There are times when you want to know the time – and times when you want to know how to build a watch. Having tracked quantum computing for two years, I already know the figurative “time” (I know what quantum computing is; I understand how quantum computers work – and its current limitations; I know about quantum algorithms and circuits. Additionally, I understand the target markets for quantum computers devices, and I’m tracking the quantum ecosystem.

Yet, even after two years of research, there has remained much that I still did not understand about how quantum computing actually works. That is, until now. Having just completed Robert Sutor’s book “Dancing with Qubits” (Packt Publishing), I now have a thorough knowledge of the science and mathematics behind the design, formation and measurement of qubits. In other words, I know how the figurative quantum “watch” works.

Sutor’s book offers a complete background of what quantum computing is; how quantum computing differs from classical computing; the mathematics behind quantum physics (including an excellent discussion of probability); a review of how qubits (quantum bits) derive results; it explores the design of quantum circuits and the use of quantum algorithms; and it describes the physical design of physical quantum systems.

In short: it is a tutorial that puts the whole field of quantum computing into order.

Key Takeways
The key takeaways after reading this book fall into four categories:

1. Nature;
2. Mathematics interrelatedness;
3. Probability;
Nature

Probably the most insightful point the book makes is that quantum computing is “natural,” (that is: quantum works the way that nature really works – in a binary fashion ["yes" or "no," "on" or "off"]). In nature, electrons are continually spinning around atoms; protons are generating light – both constantly in a state of flux – not resting in binary positions.

Binary classical computing is the basis for how we perform most computing today – and will remain vital for decades to come. With classical computers, a single byte consists of eight bits (in either a “0” or “1” position), meaning that a classical computer can process two digits to the eighth power (2^8) – or 256 different numbers – one value at a time. Quantum bits, because they are in a constant state of flux, can process 256 values – all at the same time! This capability gives quantum computing a considerable advantage when processing workloads that need to handle exponentially more work.

Mathematical Interrelatedness

As an IT research analyst, I like to know how technologies relate to each other. I want to understand the big picture – and how the various underlying components work in concert to deliver a result. Sutor knows how all the elements that enable quantum computing are interrelated, and does a brilliant job of showing how various mathematic disciplines progressively contributed to the understanding of how quantum bits behave, how they can be visualized and manipulated, and the role that algorithms play in achieving final results.

In all of my reading to date, I have never seen a discussion of the interrelatedness of arithmetic, algebra, geometry, trigonometry, probability and physics so logically structured and organized.

In all of my reading to date, I have never seen a discussion of the interrelatedness of arithmetic, algebra, geometry, trigonometry, probability and physics so logically structured and organized. There is a natural flow to this book that leads the reader through how quantum computers actually compute. After discussing algebraic functions, Sutor moves on to geometry – and shows how the two interrelate. He then proceeds to a discussion of 2-D and 3D dimensions and describes how vectors can be used to address many dimensions (key to understanding the exponential computing nature of quantum computing.)

After discussing how vector spaces contribute to quantum computing, Sutor moves on to quantum mechanics – and the role that probability plays. Randomness and probability play an essential role in how nature operates – and Sutor demonstrates how they both play a role in how quantum computers
Probability

It always amazes me that a critical element in deriving a quantum computing result is based on probability (this is most likely the correct answer) since probability just seems so random. But, as Sutor opens his chapter on probability, he states: “Here’s the key to what we’re going to cover in this chapter: in any given situation, the sum of the probabilities of all the different possible things that could happen always adds up to 1.” He later states that: “Our goal in quantum algorithms is to adjust the probability distribution so that the element in the sample space with the highest probability is the best solution to some problem. Indeed, the manipulation of probability amplitudes leads us to find what we hope is the best answer.”

To me, probability still looks like guesswork – albeit educated guesswork. But it forms the core of what quantum computers are designed to deliver.

Systems designs

On page 401 of this 518-page book, Sutor begins an in-depth discussion of the physical hardware involved in quantum computing – moving the text from an analysis of theoretical mathematics and physics into applied and experimental sciences. He opens with a discussion regarding the physical hardware devices (quantum computing) – and the challenges faced in quantum computing design. Quantum computers are sensitive to environmental noise – so future plans are heavily focused on “noise” reduction and elimination. As the hardware improves, the long-term goal is to have entirely error-corrected, fault-tolerant quantum computing devices.

Notable in this chapter is a discussion of the polarization of light to implement a quantum system – and the use of three filters to derive a result. Sutor mentions several technologies (such as superconducting transmon qubits) that are being used to implement today’s quantum systems – and also indicates that other approaches such as ion traps and photonic techniques hold promise for taming the qubits of the future.

Summary Observations

Sutor’s “Dancing with Qubits,” is a complete tutorial on quantum computing. It contains a description of quantum computing; it explains how quantum physics works; it explains how quantum computers have been designed; how they will be used – and the challenges they face. For me, it will be a reference tool that I will constantly reexamine as I conduct further research in the field of quantum computing.

It’s been a long time since I’ve delved into the fields of arithmetic, matrix algebra, trigonometry, geometry and physics – and a long time since I’ve considered planes, vectors, integers and dimensions – but I don’t think an in-depth knowledge in any of these fields or about any of these representations is required to follow this book.

Readers can see the general contribution of each discipline without having to understand each subject in-depth. What I found most beautiful about the mathematical discussion was how all of the disciplines interrelated and contributed to findings about the nature of quantum computing. Sutor has successfully brought into order what I sometimes consider the wild-and-wooly field of quantum computing.
For those concerned that the book sounds a little “too mathematical,” don’t worry. You don’t have to read and understand every equation in the book – only generally what each discipline is contributing to helping achieve a quantum result. Plus, Suitor and his editors have inserted “gray boxes” – sidebars that simplify and summarize material just discussed. Hey – back in college I was an English and Communications major – and I still loved this book.