Engineering Universe for scientific Research and management
ISSN (Online): 2319-3069 **Vol. XII – Issue VII**
July 2020

IMPLEMENTATION OF QUANTUM COMPUTING 4 BIT REVERSIBLE COMPARATOR

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ABSTRACT: Programmable reversible logic is emerging as a prospective logic design style for implementation in modern nanotechnology and quantum computing with minimal impact on circuit heat generation. Recent advances in reversible logic using and quantum computer algorithms allow for improved computer architecture and arithmetic logic unit designs. In reversible logic gates there is a unique one-to-one mapping between the inputs and outputs. To generate a useful gate function the reversible gates require some constant ancillary inputs called ancilla inputs. Also to maintain the reversibility of the circuits some additional unused outputs are required that are referred as the garbage outputs. The number of ancilla inputs, number of garbage outputs and quantum cost plays an important role in the evaluation of reversible circuits. Thus minimizing these parameters are important for designing an efficient reversible circuit. In this thesis 4 bit reversible comparator based on classical logic circuit is represented which uses existing reversible gates. In this design we try to reduce optimization parameters like number of constant inputs, garbage outputs, and quantum cost.

Keywords: *Programmable reversible logic, quantum computing, power calculation, quantum cost.*

1. INTRODUCTION

Reversible logic is a promising computing design paradigm which presents a method for constructing computers that produce no heat dissipation. Reversible computing emerged as a result of the application of quantum mechanics principles towards the development of a universal computing machine. Specifically, the fundamentals of reversible computing are based on the relationship between entropy, heat transfer between molecules in a system, the probability of a quantum particle occupying a particular state at any given time, and the quantum electrodynamics between electrons when they are in close proximity. The basic principle of reversible computing is that a bijective device with an identical number of input and output lines will produce a computing environment where the electrodynamics of the system allow for prediction of all future states based on known past states, and the system reaches every possible state, resulting in no heat dissipation.

2. ENTROPY AND THE REVERSIBLE PROCESS

Clausius demonstrated in [7] that it is not possible for a single transfer of heat from a body of lower temperature to a body of higher temperature without another connected change taking place at the exact same time. Whenever some quantity of heat Q is converted into work W, another quantity of heat must necessarily be transferred from a warmer to a colder body. The value of Q may be related to the converted work and the equivalent heat per unit of work A, and this relation is shown in (1):

$$Q = U + A * W \quad (1)$$

The value for *U* is determined by the initial and final states of the system, *W* is the work done by the system, and *A* is the equivalent heat per unit of work. In a cyclical process – meaning that the initial state and final state of a system are identical – *U* is 0, which reduces the equation to \

$$Q = A * W.$$

Clausius then defined the equivalence-value, where two transformations may occur without requiring an additional energy transfer, as *Q/T*, where *T* is a function of the temperature. By substituting the temperature function into the equivalence-value, the transfer of temperature between two bodies may be represented by (2):

$$Q = \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad (2)$$

In a system where *N* transformations take place, the total change in the equivalence-value is the sum of the equivalence values, which is equivalent to the rate of heat generation *dQ* divided by the temperature function *T* :

$$\frac{Q_1}{T_1} + \frac{Q_2}{T_2} + \cdots \frac{Q_N}{T_N} = \sum \frac{Q}{T} = \int \frac{dQ}{T} \quad (3)$$

Therefore, the sum of all heat transformations in a cyclical process, such as a Carnot engine, must be greater than or equal to zero, which produces the equality $\int \frac{dQ}{T} \geq 0$. The instance where $\int \frac{dQ}{T} = 0$ is a unique case where the system reaches all of the possible states, thus all of the transformations exactly cancel each other, and is known as a reversible process.

In [7], Clausius defined the rate of change of entropy of a system to be equivalent to the rate of change of heat in a system divided by the temperature function. Therefore, the change in entropy in a system is determined by Eqn. (4):

$$S = S_0 + \int \frac{dQ}{T} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (4)$$

The value of *S* denotes the transformation content of the body, and this value is defined as the *entropy* of the body. In a reversible system, the integral is equal to zero, reducing (4) to $S = S_0$. Resultantly, reversible systems generate zero entropy gain through their transformations. Boltzmann presented a probabilistic expression for entropy in [1] by defining kinetic energy in the context of kinetic gas theory. The relationship, shown in (5), between the number of particles *N* of an ideal gas in an isolated system, a volume *V*, constant energy *U* is as a function to determine the number of microstates of the particles in the system by relating them to the mass of an atom *m* and Planck's constant

$$S = \Omega\ (U,V.N) =$$

$$\left(\left(\frac{2\pi mkT}{h^2} \right)^{\frac{3}{2}} \frac{Ve^{\frac{5}{2}}}{N^{\frac{5}{2}}} \right) \approx e^N \quad (5)$$

Boltzmann demonstrated that the entropy of a system was directly proportional the logarithm of the energy, volume and number of particles in the system, as in (5), as well as the gas constant. The entropy is also inversely proportional to Avogadro's number. The relationship between the gas constant and Avogadro's number, which is the numerical constant representing the proportion between the logarithm of the microstates came to be known as Boltzmann's constant, *k*. This allowed for the equation in (5) to be reduced to $S = k \ln \Omega\ (U, V, N)$. Since the natural logarithm of $\Omega\ (U, V, N)$ is approximately equal to $\ln (e^N)$, this equation may be simplified to (6), where W is the number of possible energy states in the system:

$$S = k \ln (W) \qquad (6)$$

Planck determined in [29] that a given number *N* of resonators would produce an entropy of

$$S_N = S * N,$$

where S is the entropy of a single resonator, and that the total system entropy is found by the logarithm of its probability, $S_N = k_B \ln (W) + U$, supporting Boltzmann's claim. By directly relating the entropy to the number of resonators in the system, he determined that the distribution of energy elements can result only in a finite, integral number, which allowed him to postulate that electromagnetic energy could only be emitted in discrete quantized amounts. Therefore, Clausius' definition pertaining to the heat given off in a system may be related to Boltzmann's equation, giving the result shown in (7), where $\int \frac{dQ}{T}$ must be a discrete, and finite integral:

$$k\ln\left(W_f\right) = k\ln(W_0) + \int \frac{dQ}{T} \qquad (7)$$

Resultantly, in a reversible system, since $\int \frac{dQ}{T} = 0$, the number of input states must be equal to the number of output states, since $k\ln(W_f) = k\ln(W_0)$, which gives $(W_f) = (W_0)$. Therefore, Planck's postulate allows for a quantum representation of a reversible system when the number of input states is identical to the number of output states.

3. RESULTS

The proposed design for our comparator is presented below, as you can see we are using four RC reversible gates and one BJN gate. The project was simulated with the help of the Xilinx ISE 9.2 tool. Remember that the real inputs for this project were the 4 bits A and B. The rest (K1 through K10) are only the ancilla bits and they need to remain always in zero. The simulation result as wellas the synthesis report are shown in the figures below.

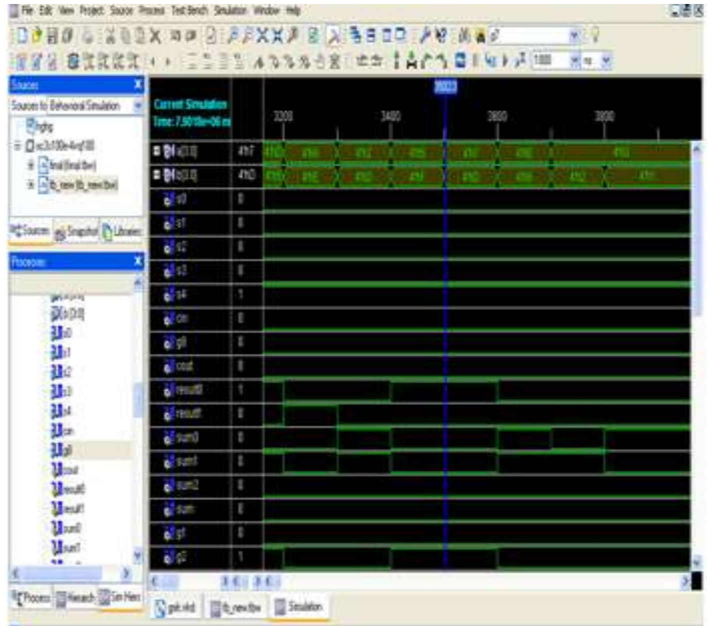

Fig. 1: simulation wave for comparator

Figure below shows the rtl summary of comparator which shows different logic gates used in comparator.

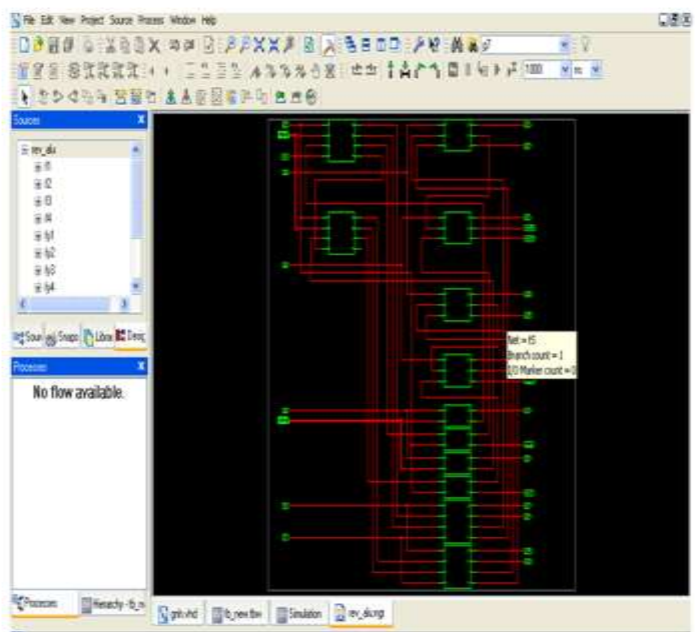

Fig. 2: RTL schematic for reversible comparator

4. CONCLUSION AND FUTURE WORK

In this thesis a new design for reversible numerical comparator is presented. The design is very useful for the future computing techniques like ultra low power digital circuits and quantum computers. It is shown that the proposed circuit is highly optimized in terms of number of reversible logic gates. Number of garbage and quantum cost.

The presented circuit uses less number of gates, producing small number of garbage outputs and least quantum cost. The design method is definitely useful for the construction of future computer and other computational structures in nanometrics fashion. On the other hand the application of the reversible logic is going to be enormously increasing. The reason behind that is that the reversible logic is basically used to provide larger digital circuit with specific functions. Moreover the reversible logic gate catalyzes the design of quantum computer.

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