Acta Scientific COMPUTER SCIENCES

Volume 4 Issue 4 April 2022

Review Article

# Clarification of Power Loss Redemption through Reversibility Concept

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**Received:** January 27, 2022

**Published:** March 03, 2022



## Abstract

When it comes to designing nano-electronic systems, one of the most important considerations is to create a product that is efficient while also using less power. However, the best possible power value is achieved without sacrificing speed, area, or high-performance applications in the process. This is geared at the use of modern technologies. As a result, quantum technology is a completely new technology for the next generation of nano-electronics applications, and it represents a paradigm shift. This article provides an overview of upcoming ideas such as quantum technology in circuit synthesis with power loss redeemed via the reversibility notion, as well as quantum technology. Reversible gates are a fundamental building component in the construction of quantum circuits. In addition, in this work, we will look into power loss and redemption via the reversibility notion, namely the reversible circuit synthesis, in more depth. A special emphasis is placed on logical and physical reversible systems in this paper. After that, we'll go through the fundamental quantum gates, which include additional qubits such as Pauli gates and Hadamard gates as well as the Phase gate, Controlled NOT gate, Phase Gate, Controlled Z gate, and Swap gate.

**Keywords:** Quantum Computing; Logical Reversibility; Physical Reversibility; Power Loss; Qubit

## Introduction

A vital limitation of electronic devices is power or heat dissipation [1]. Loss of power causes overheating of electronic components as well as information loss and component failure in certain circumstances [2]. Integrated circuits are doubled in transistor count every two years, according to Moore's law. In general, the amount of power required by a device is directly proportional to the amount of heat lost by that device, and the greater the number of components in a device, the greater the amount of power needed [3]. The quantity of heat dissipated increases in direct proportion to the amount of electricity used by the device. That is to say, if the power expended by a device is more than the power required by the device's design, the heat created will not be able to be removed as quickly as it should, ultimately resulting in overheating. Excessive heating leads to component failure and, in the worst case scenario, partial or complete failure of the device itself [4]. Low heat dissipation of the system provides an advantage for large densities and speeds in electronic systems while preventing information loss from occurring. Since the previous two decades, a number of low-power approaches have been developed and used to overcome the limitations of CMOS technology. In order to circumvent this shortcoming, numerous quantum nanotechnologies have arisen in which quantum gates are easily accessible [5,6].

As per famous Landauer's principle [6] drawn that logically irreversible systems, which erasure of a logic-bit is always associated with a high value of the entropy. All the erased logic bits in the system during computation will lead to dissipate of at approximate kTln2 amount of heat, where k is the Boltzmann's constant and T is the absolute temperature at which the operation is performed. Bennett, principal drawn that energy- free computations system must be reversible [7]. Quantum Computing uses the concept of "Quantum mechanics" of superposition and entanglement through quantum gates, which are reversible in nature both physically and logically, thereby reducing loss of power in electrical systems [8].

This article is organized as follows. In the first section, the introduction of quantum computing is given. Basic Principles are presented as well. In Section 2, the logical and physical reversibility concept is discussed. Section 3 provides a basis of quantum computing and basic quantum gates. Concluding remarks are given in the last section.

## Fundamentals of reversible computing

Reversibility uses the concept of "Second law of Thermodynamics" which states that if any system is reversible in nature, then the entropy of that system is constant. No heat is dissipated in a system if system entropy is constant [9]. The system should be in equilibrium, for it to be reversible in nature. So, if we make use of this concept and design a digital electronic system components reversible, then there will be no heat dissipation leading to no power loss. Designing a reversible digital electronic system requires designing at two important sub-systems, namely gate level designing and transistor level designing. The digital electronic system, both the logic and physical hardware components should be reversible. So, reversibility concept needs to be applied at both gate level and transistor level, making the energy, recyclable digital systems or circuits with neither heat nor information loss.

## Logical-reversibility

In gate level designing reversible logic gates are employed. Reversible logic gates have equal number of inputs and outputs. There is an equal number of one-to-one mapping between input vectors and output vectors in reversible logic gates such that inputs can be recovered using outputs and vice versa. Except for NOT gate, no other logic gate is reversible in traditional CMOS technology. Reversible gates get balanced functions at the outputs, if inputs don't have any constants [10]. If some of the inputs of reversible gates have constants, then outputs can have unbalanced functions with extra inputs and garbage outputs (outputs which are not important for execution of the function) depending on the functionality of reversible gates. Several novels reversible logic gates have been introduced by researchers since last decade. Some of basic reversible logic gates are Toffoli gate, Feynman gate, Fredkin gate etc.

## Physical-reversibility

Physical reversibility is achieved by making transistor level design reversible. If any system at the transistor level doesn't have any energy loss while running the system backwards, then the system is said to be physically reversible. To achieve physical reversibility, adiabatic logic is applied to CMOS circuits. Adiabatic circuit gives stored energy or RC across the load capacitance back to the Power clock's purpose is to not turn "transistor on" when voltage is across it and not turn "transistor off" when current is flowing through it. If we maintain above conditions in all phases in the slow movement, then restore phase will recover energy back to power clock. This helps in restoring energy without loss when the system or circuit run backwards. Using Reversible logic gates and applying adiabatic logic to any CMOS circuit can help in reducing power and heat. But adiabatic CMOS circuits have disadvantages because of slow speed and high area overhead. Technologies such as Quantum Dot Cellular automata (QCA), Magnetic spin devise, adiabatic CMOS and nanomagetic (pNML or iNML) etc. have succeeded in quantum computing technology for physical reversibility [12,13]. In the digital hardware flow chart as shown in figure 1, the various stages are shown; in a fifth level presents the logical reversibility and sixth level present the physical reversibility [11].

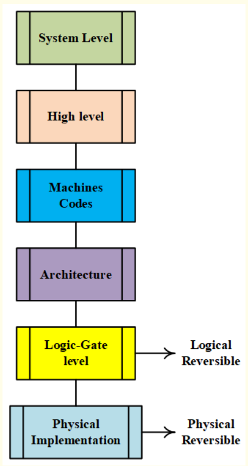


**Figure 1:** Logical and Physical reversible approach in digital hardware system.

### Quantum technology and quantum gates

Quantum technology is a promising developing technology that makes use of the notion of quantum physics for cryptographic calculations, sensing, imaging, and simulations, among other applications [14]. Quantum technology makes advantage of fundamental quantum physics phenomena such as tunnelling, entanglement, and superposition.

For quantum computing, the quantum circuits are built using quantum gates, which are reversible and operate on "qubits". Quantum computing for retracing information uses entangled (sealed) qubits while entering quantum gate and qubits maintain entangle while coming out of quantum gate [15]. Quantum gates are reversible, which retrace and restore information. Representation of quantum gates can be done by using a unitary matrix. The input qubits are equal to output qubits in a quantum gate. Quantum gates states or vectors are known as "kets" which can be 0, 1 or both unlike classical gate states which are either 0 or 1. A single qubit "p" has two probability kets or vectors in matrix representation given below.

$$|p\rangle = \begin{bmatrix} V_0 \\ V_1 \end{bmatrix}$$

Here, ket for "0" value $|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ and ket for "1" value $|1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$

Similarly, two qubits "p and q" have four vectors in a matrix given below.

$$|pq\rangle = \begin{bmatrix} V_{00} \\ V_{01} \\ V_{10} \\ V_{11} \end{bmatrix}$$

Some of quantum gates that work on one or more qubits are Pauli gates, Hadamard gates, Phase gate, Controlled NOT gate, Phase Gate, Controlled Z gate, Swap gate etc. When compared to logic gates, quantum gates can handle complex information calculations safely and without loss at high rates while using less power. However, since quantum gates have a greater margin for error, developing quantum gates is more difficult. Quantum technology conveniently provides reversibility, confidentiality, and the ability to do very complicated and delicate calculations with ease. Given that quantum technology consumes less power than traditional complementary metal-oxide-semiconductor (CMOS) technology, there is much more research to be done in the future to construct an efficient error-free quantum circuit.

## Conclusions

Power loss and fast switching are becoming more important problems in current nano-scale CMOS logic circuits, and they have become a fundamental challenge. Technology such as reversible logic, on the other hand, offers a solution for managing the information erasure in logic circuits, and it may also be a viable answer for power reduction in coming technologies like advanced computing systems. The logic synthesis of reversible logic circuits is significantly different from the irreversible logic computing system. However, some fundamental of reversible and quantum computing are presented here. Logic synthesis in quantum computing is always depends on the technology to meet certain objectives which are covered in this article. Admittedly, this article works deal with covers the fundamental of logical and reversible computing effectively. Finally, it is important that the quantum computing synthesis the basic qubit gates, which are presented here successfully.

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