Reversible Logic Gates for Efficient Circuit Construction and Quantum Computing

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Abstract.

Reversible logic, also known as information lossless logic, is a promising technology that allows embedded data within circuits to be retrieved in case of failure. This study explores the use of reversible gates, such as Feynman gates, Toffoli gates, Fredkin gates, Peres gates, Double Feynman gates, NFT gates, DKG gates, and DFT gates, to construct logic circuits. These reversible logic gates can be effectively used for the implementation of any higher logic circuits-based applications. In the proposed paper the Arithmetic logic unit based on reversible logic hates is implemented in Verilog as well as IBM quantum software. The major applications of reversible logic gates include quantum computing, low power circuits, nano and CMOS technologies, photonics. In the last part of the paper the circuits implemented using Verilog and IBM quantum a chip level design using Cadance layout is implemented.

Keywords: Arithmetic logic gate, IBM quantum, Reversible logic gates.

1. INTRODUCTION

In the current scenario the building digital circuit demands the low power techniques efficient layout design for easy fabrication of integrated chips[1][2][3][4]. The traditional methods of implementation of digital circuits includes the usage of basic gates, universal gates and special gates. The advantages of reversible logic gates like higher performance and easy implementation of lower based device have started a new ear of using reversible logic gates for implementation of any logic circuit[5][6[7]. These reversible logic gates are also a better replacement due the lossless operational capabilities for a wide range of applications. In case of these devices the loss of information during the circuit operation is comparatively less, these are efficient in building the quantum-based circuits.

In the paper the various design implementation of different reversible logic gates is implemented the Verilog and IBM quantum. The different type of reversible logic gates includes DFT gates, Toffoli gate, Feynman gates, Peres gates, Fredkin gates, DKG gates, NFT gates and Double Feynman gates. In addition to this an IC layout includes a combination of these gates together is implemented with various power analysis. The working of reversible logic gates is implemented using both results of IBM quantum and Verilog.

2. THE CONCEPT OF REVERSIBLE LOGIC GATES

The unique feature of the reversible logic gate is the which allows the retrieval of the output data from the input values and it ensures the less loss of information and preservation of data. The concept of one-to-one mapping of data flow is easily implemented using these gates in between output and inputs also facilitates backward computations[8][9]. The Feynman gate implements is s one qubit gates in quantum computing which is also called as quantum Fourier transform reversible gate named after Richard Feynman in 1980. This gate is unitary gate that performs a norm of the quantum states[10][11][12]. The controlled swap or Fredkin gate is a three-input bit based reversible that swaps the third and second bit when the first input bit is 1 and the values remain unchanged when the first bit value is set to 0. These can be used for building quantum circuits for applications of the cryptography. The controlled- controlled not gate or Toffoli gate is a universal reversible gate which can be used to implement any circuit using reversible gate[13][14][15]. This is basically used for the design of error correction circuit for correction codes and the trapped ions and superconducting qubits are implemented in quantum circuits. Implementation of this gates demand the controlled precision over various states for all three inputs. The Peres gate is reversible gate that is used for electro optic effect in lithium based devised and also used to build various memory devices. These require the multiple qubits usage. These gates are used for implementing the applications based on quantum computing and processing quantum information. Double feynman gate is built using single qubit that is subjected to the two set of successive Feynman gates implementations. The divided krnecker gate is built using 2 sets of qubit gates this has the ability to entangled states, these gates are used to build the quantum multipliers and adder circuits. Non-FT gates are next set of reversible gates which have fault tolerances and more resistance to short mistakes, and to fix faults in the quantum codes and error correcting codes. Discrete forurier transform are combination of input bits applied for FFT which transfers the operations for output. The IC layout design of these gates is implemented and power analysis is made for the circuit. The ALU includes execution of various arithmetic operation addition, subtractor and multiplication. Performs MUX 2x1, implementation of all loc operations like AND, NOT, OR, EXOR, XOR. These logical operations are included using Peres gates, Toffoli gates, Feynman gates and Fredkin gates.

3. Results

In this paper the reversible logic gates are implemented in IBM quantum Lab, Xilinx Vivado and Cadence tool. An application which includes all the arithmetic and logical operation is also implemented. The functioning of these gates is verified using all the three software and verified. The results include schematic implementation of gates along with gate level analysis and layout generation. The figure 1a and b included the implementation of Feynman gate. The figure 2a and b includes Toffoli gate design for various input and output combinations. The overall implementation of all the reversible logic gates are implemented in the figure 4. The implantation of ALU is represented in the figure 5 and 6 using Verilog and IBM quantum. The final implementation of IC layout design depicted in figure 7 which can be easily converted to chip for various applications.

Figure 1: a)Implementation of Feynman Gate

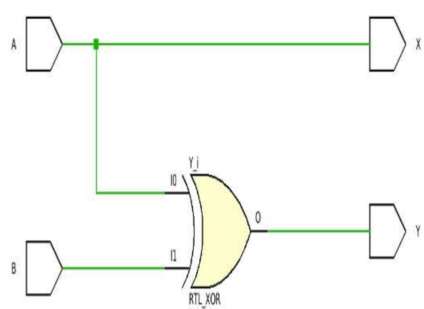

Figure 1: b)Schematic diagram of Feynman gate

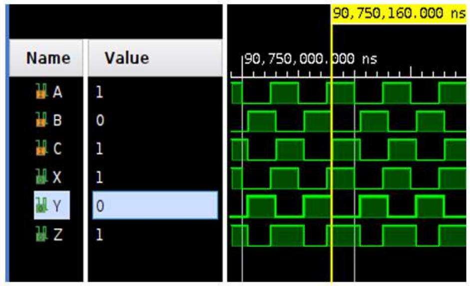

Figure 2: Implementation of Toffoli gate

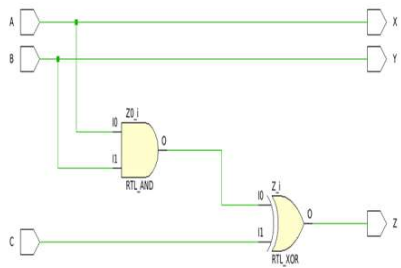

Figure 2: b) schematic diagram of Toffoli gate


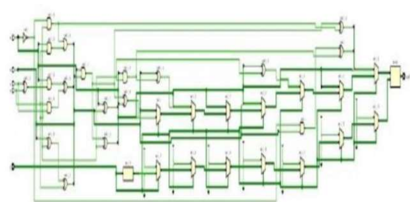

Figure 3a and b The output of combined reversible logic gates and schematic.

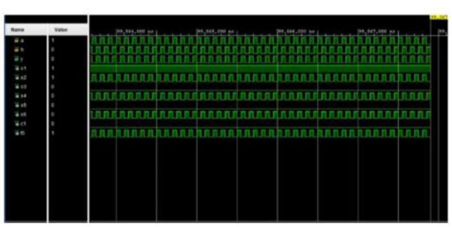
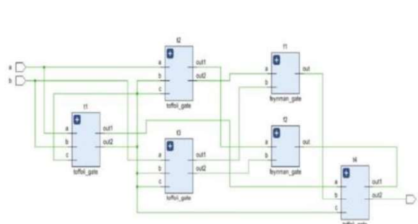

Figure 4a output of all the combinations sample combinations for all operations. 5b Schematic diagram of reversible logic gate based ALU.

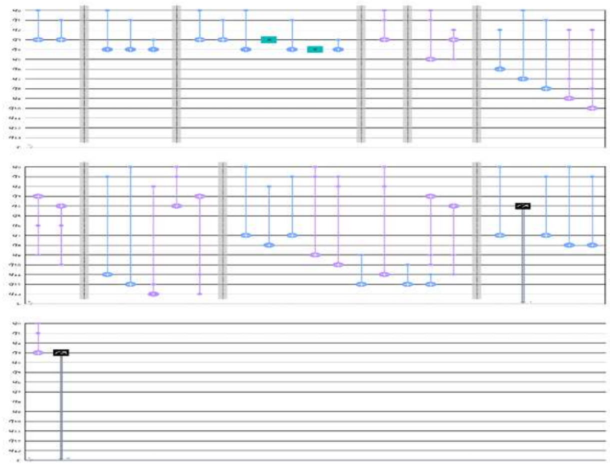

Figure 5.ALU implementation in IBM Quantum lab

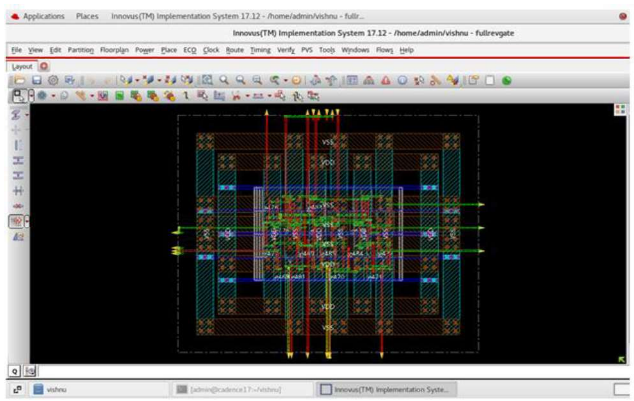

Figure 6. Final IC layout design implemented in Cadence

4. CONCLUSION

In this research paper the various implementation of reversible logic gates is implemented in three software and an application of implementation of arithmetic logic unit is implemented and the results are presented. The working and performance of these gates are verified for all the different combinations of the input and outputs. The layout design of the ALU and combined reversible logic gates are presented which can be easily converted in to integrated chips. The future of reversible logic gates are promising as the efficiency and low power applications.

5. REFERENCES

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