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Design and Implementation of Logic Gates Using Quantum Computing Technique

[1] G Divya, [2] K Ravi Kiran
Assistant Professor, CMR Engineering,College Hyderabad
Assistant Professor, CMR Engineering College, Hyderabad,India

***Abstract:* -- Reversible computing is a model of processing where the computational process to some extent is reversible. A necessary condition for reversibility is that there should be one to one mapping between input and output. It is generally considered an unconventional form of computing. There are two major types of reversibility that are of particular interest for this purpose: physical reversibility and logical reversibility. A process is said to be physically reversible if it results in no increase in physical entropy. These circuits are also referred to as charge recovery logic or adiabatic computing.**

***Index Terms:* -- QCA, DNA, Reversible Logic.**

1. INTRODUCTION

While no non-stationary physical process can be exactly physically reversible or isentropic. Reversible logic is arising as a forecasting computing perspective with applications in quantum computing, optical computing, nanotechnology, DNA Technology, cryptography etc. In contemporary VLSI system waste of power is very high because of speedy changeover of internal signals. The zero power dissipation in circuits is attainable only if circuit is compiled of reversible gates. The circuits that do not suffer with information loss are called reversible circuits. Reversible computation is only affirmable when the system incorporates reversible gates. These circuits can produce specific output from each input, that is, the circuit is Objective means there is one-to-one mapping between input and output. According to Landauer the per irreversible bit operation dissipate kTln2 joules heat energy, where k is Boltzmann‟s constant and T is the absolute temperature at which computation is taking place[5].Bennet proposed that energy dissipation will be zero if computation is carried out in reversible way[6]. For any gate to behave like reversible gate as allows:

- Input and Output count should be the same.
- Any kind of loop or feedback is not permissible.
- One to One mapping
- No Fan Out is allowed

II. IRREVERSIBLE CLASSICAL LOGIC

Classical computation theory began for the most part when Church and Turing independently published their inquiries into the nature of computability in 1936 [19]

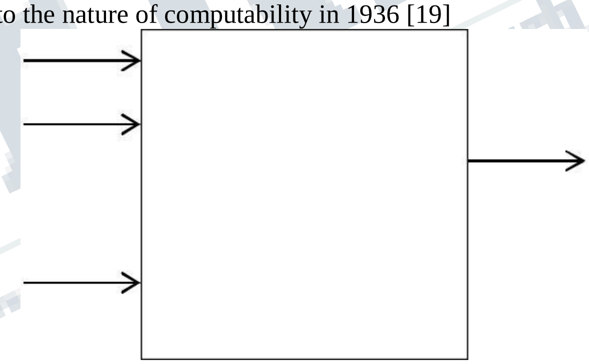

Fig. 1.1 Irreversible Logic Function

where Y = F(X_1, X2, ... , Xn) describes a single-valued function on n discrete inputs. It is assumed that such a function can be simulated or computed physically. As is usually done in conventional computation, we can use base-2 arithmetic to describe the inputs and outputs, in which case X1,X2…Xn, and Y become binary variables, which will take one of two values, 0 or In this case, the function F(X1, X2, ... , Xn) is known as an n-bit Boolean function. It has been known that NAND and NOR are universal gates any Boolean function mentioned in above block can be realized using these two gates. Apart from this AND, OR, NOT are considered to be fundamental gates. The AND & OR gates have two inputs and one output, while the NOT gate has one input and one output. Gate functions in traditional computing are generally represented by truth table. A truth table consists of all the probable combinations of inputs and their corresponding outputs

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A	B		Y
0	0		0
0	1		0
1	0		0
1	1		1

(a) AND Gate

A	B		Y
0	0		0
0	1		1
1	0		1
1	1		1

(b) OR Gate

A		Y
0		1
1		0

(c) NOT Gate

Table 1.1 Truth Tables of AND, OR, NOT Gates

Hence as the number of bits increases their input combinations also increases exponentially because an n bit Boolean function has 2n lines in its truth table. In irreversible logic there is no one to one mapping among inputs and outputs, it means they are not bijective in nature. No one can conclude individual input combination for a particular output. As each operation in this logic is irreversible, therefore each irreversible bit operation will contribute in kTln2 amount of energy dissipation

III. REVERSIBLE LOGI

The first concern about the reversibility of computation was elevated in the 1970s. There were two associated issues, logical reversibility and physical reversibility, which were closely connected. Logical reversibility refers to the ability to reconstruct the input from the output of a computation. For instance, the AND gate is explicitly irreversible, taking two inputs to one output, while the NOT gate is reversible because single input and single output and producing its own inverse i.e. Unique in nature. The model for reversible computation will be analogous to that of Figure 1.1 except that the Input and output counts of the function F will be the same, there should be one to one mapping.

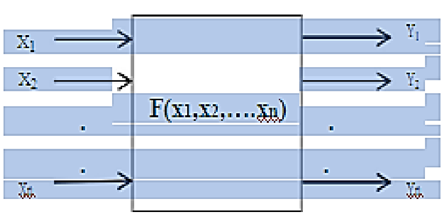

Fig. 1.2 Reversible Logic

The connection to physical reversibility is usually made as follows. Since the AND gate has only one output, one of its inputs has effectively been wiped away in the process, whose information has been permanently lost. The change in entropy that we would associate with the loss of one bit of information is ln2, which thermodynamically, corresponds to an energy increase of kT ln2, where k is Boltzman‟s constant and T is the temperature. The heat dissipated during a process is generally taken to be a indication of physical irreversibility, that the microscopic physical state of the system cannot be repaired exactly as it was before the process took place. There were two tempting questions, which were interlinked. One was whether a computation can be done in a logically reversible fashion and the other was whether any heat needs to be dissipated during a computation. That classical computation can be done reversibly with no energy dissipated per computational step was discovered by Bennett in 1973 [6].He showed that any problem that can be simulated on the original irreversible machine can also be simulated with the equal effectiveness on the reversible model. The logical reversibility inherent in the reversible model suggested that an execution of such a machine would also be physically reversible. This started the exploration for physical models for reversible classical computation. In reversible logic also we have universal logic gates which can serve to fulfill desire of any computation or circuit. As we have already considered NOT as a reversible gate, there is one more gate CNOT called as controlled NOT gate.

A	B		P	Q
0	0		0	0
0	1		0	1
1	0		1	1
1	1		1	0

Table 1.2 Truth Table of CNOT Gate

When A signal is High then it inverts the value of signal B Otherwise it will pass the signal B as same. In this inversion occurs in a controlled manner, therefore it is called CNOT gate.

a. Quantum Computing

This technique was first proposed in the 1970s; quantum computing relies on quantum physics by taking advantage of certain quantum physics properties of atoms or nuclei that allow them to work together as quantum bits, or qubits, to be the computer's processor and memory. By interrelating with each other while being inaccessible from the external environment, qubits can perform certain calculations exponentially faster than conventional computers. Qubits do not rely on the conventional binary nature of computing. While traditional computers encode information into bits using binary numbers, either a 0 or 1, and can only do calculations on one set of numbers at once, quantum computers encode information as a series of quantum-mechanical states such as spin directions of electrons or polarization orientations of a photon that might represent a 1 or a 0, might represent a combination of the two or might represent a number expressing that the state of the qubit is somewhere between 1 and 0. A quantum computer can do a random reversible classical computation on all the numbers simultaneously, which a binary system cannot do, and also has some ability to produce interference between various different numbers. By doing a computation on many different numbers simultaneously, a quantum computer has the potential to be much more powerful than a classical computer of the same size. Quantum computing is not suited for tasks such as word processing and email, but it is ideal for tasks such as cryptography and modeling and indexing very large databases. Quantum computers will harness the power of atoms and molecules to perform memory and processing tasks

Elementary Quantum Gates

Elementary gates are the building blocks for quantum computation. Qubit is the basic cell of a quantum computation. A qubit is defined as a two level quantum system defined by two dimensional Hilbert Space.

- Inverter (NOT): A single qubit is inverted.
- Controlled inverter (CNOT): The target qubit is inverted if the control qubit is 1.

- Controlled V gate: The V operation is also known as the square root of NOT, since two consecutive V operations are equivalent to an inversion.

- Controlled V+ gate: The V+ gate performs the inverse operation of the V gate, i.e. + =V -1 All elementary gates are assumed to have unit cost [2]. Additionally, when a CNOT and a V (or V+) gate are applied to the same two qubits, the cost of the pair can be considered as a unit [18].

Fundamental Reversible Gates

In this section I will explain briefly about the basic and fundamental reversible gates. The importance of reversible gate is that only a single gate can perform multiple functions simultaneously. Each reversible gate follows with truth table, multiple functions logic table, and quantum representation

Feynman Gate [16]

This gate can be constructed using on CNOT gate, and it will work like reversible XOR gate.

A	B		P=A	Q=A ⊕ B
0	0		0	0
0	1		0	1
1	0		1	1
1	1		1	0

Table 1.4 Truth Table of FG

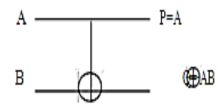

Fig. 1.4 Quantum Representation of FG

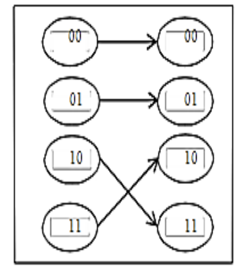

Fig. 1.5 Logical Reversibility of FG

Toffoli Gate

It is the first reversible gate invented in 1980 by T.Toffoli [8].This Gate is said to be self reversible, because its twofold combination is the same as itself [9].It has three inputs and three outputs.

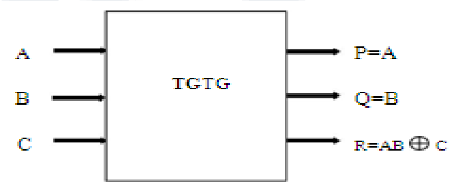

Fig. 1.6 Toffoli Gate

A	B	C		P	Q	R
0	0	0		0	0	0
0	0	1		0	0	1
0	1	0		0	1	0
0	1	1		0	1	1
1	0	0		1	0	0
1	0	1		1	0	1
1	1	0		1	1	1
1	1	1		1	1	0

Table 1.5 Truth Table of TG

S.No.	A	B	C	P	Q	R	Logic Functions
1	0	B	C	0	B	C	PASS LOGIC
2	1	B	C	1	B	B ⊕ C	XOR
3	A	0	C	A	0	C	PASS LOGIC
4	A	1	C	A	1	A ⊕ C	XOR
5	A	B	0	A	B	AB	AND
6	A	B	1	A	B	$\overline{AB}$	NAND

Table 1.6 Multifunctional TG

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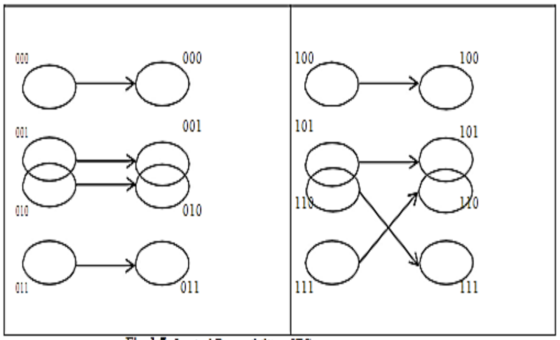
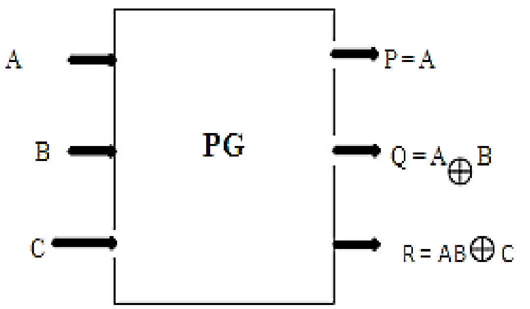


Fig. 1.7 Logical Reversibility of TG

Peres Gate [25]

This is a combination of toffoli gate and Feynman gate. It was invented in 1985



A	B	C		P	Q	R
0	0	0		0	0	0
0	0	1		0	0	1
0	1	0		0	1	0
0	1	1		0	1	1
1	0	0		1	1	0
1	0	1		1	1	1
1	1	0		1	0	1
1	1	1		1	0	0

Table 1.7 Truth Table of PG