A Brief Introduction to Quantum Computing from the Perspective of Ladder Logic

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Abstract

While Quantum Computing is a fairly advanced topic, it suffers from a perception of complexity beyond what is reasonable for the actual subject matter. This paper provides a means to take that perception and bring it down to a more realistic level. The primary targets of this paper are students currently enrolled in or freshly graduated from an electrical engineering or similar program; however, any individual with a base knowledge in programming or digital logic should be able to gain some level of benefit.

Keywords: Quantum, QISKit, Computing, Ladder, Logic, QASM, Introduction

1 Introduction

Make no mistake, quantum physics as a whole is an exceptionally advanced topic. The type of scenarios it brings to the table can be almost mind boggling at times [4]. Add to this a slew of misleading analogies and the fact that "Qubit" may refer to any number of technologies, such as ion traps, superconducting qubits, or spin qubits and it's no wonder that people get confused. With all of that said, while quantum computing does use the underlying principals of quantum mechanics, it is still nothing more than a programming architecture. To put this statement in another context, an individual does not need to understand how to bias a transistor to be good at programming in C.

2 Background Concepts

In order to avoid excessive noise, this paper assumes the reader has some basic knowledge of programming as well as electronics. It will not go into depth with much of the math, instead focusing primarily on the act of programming itself. There are many topics which should be covered if one wishes to become skilled in quantum computing, most of which the reader will need to research on their own time; however, the sections below should provide enough context in order to provide a suitable foothold should one wish to continue with the subject.

2.1 Use Case for Quantum Computing

Quantum computing is what's called a Disruptive Emergent Technology. Meaning, as far as industry is concerned, the implementation of these concepts have not only never been seen in any technology prior, but they also have the potential to revolutionize how things are done should these implementations prove successful. Quantum computing is not a magic bullet that can handle every problem; however, it does have the potential to be exceptionally good at problems that current technology has issues solving. Examples of such problems can be as varied as weather prediction, factoring [1], or even protein folding. [5]

2.2 Removing Misleading Assumptions

The first and easily one of the most important concepts in quantum computing is to understand that the general public and most media 'experts' do not work in the field of quantum computing. Therefore, it is important to note that many of the common assumptions people tend to have can be misleading or plain wrong due to lack of context or the background knowledge required to properly articulate the concepts at hand.
One prime example of this is Erwin Schrödinger and the concept of Schrödinger's cat. To preface, this is not at all meant to downplay or discredit his work, merely to illustrate that without proper context even an otherwise correct statement from a Nobel laureate can be misconstrued.

To briefly summarize, Schrödinger's cat is a brilliant thought experiment meant to illustrate a potential paradox present within the Copenhagen interpretation of quantum mechanics. This thought experiment was meant to highlight the bizarre nature of EPR (Einstein, Podolsky, Rosen), or superposition states. This is demonstrated via a cat, radioactive particle, flask of poison, and a Geiger counter being sealed in a theoretical box. Should the counter detect radioactivity, the flask would be broken causing the cat to die immediately. Under the Copenhagen interpretation of quantum mechanics, this cat should be considered simultaneously both alive and dead, however, looking into the sealed box will reveal either a very scared cat, or a testament to animals killed in the name of science.

In context, this is meant to demonstrate the concepts of complex, superimposed states collapsing upon measurement. For better or worse, this concept of a not dead, yet dead cat in a box has spread like wildfire, it has become the cornerstone of what the public sees as quantum computing. This has allowed the idea that the quantum state is both 1 and 0 to become the very first thing that anyone learns in regards to quantum computing. While this statement is not technically wrong, it is fundamentally incomplete. In many ways, it's similar to the question "which came first: the chicken, or the egg?", the answer to which can only be something along the lines of 'invalid question', as it not only fails to define what denotes the term chicken, but it also leads the individual being asked to assume the term 'egg' is specifically in the context of a chicken egg.

In reality, a better way to think of this is through vectors and complex numbers. The value is in fact both 1 and 0, but it's that way not because it is two things

Decimal	Binary (IEEE 754*)	Balanced Ternary
0	0	0
3	11	10
5	101	+ 0 -
-254	11000011011111110000000000000000*	- 0 0 - + -

Table 1: comparison table showing equivalent numbers in different display forms

in a binary sense, but because it is a complex mixing of both. To put this back into cat analogies, let's take the premise back to the start. There is a cat, that cat is now infected with a zombie pathogen. For all purposes, the cat is neither alive, nor dead, as it cannot cleanly fit into either category, yet it does have many of the defining characteristics that comprise both. From here, the cat is injected with an antidote, being a rushed marvel of medicine meant to save the feline race, it will near instantly result in either a complete cure or certain death for our kitten subject. For this analogy, the zombified state represents the ability of qubits to be in a mixed state, the antidote representing the act of measuring this mixed state and thus collapsing the end result into a binary value: 1 or 0, alive or dead.

2.3 Balanced Ternary

insert balanced ternary section here along with comparison table.

Use the table and tabular commands for basic tables — see Table 1, for example.

2.4 Reversible Logic Gates

Talk about why reversible logic gates are important to quantum computing, a bit of the history, etc.

3 Theory 2-3 pages

4 Experiment 1-2 pages

5 Results and interpretation 2-3 pages

Show a graph of the longitudinal resistivity (ρ_{xx}) and Hall resistivity (ρ_{xy}) versus magnetic field, extracted from the raw data shown in figure **??**. You will have the link to the data in your absalon messages, if not e-mail Guen (guen@nbi.dk). Explain how you calculated these values, and refer to the theory.

6 Discussion 1/2-1 page

Discuss your results. Compare the two values of n_s that you've found in the previous section. Compare your results with literature and comment on the difference. If you didn't know the value of the resistance quantum, would you be able to deduce it from your measurements? If yes/no, why?

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For extended reading list, consult source code, available at:
https://www.github.com/Macrofarad/ABriefIntroductionToQuantumComputingFromThePerspectiveOfLadderLogic