A Survey on Reversible Logic Gates

Santosh Rani
Research Scholar
Department of ECE
Punjabi University, Patiala

Amandeep Singh Bhandari
Assistant Professor
Department of ECE
Punjabi University, Patiala

ABSTRACT
Nowadays, reversible computing is more fascinative research area to curtail power dissipation in comparison of conventional computing. In conventional computing, logic circuit dissipates more power by losing bits of information. Reversible computing recovers from losing bits of information through same number of output vector from same number of input vector and thus decreases the power dissipation. Since there are different cost considerations such as garbage outputs, gate count, quantum cost methods for specific cost reductions may be established.

Keywords
Reversible logic gates, garbage output, quantum cost, power dissipation.

1. INTRODUCTION
Reversible computing includes that information about the computational states never be lost. In Conventional computing all logical operations performed by millions of gates therefore lost the bits of information then it is dissipated in the form of heat. It has been presented that for every bit of information lost in conventional computations KT*log2 joules of heat energy are produced where K is Boltzmann's constant and T is absolute temperature. For room temperature the amount of dissipate heat is small, but not negligible. Landauer.R [1] proved that heat dissipation is avoidable if system is made reversible. Bennett [2] showed that a reversible computing, in which no information is devastated and scatter small amount of heat. There are two main types of reversibility are in terms of logically and physically reversibility. A reversible logic gate must have unique output vector produced from each input vector. This is termed as "logically reversibility". Physical reversibility is a process that dissipates no heat in terms of wastage of energy.

One of the major constraints in reversible logic is to minimize the number of reversible gates used. Complexity of the circuits becomes very less due to less requirement of primitive gates. Fan-out is not allowed in reversible logic. Garbage output refers to the output that is not used for further computations. Constant input is also main parameter of reversible logic gates. Constant input which is used in reversible logic function to maintain constant either 0 or 1 for making it reversible. Each reversible gate has a cost associated with it called quantum cost. Quantum cost of the circuit is calculated by knowing the number of basic reversible gates required to realize the circuit. Every reversible circuit is built from 1x1 and 2x2 quantum primitives and its cost is calculated by sum of 2x2 gates. In 2011, Prashant.R.Yelekar et.al described that reversible logic gates ability to reduce the power dissipation which is main requirement in VLSI design. Reversible computing which is requires high energy efficiency, speed and performance. It include the applications like low power

Quantum cost of 1x1 reversible gate is zero and 2x2 reversible gate is 1.

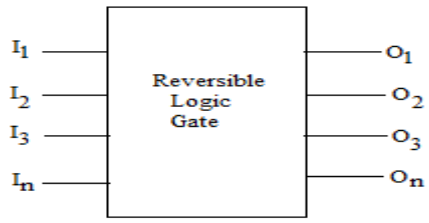


Figure1: Symbol of Reversible logic gate with n*n input and output

2. LITERATURE SURVEY
In 1961, R.LANDAUER described that the logical irreversibility is associated with physical irreversibility and requires a minimal heat generation per machine cycle. For irreversible logic computations, each bit of information lost generates kTlog2 joules of heat energy, where k is Boltzmann's constant and T the absolute temperature at which computation is performed. In conventional system the millions of gates used to perform logical operations. Author proved that heat dissipation avoidable if system made reversible [1].

In 1973, C.H.BENNETT described that if a computation is carried out in Reversible logic zero energy dissipation is possible, as the amount of energy dissipated in a system is directly related to the number of bits erased during computation. The design that does not result in information loss is irreversible. A set of reversible gates are needed to design reversible circuit. Reversible gate can generate unique output vector from each input vector and vice versa [2].

In 2008, Majid Mohammdi et.al presented that quantum gates to implement the binary reversible logic gates. Quantum gates V and V+ to be represented in truth table forms. Author proved that several reversible circuit benchmarks are optimized and compare with existing work. A new behavioral model to represent the V and V+ quantum gates based on their properties. This model used to simulate the quantum realization of reversible circuits [3].

In 2010, D.Michael Miller and Zahra Sasanian presented the reducing the number of quantum gate cost of reversible circuits. To reduce the quantum cost improves the efficiency of the circuit. To determine a quantum circuit is to first synthesis circuits composed of binary reversible gates then map that circuit to an equivalent quantum gate realization [4]

CMOS, Quantum computer, Nanotechnology, Optical computing and self-repair [5].

In 2011, Md.Mazder Rahman et.al presented a quantum gate library that consists of all possible two-Qubit quantum gates which do not produce entangled states. These gates are used to reduce the quantum cost of reversible circuits. They

proposed a two-qubit quantum gate library that plays a significant role in reducing the quantum cost of reversible gates [6].

In 2012, B.Raghu Kanth et.al described that implementing of reversible logic has advantages of reducing garbage outputs, gate count and constant inputs. Addition, Subtractions operations are realized using reversible DKG gate and it compare with conventional gates. The proposed reversible adder/substractor circuit can be applied to design of complex systems in nanotechnology [7].

In 2012, Mr. Devendra Goyal presented VHDL CODE of all Reversible Logic Gate, which provide us to design VHDL CODE of any complex sequential circuit. Here author have been tried to make the VHDL code as much as possible. Author can simulate and synthesis it using Xilinx software [8].

In 2013, Marek Szyprowski presented a tool for minimizing the quantum cost in 4-bit reversible circuits. Here Author shown that for benchmarks and for designs taken from recent publications it is possible to obtain saving in quantum cost comparing with existing circuits [9].

In 2013, Raghava Garipelly provided that the basic reversible logic gates, which in designing of more complex system having reversible circuits as a primitive component and this can execute more complicated operations using quantum computers. Author introduced some new Gates which are BSCL, SBV, NCG, and PTR etc. [10].

In 2014, Ashima Malhotra et.al described that reversible modified Fredkin gate used to design the multiplexers with low quantum cost and compare it with existing work. They also compare the quantum cost of multiplexers design using Fredkin gate with Modified Fredkin gate used to design he multiplexers [11].

3. SOME OF IMPORTANT REVERSIBLE LOGIC GATES

3.1 FEYNMAN GATE

Feynman gate is a 2x2 gate. The input vector is I(A,B) and the output vector is O(P,Q).The output is P=A,Q=A$\oplus$ B. Quantum cost of a Feynman gate is 1.Feynman gate can be used as copying gate.

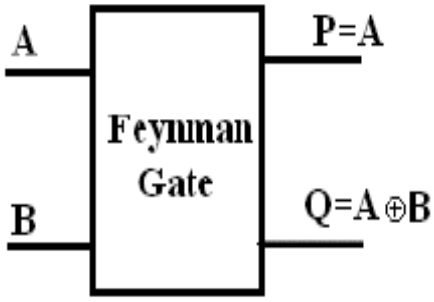


Figure 2: Symbol of Feynman gate

3.2 BJN GATE:

BJN gate is 3x3 gate with input vector is I(A,B,C) and the output vector is O(P,Q,R).The outputs are P=A,Q=B,R=(A+B)$\oplus$C. Quantum cost of a BJN gate is 5.

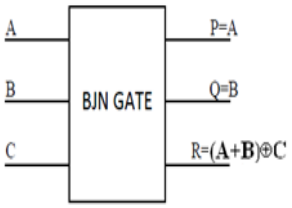


Figure 3: Symbol of BJN gate

3.3 PERES GATE

Peres gate is 3x3 gate with input vector is I(A,B,C) and the output vector is O(P,R,S).The output is P=A,Q=A$\oplus$ B and R=AB$\oplus$C. Quantum cost of a Peres gate is 4.

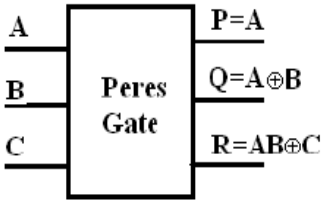


Figure 4: Symbol of Peres gate

3.4 FREDKIN GATE

Fredkin gate is 3x3 gate with input vector is I(A,B,C) and the output vector is O(P,Q,R).The output is P=A,Q=A'B$\oplus$ AC and R=A'C$\oplus$AB. Quantum cost of Fredkin gate is 5.

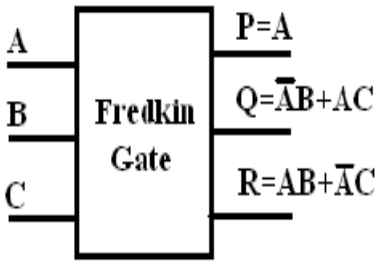
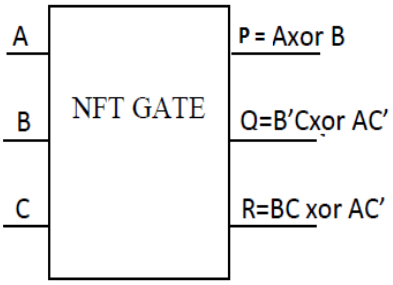


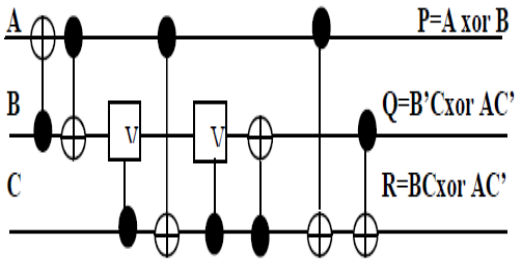
Figure 5: Symbol of Fredkin gate

3.5 NFT GATE

NFT gate is 3x3 gate with input vector is I(A,B,C) and the output vector is O(P,Q,R).The output is defined by P=A$\oplus$ B,Q=B'C$\oplus$AC' and R=BC$\oplus$AC'. Quantum cost of a NFT gate is 5.



(a) Block Diagram

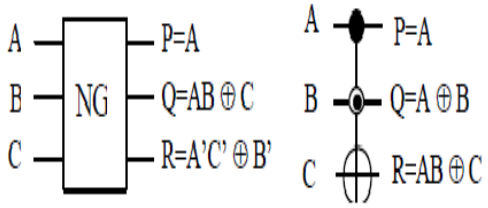


(b) Symbol

Figure 6: NFT gate

3.6 NG GATE

NG gate is 3x3 gate with input vector is I(A,B,C) and output vector is O(P,Q,R,).The output is P=A,Q=AB $\oplus$ C,R=(A'C' $\oplus$ B').



(a) Block diagram **(b) Symbol**

Figure 7: NG gate

4 PARAMETERS RELATETED TO REVESIBLE GATES

4.1 Reversible Gate

Reversible gates are circuits in which number of outputs is equal to the number of inputs and there is one to one correspondence between the vector of inputs and outputs. A reversible gate is reversible only if inputs = outputs.

4.2 Garbage Output

Unwanted output of reversible gate is called garbage output. The output of reversible gate is not used as a primary output or as input to other gates is called garbage output. Garbage's outputs are needed in circuit to maintain reversibility concept. For example when 3x3 Toffoli gate is used to implement the operations like AND EX-OR, output vector produced P=A,Q=B These extra output called garbage output.

4.3 Quantum Cost

Quantum cost of the circuit is calculated by knowing the number of basic(primitive) reversible gates required to realize the circuit. Quantum cost of 1x1 reversible gate is zero and quantum cost of 2x2 reversible gate is 1. Quantum gates have some property given in equation 1, 2 and 3.

1. V*V=NOT

2. V*V+ =V+*V=1

3. V+*V+=NOT

4.4 Restriction on Reversible logic synthesis

In designing reversible circuit using reversible gate need to maintain some inhibitions such as , more than one fan-out is not allowed and loop or feedback is strictly restricted.

4.5 Delay of Reversible Circuit

Delay of reversible circuit is defined as delay of critical path. Here Critical path state that the maximum number of gates for any input to any output in the circuit. Each reversible gate will take same amount of time for internal logic operations in the circuit.

5 CONCLUSION AND FUTURE WORK

Reversible computing has its great significance in reducing the complexity of the digital circuits. For this purpose various reversible logic gates are introduced by various researchers. In future, by using these gates we can design any of combinational or sequential circuit with numerous advantages over conventional gates such as, low power, low complexity, less delay, high speed etc. Reversible computing is becoming an important research area include Quantum computing, Nanotechnology, Low power CMOS design, Spacecraft, Cryptography, Digital signal processing.

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