distributed for each clock cycle, $E_{ox}$ is the total energy transfer between QCA cells and the clock separated for each clock cycle, $E_{ox,1}$ is for each clock cycle. $S_{p}$ is the sum of total energy moves to the bath through the entire simulation and $S_{BE}$ is the related energy. $A_{A}$ is the average standards of the energy moving to the bath and the error for every single clock cycle. $S_{c}$ is the movement of energy or from the clock during entire simulation, where $A_{C}$ is the average energy moving through a clocking cycle. To complete the full simulation process, 1-bit magnitude comparator took 9 iterations to converge the initial steady state polarization.

A comparison of energy dissipation between proposed and existing designs in shown in table-3. It concludes that the proposed design of 1 bit magnitude comparator has very less energy dissipation as compared to existing designs.

VI. CONCLUSION

In this work, an efficient design of 1-bit binary magnitude comparator has been planned. The proposed design is more effective as compared to preceeding designs in terms of area and clocking cycle as well as energy dissipation also. The process of the proposed designs has been confirmed using QCA DesignerE tool. The proposed designs are compared with respect of the number of cells, area, latency (clocking cycle) and energy dissipation (eV). A simulation carried out and discloses that the proposed structure of the 1-bit comparator beat the state of the art of preceding designs and demonstrated promising ability against Nano electronics technology. Here in this work both the better primitive’s results and proper simulation patterns of individual blocks have been accomplished concurrently. The proposed course of study involves just around 29 % of the area as compared to the preceding figure with the lesser speed and clocking cycle performance and energy dissipation also. This magnitude comparator design can be applied in many computing applications like ALU, microcontroller and low power devices.

REFERENCES

AUTHORS PROFILE

**Divya Tripathi**, she did B. Tech. in Electronics & Communication from UPTU, Lucknow, India in 2009 and M. Tech VLSI Design from JVWU, Jaipur, India, in 2012. At present she is pursuing her Ph.D Degree in Electronics Engineering from the Dr. A P J Abdul Kalam Technical University, Lucknow, India. Her current research interests include low power, high speed VLSI circuits and Nanoelectronics.

**Dr. Subodh Wairya**, he did B. Tech (1993), M.Tech and Ph.D (2012) from HBTI, Kanpur, Jadavpur University, Kolkata and MNNIT Allahabad, India, respectively. His research interest are High speed network, Low power VLSI, Nanoelectronics. At present, he is Professor at IET, Lucknow from 6 May 1996-Present. He has also served as Scientist “B” Adhoc (One Year) at DRDO, Lucknow during January, 1995-January, 1996 and Graduate Engineer under Consultancy Project at HAL, Lucknow during From January, 1994-January, 1995 (one year).