# DEVELOPMENT OF COMPUTATIONAL SYSTEM USING QUANTUM COMPUTING

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**Abstract -** *Quantum computers are the next great technology that will take over the world, because of it applications on difficult problems related to the classical computers. The proposed work attempts to create an ALU using the quantum technology and its circuits using quantum gates. The ALU performs 7 qubit operations in the local simulator and also the same is executed on the cloud on the using the quantum computer hosted by IBM. Analysis is carried to find the differences between the simulator output and the quantum computer output. Here a 16 qubit ALU capable of performing all the arithmetic and logical operations is also built, that executes on the simulator. The simulator locally replicates the properties of quantum computer on local system.*

***Key Words*: Qubits, Qiskit, ALU, Registers, Gates**

## 1.INTRODUCTION

Quantum computing is an advanced form of computing rooted in quantum mechanics, combining principles from physics, mathematics, computer science, and information theory. It offers significant advantages over classical computers, such as higher computational power, lower energy consumption, and exponentially faster processing, by manipulating microscopic particles like atoms, electrons, and photons.

This paper introduces quantum computing, beginning with the evolution of traditional computing and the limitations that have led to the development of quantum technologies. It explains the basic concepts of quantum computing, including key quantum properties like superposition, entanglement, and interference.

The paper also explores the architecture, hardware, software, design, types, and algorithms specific to quantum computers, highlighting their potential impact on areas such as cybersecurity, traffic optimization, medicine, and artificial intelligence. While small-scale quantum computers are currently being developed, ongoing research suggests a promising future for this technology.

Finally, the paper discusses the importance, advantages, and disadvantages of quantum computers, emphasizing the need to understand the challenges of traditional computing to fully appreciate the potential of quantum technology.

## 2. BACKGROUND

Classical computers use bits that represent either 0 or 1, while quantum computers use qubits, which can exist in superpositions of states, representing both 0 and 1 simultaneously. Each state in a superposition has an associated amplitude, a complex number that differs from the positive probabilities in classical computing. By manipulating these amplitudes, quantum algorithms can amplify correct answers and cancel out incorrect ones, offering a significant speed advantage over classical computers for certain problems.

Quantum computing power increases exponentially with the number of qubits, unlike the linear relationship between transistors and processing power in classical computing. Quantum computers excel in tasks like optimization, data analysis, and simulations, whereas classical computers are better suited for everyday processing tasks

## 3. OBJECTIVE

The main objectives of our proposed system are as follows:

- To develop computing system using quantum gates to analyse its performance.
- Tools to leverage the quantum paradigm to develop an ALU.
- 4 /8 qubit ALU for performing arithmetic and logical operations on numbers such as Addition, Subtraction, AND, OR, NOT.
- Simulation of the quantum circuit using Qiskit and IBM cloud quantum lab.
- Comparison and analysis of other quantum modules with respect to Qiskit.

## 4. LITERATURE SURVEY

Overview on Quantum Computing and its Applications in Artificial Intelligence [15]: -

This paper explores the fundamental components of quantum computing and examines its potential to enhance artificial intelligence (AI) applications. Quantum computing and AI share several complementary features. Quantum computers offer AI and machine learning algorithms faster training times and greater computational power at a lower cost, while AI can contribute essential error correction algorithms to quantum computing. The paper highlights successful implementations of AI algorithms on quantum computers, including unsupervised learning methods like clustering and principal component analysis, as well as supervised learning techniques such as support vector machines.

Reversible Arithmetic Logic Gate (ALG) for Quantum Computation [7]: -

Currently, computations based on Boolean algebra using silicon-based semiconductor technology are irreversible due to a mismatch between the number of inputs and outputs. Reversible logic circuits, which map unique inputs to unique outputs, offer a solution, enabling emerging applications such as low-power design, quantum computation, optical computing, bioinformatics, and nanotechnology. The Arithmetic Logic Unit (ALU), a key component in computing, performs intensive arithmetic and logical operations. This paper emphasizes the need for a reversible ALU to support future computing technologies. It proposes a 4x4 reversible gate that performs both arithmetic and logic operations, and compares it with other reversible gates like TSG, HNG, and MKG in terms of quantum cost, I/O lines, and Toffoli gates. The proposed gate outperforms existing methods, ensuring efficient execution of operations such as full addition, full subtraction, and various logical operations with reduced hardware costs, where other gates fall short.

The Implementation of Reversible Gates in Design of 1bit, 4-bit ALU and 8b/10b Encoder & Decoder [8]:-

The use of conventional, irreversible logic gates can result in high power consumption and is incompatible with quantum computation. Reversible circuits, on the other hand, are essential for quantum computing and have applications in digital communication, signal processing, cryptography, and computer graphics. These circuits minimize gate usage during synthesis and avoid redundant input-output pairs.This paper presents the design of 1-bit and 4-bit arithmetic logic units (ALUs), as well as an 8b/10b encoder and decoder, using both conventional and reversible logic gates. The designs were synthesized on FPGA and coded and simulated using Xilinx 14.7 and ModelSim 6. Performance analysis, considering factors like propagation delay, quantum cost, garbage outputs, and the number of reversible gates used, shows that the proposed designs deliver superior results.

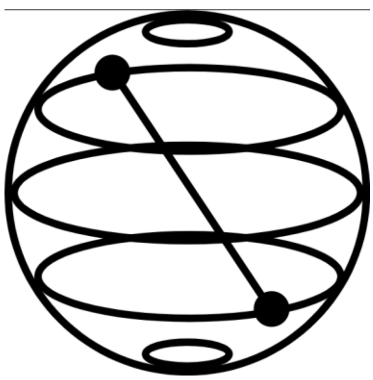
Low Power 8 Bit quantum ALU Implementation Using Reversible Logic Structure [9]:-

Reversible computation, which leverages principles of quantum mechanics, has significantly influenced digital logic design. Reversible logic units, essential for recovering input states from outputs, will impact instruction sets and high-level programming languages, necessitating their reversibility for optimal efficiency. Future advancements in reversible logic will pave the way for new computer architectures and enhanced quantum algorithms.

While much of the literature has focused on designing reversible logic gate structures and arithmetic units, there has been limited effort towards developing reversible ALUs. This work introduces novel programmable reversible logic gates and demonstrates their application in designing a reversible Arithmetic Logic Unit (ALU). An 8-bit ALU was designed and verified using a 1-bit ALU, and it was compared with existing 8-bit ALUs in terms of power dissipation and propagation delay. The proposed ALU offers more operations with a given number of select inputs and consumes less power, making it suitable for low-power VLSI design, nanotechnology, quantum computing, and optical computing.

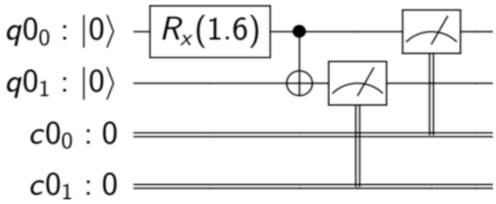
## 5. PROPOSED WORK

Classical Qiskit is an open-source SDK for working with quantum computers, allowing users to create and manipulate quantum programs. These programs can run on IBM Quantum Experience devices or local simulators. Qiskit supports quantum hardware like superconducting qubits and trapped ions, following the circuit model of quantum computation.



In [7]:
```
from qiskit import QuantumRegister, ClassicalRegister, QuantumCircuit
from qiskit.tools.visualization import circuit_drawer
import numpy as np

qr = QuantumRegister(2)
cr = ClassicalRegister(2)
qp = QuantumCircuit(qr,cr)

qp.rx( np.pi/2,qr[0])
qp.cx(qr[0],qr[1])

qp.measure(qr,cr)

circuit_drawer(qp)
```

Out[7]:




Qiskit, developed by IBM Research, is an open-source SDK created to support software development for IBM's cloud quantum computing service, IBM Quantum Experience, with contributions from academic institutions. While the primary version is in Python, early explorations into Swift and JavaScript have ceased, leading to the development of MicroQiskit, a simplified version for alternative platforms.Qiskit provides various Jupyter notebooks that demonstrate quantum computing applications, including exercises and source code for scientific studies. An open-source textbook based on Qiskit serves as a university-level supplement for courses on quantum algorithms and computation.

Qiskit is composed of elements designed to make quantum computing accessible to users of all skill levels, allowing them to design, experiment, and run applications on quantum computers or simulators. It supports development from low-level machine code (OpenQASM) to higher abstraction levels for non-experts. The circuit library offers a collection of essential circuits and gates, which can be used to build algorithms or work with circuits difficult to simulate classically.

Transpilation, a key process in Qiskit, involves rewriting quantum circuits to align with a specific device's topology and optimizing them for noisy quantum systems. This process, which often includes iterative and conditional steps, ensures that

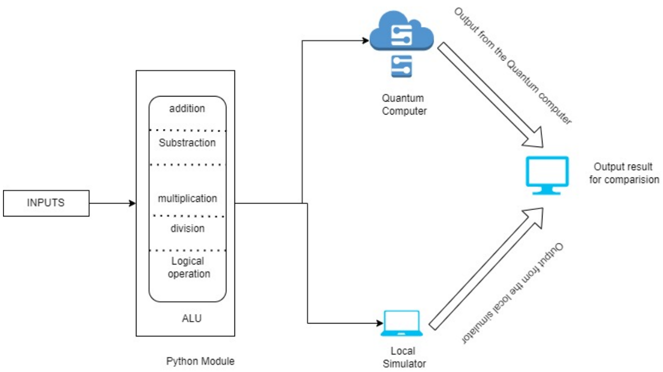



**Fig 1:-** flow chart of the entire program

## 6. RESULTS

We developed a 7-qubit ALU that operates on both a local simulator and an actual quantum computer in the cloud. A comparison between the two revealed a significant execution time difference. Additionally, we created a 16-qubit ALU that runs on the simulator, as the current quantum computer only supports up to 7 qubits.

Quantum computers have the potential to transform computation by solving problems that are intractable for classical computers. Although no quantum computer is yet capable of outperforming classical computers, significant progress is being made. Several companies have developed non-error-corrected quantum computers with tens of qubits, some of which are accessible to the public via the cloud. Quantum simulators are also advancing in areas like molecular energetics and many-body physics.

As these small systems become available, a new field focused on near-term quantum applications is emerging. This progress could enable us to realize some of the advantages of quantum computing well before the development of large-scale, error-corrected quantum computers is achieved.

### 6.1 Addition

For Addition (fig 2) the number is first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then perform addition

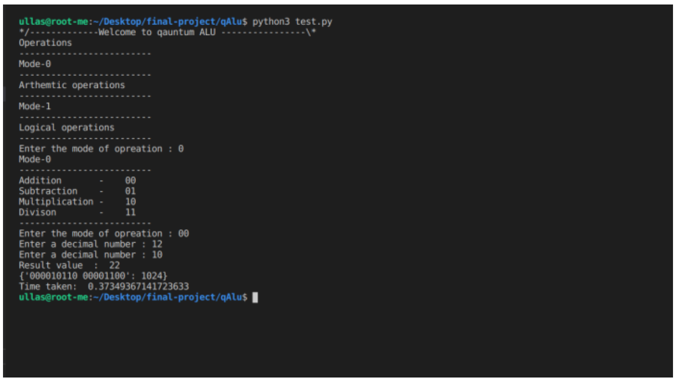



**Fig 2: -** addition of two numbers

### 6.2 Subtraction

For Subtraction (fig 3) the number is first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then perform Subtraction.


**Fig 3: -** Subtraction of two numbers

### 6.3 Multiplication

For Multiplication (fig 4) the number is first brought to the closest multiple of 10 by adding or subtracting a number then the added or subtracted number is also multiplied with the multiplier and then the first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then perform multiplication after that it adds or subtracts according to the operation performed in the beginning.


**Fig 4: -** Multiplication of two numbers

### 6.4 Division

For Division (fig 5) the number is first brought to the closest multiple of 10 by adding or subtracting a number then the added or subtracted number is also multiplied with the multiplier and then the first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then perform division after that it adds or subtracts according to the operation performed in the beginning.

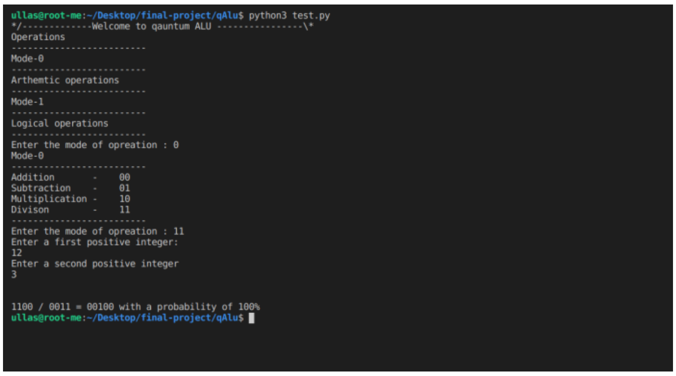



**Fig 5: -** Division of two numbers

### 6.5 Logical operations

For OR Operation (fig 6) the number is first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then operation is performed.


**Fig 6: -** OR Operation of two numbers

For AND Operation (fig 7) the number is first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then operation is performed.


**Fig 7: -** AND Operation of two numbers

For XOR Operation (fig 8) the number is first converted to its binary form and then the binary form is sent to the simulator and the quantum computer in the cloud where it utilizes big-endian to read the binary number and then operation is performed.


**Fig 8: -** XOR Operation of two numbers

## 7. CONCLUSION

Quantum computing is poised to revolutionize our approach to solving complex problems. Although still in its developmental infancy, this technology holds the promise of significant advancements in areas like process optimization, cryptography, and machine learning. Despite existing challenges such as the need for specialized algorithms and the requirement for extreme operational conditions, recent developments indicate that quantum computers may eventually surpass classical systems in tackling specific, previously intractable problems.

In our study, we developed a 7-qubit Arithmetic Logic Unit (ALU) and tested it using both local simulators and cloud-based quantum computers, uncovering a notable difference in execution times between these platforms. Additionally, we designed a 16-qubit ALU to simulate the actual quantum computer of current cloud-based systems, which are restricted to a maximum of 7 qubits. These results highlight the potential of quantum computing as well as its current hardware constraints. With ongoing technological advancements and increasing access to quantum systems via cloud platforms, we are approaching a future where the theoretical advantages of quantum computing may soon become practical, marking the dawn of a new era in computation.

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