Design of Ultra Low Power TMDS Encoder using QCA (Quantum Cellular Automata) for Nanoscale Communications

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Abstract - Advancement in the VLSI field requires extensive scaling without compromising the performance parameters. Device scaling however leads into more detrimental effects than performance improvement due to sub threshold effects etc. Quantum dots and later quantum cellular automata have emerged from the vast research on the integration capabilities at nanoscale. This paper deals with the fundamentals of QCA which includes basic quantum dot cell, primary gates of QCA etc. it is observed that QCA outperforms CMOS in terms of speed, density and power consumption, besides size miniaturization and hence will be the potential alternative to CMOS technology in future. As QCA technology uses bistable charged configurations for basic logic representation rather than current switching, it will be a promising technology for nanoscale digital IC design. This paper focuses implementation of TMDS(transition minimized differential signalling) encoder using QCA.TMDS is a method of transmitting high speed digital signals serially. It is a technology used in DVI(digital visual interface) for establishing communication between graphic board and display. This interface specification provides high speed digital connection for visual data and overcomes the drawback of conventional LVDS technology. As TMDS encoder gives better disparity and minimizes transitions; it reduces emissions and improves noise immunity. It is observed that there is a reduction in area by 75% and power by 50% by designing TMDS using QCA rather than that of conventional CMOS technology.

Keywords:- Quantum dot cellular automata, Nanotechnology, Communications

I.INTRODUCTION

VLSI fabrication process keep on shrinking the physical sizes down to atomic scale dimensions and the operational frequencies of terahertz can be easily obtained if the devices can operate with less no. of electrons. However, there is a need for a trade-off to be made between increasing requirements of performance parameters and the feature size. The eventual saturation of CMOS technology is not due to inability to reduce its physical size further, but the detrimental effects of quantum mechanical effects on tiny transistors. for e.g., In nanoscale transistors, impermissible amounts of current leaks due to such highly narrow channels and ultra thin insulating layers.

Nanotechnology is one of the possible alternatives to the stated trade off problem. ITRS report [1] summarised several possible solutions. The possible variants are i) Deltt (double–electron-layer tunnelling transistor) developed by scholars at SN labs, ii) SET(single electron transistors) iii) rapid single quantum flux logic,iv0 quantum cellular automata. SET's are a promising technology for non volatile memory. TMDS (transition minimised differential signalling)link is used in visual interfaces to send the graphics data to the monitor, an advanced encoding algorithm is used on each of the three channels to encode 8 bit audio or video data to 10 bit transition minimised sequence.

The rest of this paper is organised in the following sections, Paradigm of QCA i,e the basic concepts of the technology and then TMDS algorithm , Design methodology and Results.

II.LITERATURE SURVEY

As a replacement for CMOS technology, quantum cellular automata was proposed by Lent et al. [2] to implement classic cellular automata with quantum dots to perform computations. Electrons that tunnel through barriers and hop on and off quantum dots are at the core of upcoming transistor generations [3].

There are many designs done using QCA in the past. apart from the basic cell designs, some complex circuits like sequential circuits and memories are also designed using the QCA designer tool[2].However, the QCA implementations of communication algorithms is not yet studied and practiced. This paper deals with procedure of implementation taking of one of the communication algorithms as an example.

III.PARADIGM OF QCA

A. Quantum cells & dots:

Quantum dots are nanometre sized structures that are capable of trapping electrons in three dimensions. They are made by creating an island of non insulating material surrounded by insulating material. Electrons that enter the quantum dot requires very high potential to escape. It is necessary to build a vessel like structure in which an electron can be trapped and counted as present or absent to implement a system that process the information in the form of electron position. Quantum dots establish a region of the low potential surrounded by a ring of higher potential. For e.g., nanometre dots can be constructed from aluminium using electron beam lithography techniques.

Figure-1: Vertical quantum dot.

Quantum cell is composed of quantum dots as shown in figure(2), placed next to each other on a semiconducting material. The cell is said to receive two electrons that can't escape when created. The signal propagation happens through the cells itself .The electrons have the ability to tunnel only from one quantum dot to other .i.e. In other word the four quantum dots are connected by tunnel junctions.

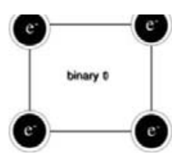

Figure-2: Quantum cell with four electrons

B. Logic state representation:

Logic states in QCA are stored as position of individual electrons not as voltage levels. i.e. QCA represents the binary info not by utilising current switch but by bistable charge configurations. Unlike conventional circuits in which information is transferred by electric current, QCA connects one state of cell to its neighbour by columbic interactions. Quantum dot is a site inside the cell where the charge can be localised. The polarisation of input cell results in the output cell polarisation state. i,e the logic value of any cell in the array depends on its polarisation as shown in the below table

Polarisation value	Logic
+1	1
-1	0
0	null

Figure-3: QCA logic values

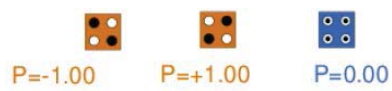

Figure-4:Polarization states of a cell

C. Cell to cell response:

A single cell in QCA can present bistable behaviour and also a ternary NULL state. Cell to cell coupling must be in a way that it can influence its neighbour cell or get influenced by other cell. The bistability of a QCA cell can be seen as the abrupt polarisation shift, when the cell is influenced by the states of other cells. the cell to cell response is as shown in fig. the graph is plotted for driver cell polarization (P1) over cell polarisation(P2) as shown in figure(5)

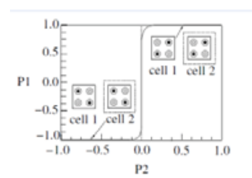

Figure-5: cell to cell response function.

D. Computations:

QCA is a technology in which information transfer is same as information transformation .In detail, interconnections and logic manipulations are done by the same array of cells. The computational paradigm of QCA is actually independent of the physical implementations.
The basic logic gate in QCA is the majority gate in which the operation of majority vote among the three inputs is done . the circuit of maj gate is as shown in the below figure(7), where A,B,C are the inputs and MAJ is the output. And the truth table is show in fig(6)

Maj(A,B,C) =AB=AC=BC

A	B	C	MAJ
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Figure-6: Majority logic truth table

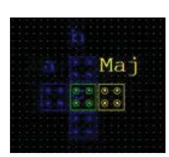

Figure-7:majority gate

The other basic logic gates like and gate and or gate can be directly constructed from Majority gate as show in below figures8,9

Figure-8:or gate

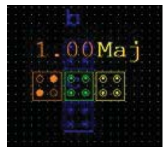

Figure-9:and gate

E.QCA implementations:

Physical QCA implementations can be broadly classified as i0 electrostatic interaction based QCA ii) magnetic QCAs. Metal-Island semiconductor and molecular comes under the first category.

Metal-Island QCA:

The metal-island QCA cell was implemented with relatively large metal islands (about 1 micrometer in dimension) to demonstrate the concept of QCA [4, 5].in this, aluminium oxide tunnel junctions are surrounded by dots made of aluminium, where the electrons can easily tunnel via tunnel junctions. However, the operating temperatures are very low, i,e approximately milli-kelvin.so, construction of very complex QCA systems with room temperature is difficult. Therefore, these are considered as the practical approach for QCA implementations.

Semiconductor QCA:

A semiconductor QCA cell is composed of four quantum dots manufactured. From standard semi conductive materials [6-8].In this, the four quantum dots are defined by using metallic surface gates. Each cell comprises of two half cells which are capacitively coupled .however, the current fabrication techniques cannot equip the mass productions with such nanoscale physical sizes

Molecular QCA:

A molecular QCA cell [9-12] is built out of a single molecule, in which charge is localized on specific sites and can tunnel between those sites. There are four quantum dots made of ferrocene groups and at the centre of the square is the cobalt group. Electrons can switch between the four dots due to electrostatic interactions and the centre group acts as a tunnelling path

Magnetic QCA:

A magnetic QCA cell is an elongated nanomagnet with a length of around 100nm and a thickness of 10 nm [13-15]. In magnetic QCA, the binary data is based on the magnetic dipole moments and since the interaction is based on magnetic moments, the energy is minimised .It has many advantages like room temperature operations, low power dissipation, good thermal stability etc., however its operating frequencies are low (i.e. nearly 100 MHz).

A three-input majority gate in magnetic QCA has been fabricated [15]. Large scale QCA systems are possible with magnetic QCA

IV.OVERVIEW OF TMDS

A TMDS transmitter does the encoding and serial transmission of input data stream over a TMDS link to the receiver on the other end. The input stream consists of the pixel data as well as control data. This transmitter encodes either the control data or the pixel data depending on the state of data enable signal on any given clock cycle. The transmitter has three encoders; each drives one serial TMDS channel. The inputs to the encoders are eight bits of primary pixel data and the control signals. Now, depending on the state of enable signal, the encoder will produce the 10 bit encoded characters serially. The algorithm of encoding is as shown in the figure(11).and the control data encoding sequences are shown in figure(10).

i/ps		Output code word
C0	C1	0...9
0	0	0010101011
0	1	0010101010
1	0	1101010100
1	1	1101010101

Figure 10:control data encoding

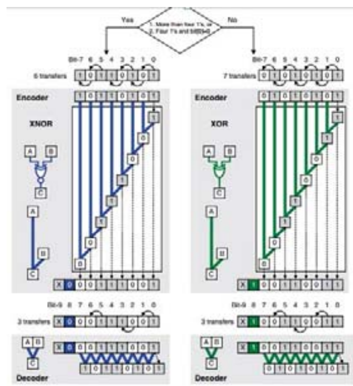

Figure 11: TMDS encoding mechanism

VI.MATERIALS AND METHODS

The design flow comprises of four phases as below.

Phase 1: Simulation:

Firstly the VHDL code is written for the required design i,e TMDS encoding algorithm. The correctness of code and functionality are verified using XILINX ISE.

Phase 2: Synthesis:

Since the aim is to design using a completely new technology and benchmark it with existing technology, the synthesis of the design for both existing and new technologies are done.

The process of synthesis is as shown below figure12

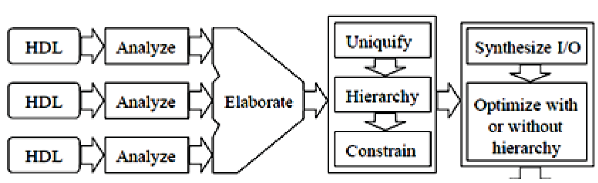

Figure 12: Synthesis flow

at first the Link and target libraries in .db format are to be setup and then the RTL design is analysed .after analysing all the sub modules of the design ,the elaboration is dine together .then the constraints are to be given Finally the compilation is to be done which lead to synthesized design basic on the library provided. The synthesis is done using Synopsys Design vision.

Phase 3: Area and power calculations:
All the required reports are checked for the required performance of the design. i.e. for e.g. the design should not violate timing rules like negative slack etc. the area and power parameters are compared for the two technologies .Reports are generated after the synthesis for acquiring the exact area required. Also not only the static power, the dynamic and leakage power is found and this is done using the design vision.

Phase 4: layouts:
The existing CMOS technology layout for the design is designed and then compared with the QCA layout. The DRC and LVS are then performed. CMOS layouts are designed using cadence virtuoso.B Since QCA libraries and concepts are entirely different, a separate tool called QCA Designer is used for designing QCA layouts and post layout simulations.

VII.RESULTS &DISCUSSIONS

Simulation Results:
The figure 14 shows the various output and disparity values obtained for various inputs considered.and figure 13 shows the output waveforms obtained usng XILINX ISE .

Din[7:0]	No. of ones	Function	X[8:0]	No. of ones in X	Disparity	Output[9:0]	New disparity
00000000	0	XOR	100000000	0	+2 0 -2	0100000000 0100000000 1111111111	-6 -8 +8
11111111	8	XNOR	011111111	8	-2 0 -2	1000000000 1000000000 0011111111	-6 +4
01010101	4	XOR	100110011	4	+2 0 -2	0100110011 0100110011 0100110011	+2 0 -2
01010000	2	XOR	100110000	2	+2 0 -2	0100110000 0100110000 1111001111	-2 -4 +4

Figure 14:TMDS encoding inputs and output

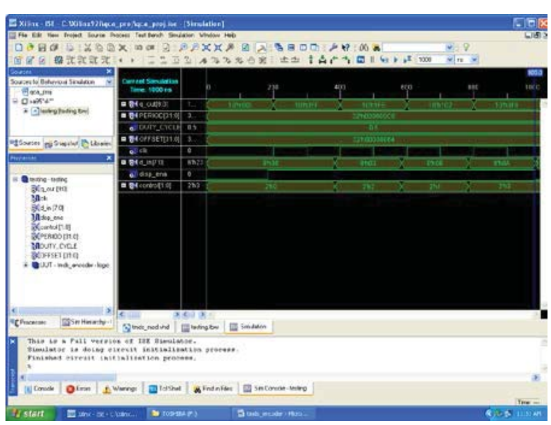

Figure 13: Simulation Results

Synthesis results: The figure15 is the schematic of TMDS using existing technologyi,e CMOS .figure16 represents the schematic of TMDS using QCA .

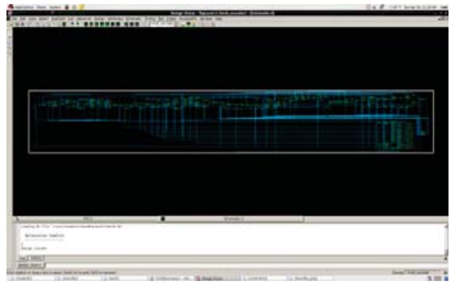

Figure 15:CMOS schematic

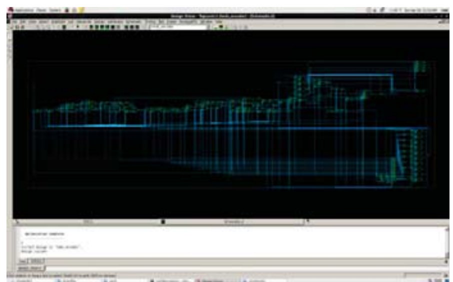

Figure 16:QCA schematic

Area and Power calculations: The below table1 shows the power and area values using Synopsys design vision

Parameters	Existing(CMOS 180 nm)	Proposed(QCA)
AREA	143593	3542.61
LEAKAGE POWER	1.52e+05pW	0
TOTAL POWER	1.2652mW	1.71e+05nW
NO.OF CELLS	288	163

Table1 :comparison of values

Layouts: The existing technology layout for the design is shown in the figure17 and this is designed using Cadence PD. The QCA layout is shown in figure 18 and is designed using QCA designer 2.0.3.

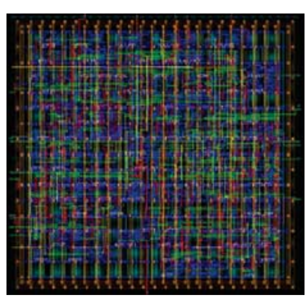

Figure17:CMOS layout

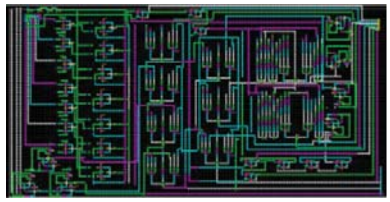

Figure 18: QCA layout

From the obtained results ,it can be observed that the area and power are drastically reduced by 75% and 50% respectively compared to the present CMOS technology and the circuit is working at high frequencies i.e. 3.5Ghz utilising just nw of power.

VIII CONCLUSION

The design under consideration, i,e TMDS encoder is said to be area effective when designed with QCA rather than CMOS. As there is an advantage of both low area and power at the same abstraction level, QCA can be seen as one of the promising technologies in near future. However there is still research going on in the interdisciplines of physical implementations and cost effective manufacturing process.

REFERENCES

[1] International technology roadmap for semiconductors(ITRS) ,http://www.itrs.net,2007

[2] Lent, C., et al., "Quantum Cellular Automata," *Nanotechnology,* Vol. 4, 1993, pp. 49–57.

[3] EEE SPECTRUM SEPTEMBER 2000. pg. 46

[4] Orlov, A., et al., "Realization of A Functional Cell for Quantum-Dot Cellular Automata," *Science,* Vol. 277, No. 5328, 1997, pp. 928–930.

[5] Amlani, I., et al., "Digital Logic Gate Using Quantum-Dot Cellular Automata," *Science,* Vol. 284, No. 5412, 1999, pp. 289–291.

[6] Khaetskii, A., and Y. Nazarov, "Spin Relaxation in Semiconductor Quantum Dots," *Physical Review B,* Vol. 61, No. 19, 2000, pp. 12639–12642.

[7] Single, C., et al., "Towards Quantum Cellular Automata Operation in Silicon: Transport Properties of Silicon Multiple Dot Structures," *Superlattices and Microstructures,* Vol. 28, No. 5, 2000, pp. 429–434.

[8] Smith, C., et al., "Realization of Quantum-Dot Cellular Automata Using Semiconductor Quantum Dots," *Superlattices and Microstructures,* Vol. 34, No. 3, 2003, pp. 195–203.

[9] Lent, C., "Bypassing the Transistor Paradigm," *Science*, Vol. 288, No. 5471, 2000, pp.1597–1599.

[10] Lent, C., B. Isaksen, and M. Lieberman, "Molecular Quantum-Dot Cellular Automata," *Journal of the American Chemical Society,* Vol. 125, No. 4, 2003, pp. 1056–1063.

[11] Li, Z., A. Beatty, and T. Fehlner, "Molecular QCA Cells: 1. Structure and Functionalization of An Unsymmetrical Dinuclear Mixed-Valence Complex for Surface Binding," *Inorganic Chemistry,* Vol. 42, No. 18, 2003, pp. 5707–5714.

[12] Wang, Y., and M. Lieberman, "Thermodynamic Behavior of Molecular-Scale Quantum- Dot Cellular Automata (QCA) Wires and Logic Devices," *IEEE Transactions on Nanotechnology,* Vol. 3, 2004, pp. 368–376.

[13] Cowburn, R., and M. Welland, "Room Temperature Magnetic Quantum Cellular Automata," *Science,* Vol. 287, No. 5457, 2000, pp. 1466–1468.

[14] Bernstein, G., et al., "Magnetic QCA Systems," *Microelectronics Journal,* Vol. 36, No. 7, 2005, pp. 619–624.

[15] Imre, A., et al., "Majority Logic Gate for Magnetic Quantum-Dot Cellular Automata," *Science,* Vol. 311, No. 5758, 2006, pp. 205–208.