The Quantum Leap
April 20, 2022

A prior post entitled "Collaboration Dominates Quantum Computing" included an overview of Classiq, a quantum algorithm design company. This post will include additional details about Classiq along with an overall assessment of the likelihood of their success which is summarized with a **Rating Alpha = 0.95/Exceptional Performance Expected** (see the Rating section for details).

Background

Classiq is a quantum algorithm design company founded in 2020 and based in Tel Aviv, Israel with offices in the US. The Company is developing software for tackling urgent and complex challenges in Quantum Computing development. Classiq's software increases the level of abstraction and permits developers to implement programs without the need to design the specific gate-level quantum circuits, enabling programmers to accelerate the development of algorithms without the need and expense of manually coding every step and function. As Yuval Boger, Classiq's Chief Marketing Officer told me "This is a new … and better way to create quantum software."

The Classiq Platform

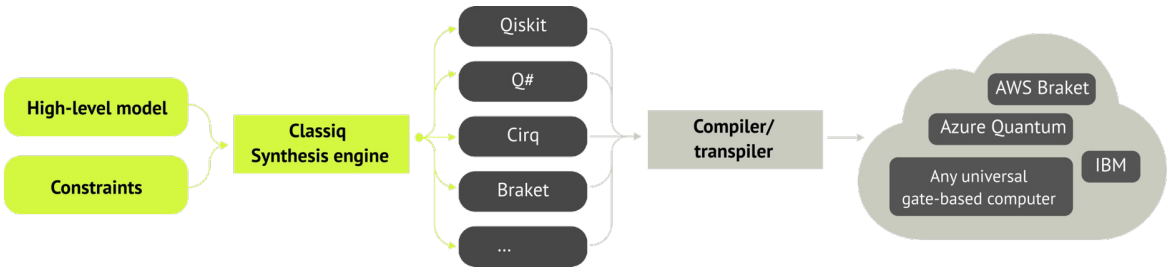
In these early days of QC, where machines have dozens or maybe 100's of qubits, many early users are able to write the code themselves, although there are few people that can manually create, test and maintain an efficient circuit with more than 25 qubits. And as QC's scale to 1,000 or 10,000 qubits or more, manually writing code for every qubit and every function will be practically impossible, so the Classiq algorithm design platform will be increasingly vital to users of QCs. And on top of the general efficiencies that Classiq can provide, their platform searches for solutions over a huge design space, meaning it can explore many more configuration options than a human can (see more details in an article entitled "Why Is It So Difficult to Write Software for Quantum Computers? And What Can Be Done About It"). This leads to circuits that are more compact and efficient and results that are more accurate since fewer gates can but used. Another unique and constructive feature of the Classiq platform revolves around their allowing customers to use the platform to build their own modular functional blocks, which they can reuse together with blocks provided by Classiq. This enables/allows customers to build and own their own intellectual property (IP) without needing to risk IP leakage to external providers. As companies build proprietary quantum software applications, enabling this IP protection will be essential.

Classiq provides software that automatically transforms high-level functional models into optimized quantum circuits for a wide range of back-end systems. Their goal is to allow

algorithm designers to write high level functional models of their algorithm and have the software automatically compile it to an optimized gate level implementation.

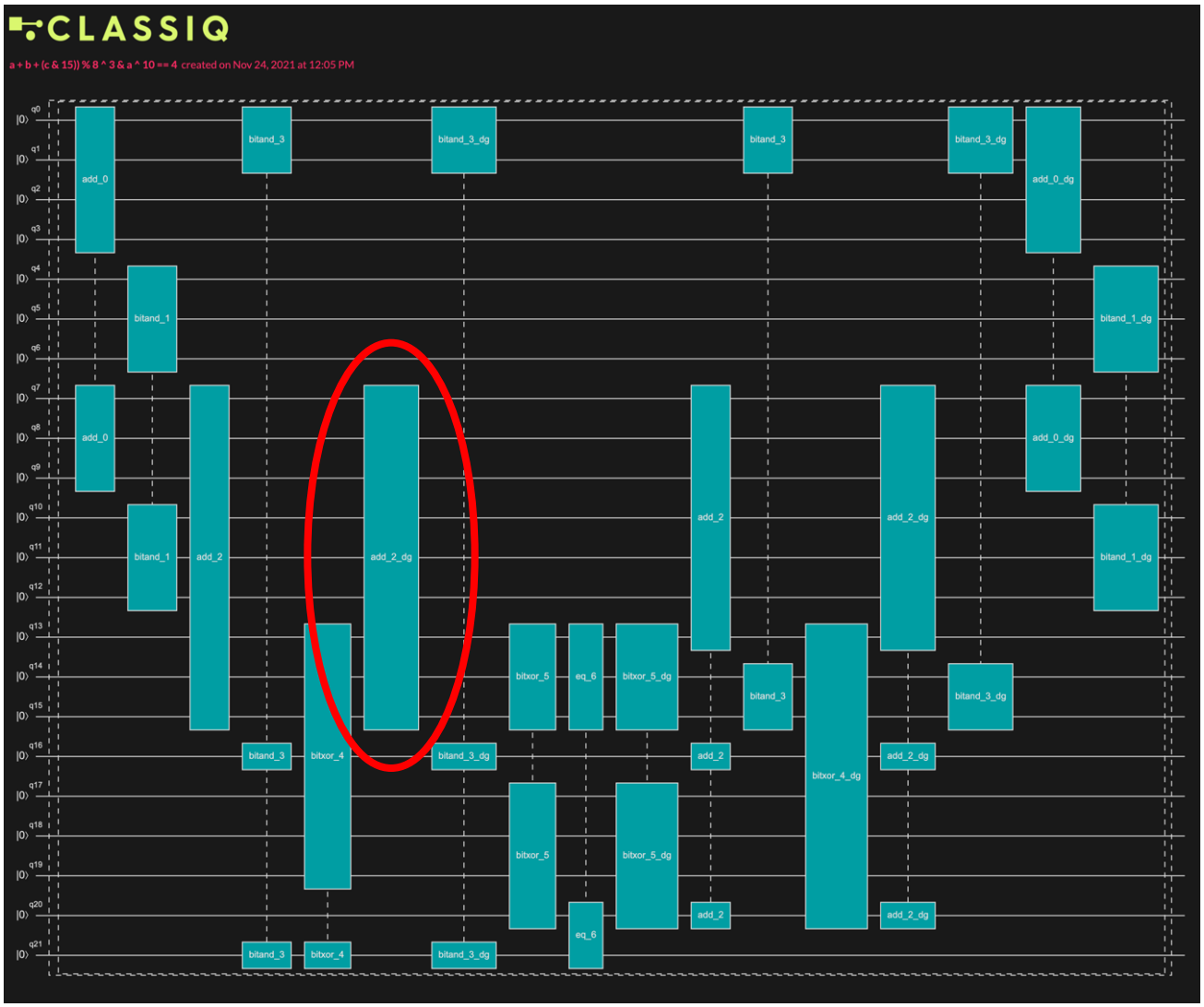
Their Quantum Algorithm Design (QAD) platform is the quantum equivalent of computer-aided design (CAD) enabling quantum software engineers and scientists to produce algorithms much faster than ever. The QAD automatically synthesizes complete quantum circuits from high-level functional models in seconds and does so in a clean and elegant visual framework. It is platform agnostic so can work with any gate-based QC, most major quantum cloud providers and can output its code in various quantum languages including Qiskit, Q#, Cirq and others.

The Classiq platform

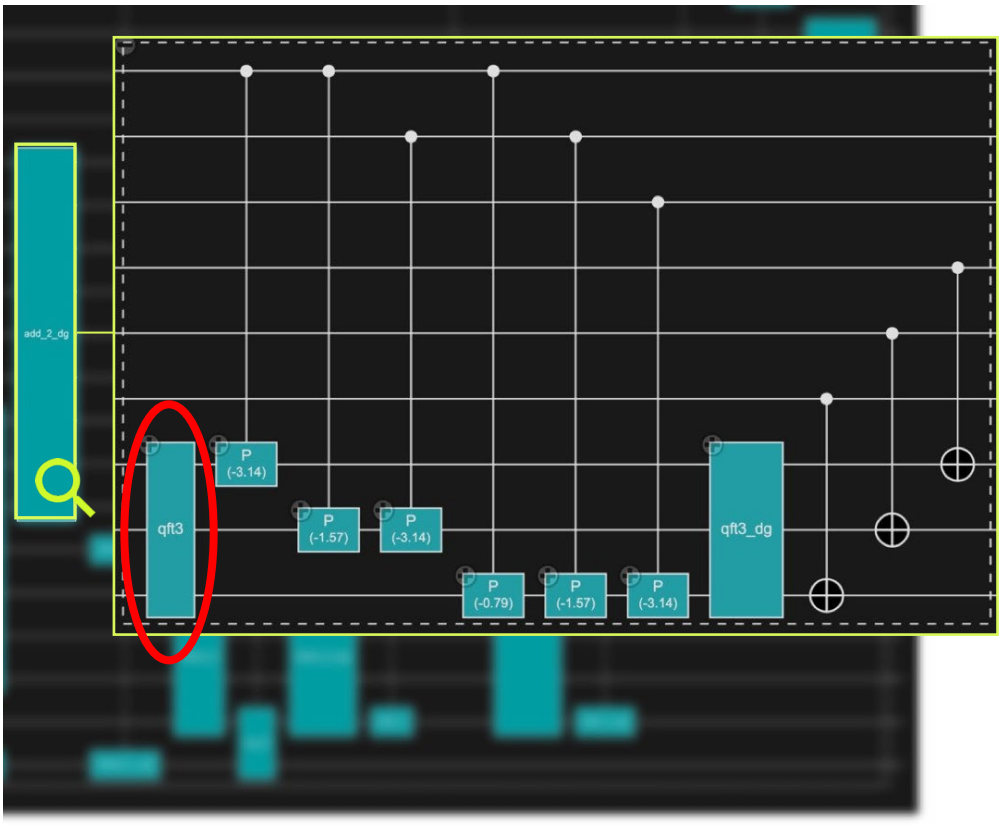


Instead of expressing quantum circuits using a series of gate-level or building block connections, algorithm designers that use the Classiq platform write functional models, similar to the very successful approach used today in designing sophisticated computer chips. The Classiq QAD platform then examines the full implementation space to find an outcome that fits resource considerations (e.g., circuit depth), designer-supplied constraints (e.g., overall accuracy) and the target hardware platform (e.g., qubit count). While it may not be obvious that circuit "optimization" is crucial for a QC with only a handful of qubits, as Amir Naveh, Classiq co-founder and Head of Algorithms noted in a recent interview "**we're not talking about twofold optimization. We're talking about a thousandfold optimization"** (emphasis added). Enabling smaller machines to achieve more powerful results. And once there are larger machines with better accuracies and fidelities, "you can go ahead and run even more complex problems. You can expand the envelope of what you're allowing your [quantum] computer to do." In essence, the Classiq platform may seem like added overhead if working with a QC with only a modest number of qubits, but it will establish practices and disciples to optimize machine capabilities, on whatever QC's are available, and provide a strong advantage over competitors that don't take advantage of the Classiq platform.

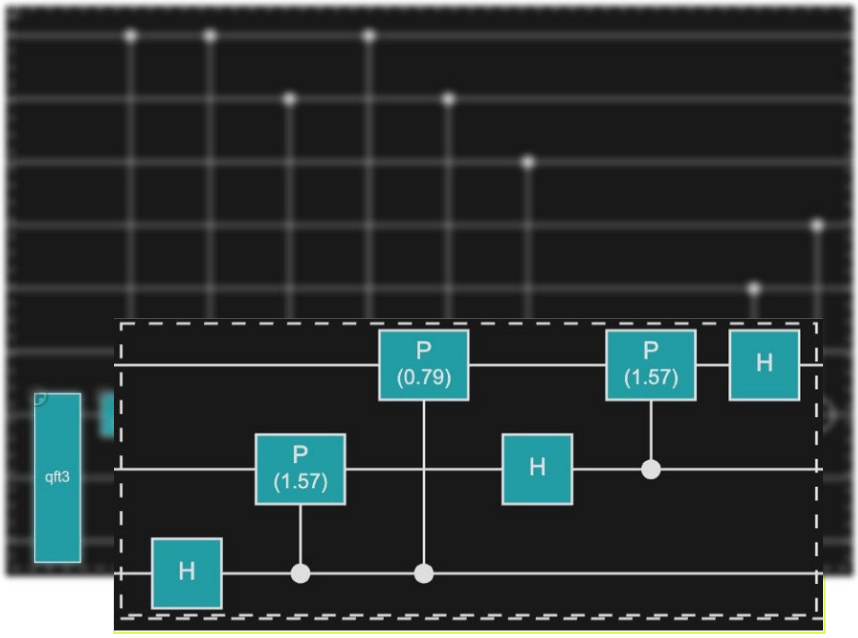
Once the various inputs and constraints are entered, the Classiq QAD will generate an algorithm that might look a bit like this:



You can see the various qubits listed along the y-axis and the various functional blocks that comprise the algorithm. If users want to drill-down to see what is within a given block (such as the block above circled in red), they simply click the "+" sign and it is further broken out visually as shown below:



Which, in turn, can be further highlighted and drilled down to the following:



The user interface is distinctive and intuitive, and the drill-down capabilities facilitate editing and debugging.

Software-as-a-Service Model

Classiq's business model is principally one of software-as-a-service (SaaS), where they offer seat licenses to end users for access to circuit conversion software via cloud access. Generally, customers download a front end such as a Visual Design Studio plug-in or Python SDK, to work out their broad coding parameters and then upload it to the Classiq provided interface for the actual algorithm synthesis. This model provides the typical benefits of SaaS including always having access to the most current version (i.e., no obsolescence cycle) without concerns regarding speed, capacity or backups/platform maintenance related to the Classiq solution. In addition, as Classiq develops various upgrades and learning packages, those are automatically available via the SaaS model. The current version has various finance, optimization and chemistry packages, with a machine learning package in development, which will automatically be available once released.

A recently released software version makes it easy for customers to add their own functionality on top of Classiq's rich set of existing functional models while leveraging the circuit synthesis and optimization capabilities of the Classiq platform. This means that instead of writing programs from scratch, Classiq users can now leverage functional models and knowledge bases created by internal domain experts, external providers, or Classiq itself. Third parties can now also create add-on packages for the Classiq platform and use those to market their unique quantum expertise. This new capability allows users to include their own unique intellectual property (IP) and custom functional models. As an example, the Classiq engine provides gaussian and log normal probability distributions as standard functions for use in things like Monte Carlo simulations, but if a user wanted to use a different probability distribution function, such as a Pareto distribution, they could define such a functional block in the Classiq platform.

Classiq Wants to Teach you How to Fish

There are other companies offering ways to simplify writing quantum algorithms, but Classiq is unique in its approach. In these early days of NISQ, certain quantum software firms offer "off the shelf" quantum primitives or pre-packaged algorithms. There are a number of problems that can be reduced to simple starting points called primitives, which allow users to run code for specific tasks. For example, Qiskit, the software development kit (SDK) put out by IBM and generally considered to be the most popular QC programming tool/platform, offers a number of primitives intended to make it easier to develop algorithms for Quantum Computers including "Sampler" and "Estimator" which perform tasks as their names imply. In fact, there are a handful of primitives today which run the gamut of most of the known and hypothesized use cases for QC. In addition to Qiskit's "Sampler" and "Estimator", other common primitives include various variational quantum algorithms (VGAs) such as QAOA, VQE and others (see github or Quantum Algorithm Zoo). There are also various intermediaries (i.e., quantum consultants) and quantum software providers that can customize such primitives for specific use cases. In fact, as noted above, Classiq offers a number of core algorithms within its platform, which users can use as provided. Therefore, you may be thinking that the industry already covers quantum algorithm synthesis, and you can hire firms to customize them if needed. So why the need for a QAD platform to build them or customize them? There are three core reasons why this is important:

1) Having tools to customize algorithms internally allows customers to build their own quantum software IP. This is a subtle but crucial difference.
2) Algorithms developed for one quantum platform, may not perform as needed on an alternative platform. QAD enables users to optimize and customize performance depending on the hardware utilized. As Amir Naveh further noted: "Maybe you built an algorithm optimized for your specific circuit and you're moving it to another hardware platform with different parameters for gate fidelity. You're going to have to redefine all of your optimization problems because the choices you made were optimized for the prior specific hardware." The Classiq platform handles this type of algorithm adaptability virtually automatically.
3) When Classiq clients are able to utilize the QAD platform, they develop internal capabilities which will enable them to be nimbler as they approach new QC challenges.

As Yuval Boger added, "We'll teach you how to express a problem. In quantum terms, we'll teach you how to implement that problem on our platform and we'll teach you how to run it on any gate-based computer of your choice. Not only will you end up with a running proof of concept, but you'll then have the expertise to continue the journey on your own. We can take off the training wheels." So, whereas external software providers or consultants will help provide quantum fish for their customers to eat, Classiq is teaching its customers how to catch their own fish.

Competition

While there are other companies attempting to improve quantum algorithms and/or reduce circuit noise (i.e., Q-CTRL and Quantum Motion), I am aware of only one company focused on higher level quantum algorithm modeling, namely Horizon Quantum Computing based in Singapore. Their tools are designed to expedite and simplify the process of developing quantum software applications and increase the productivity of experienced computing researchers, enabling software developers to harness the full power of quantum processors without prior quantum experience. While this seems like a similar model to Classiq on paper, the Company assures me that they have not run into Horizon in practice and have not faced them regarding any of Classiq's existing or prospective customers. However, last week it was reported that Horizon raised $12m from Tencent Holdings, so they may become a more formidable competitive force (although this round has not been confirmed by the company or by PitchBook).

Funding

Classiq has completed three investment rounds totaling $47.5m so are well capitalized. Classiq were in the second cohort of Intel's Ignite accelerator/incubator program and upon completion received $4m in seed funding from Entrée Capital, a London based venture firm. Last year they completed a $10.5m A-Round, led by Team8, a Tel Aviv based venture firm and joined by IN Venture (Sumitomo), OurCrowd, Wing Venture Capital and a follow-on investment from Entrée Capital. Earlier this year they completed a B-Round raising an additional $33m from IN Venture, Alumni Ventures, Hewlett Packard Pathfinder, and Spike Ventures. Samsung NEXT Ventures, Wing Venture Capital, Entrée Capital, Team8, OurCrowd, Lip-Bu Tan, Harvey Jones,

and Phoenix Insurance Company also participated in the round. This appears to be a strong, diverse and supportive group of investors including individuals/angels, financial investors and corporate/customer investors, most of which bring connections and business opportunities in addition to their capital.

Collaborations and Partnerships

In the prior post on Collaboration Dominating Quantum Computing, some of Classiq's various partnerships and collaborations were highlighted, so readers of that post may recognize some of the following details, although this post contains added details:

Classiq/ColdQuanta

In January of this year ColdQuanta and Classiq announced a partnership to make 100-qubit quantum circuits a reality for companies and researchers seeking quantum computing solutions. The partnership combines ColdQuanta's cold atom quantum computers and Classiq's quantum algorithm design software. They aim to provide customers with the ability to create, simulate and execute unique quantum circuits to address a wide range of finance, material science, supply chain, and machine learning challenges. As Nir Minerbi, CEO of Classiq noted, "as the industry moves from toy problems solved by toy circuits running on small quantum computers to solving real problems that require complex circuits on larger quantum computers, there is an acute need for a high-level platform to develop these circuits quickly and efficiently." By entering into this partnership now, the companies should be well aligned to scale together as ColdQuanta releases larger QCs in the future.

Classiq/NVIDIA

Last month Classiq announced a collaboration with NVIDIA to bring large-scale quantum circuits to customers intended to enable the exploration of the benefits of larger quantum circuits before the actual quantum hardware is available. To create and debug the next generation of quantum algorithms, customers need to simulate larger and more sophisticated quantum circuits. NVIDIA has developed the cuQuantum software development kit to speed up quantum circuit simulations based on state vector and tensor network methods. By combining with Classiq, NVIDIA hopes that cuQuantum users can write more sophisticated solutions which can be created, debugged, stress-tested and scaled in preparation for eventual availability of quantum hardware that can execute them. While some worry that quantum simulation platforms, like those powered by NVIDIA won't scale beyond 40 or 50 qubits, that is a bit of a misconception in that the threshold noted would only apply if there is full entanglement among all the qubits. Additionally, there will still be important debugging protocols that the Classiq/NVIDIA solution will enhance even once the QC's scale beyond the ability to simulate them on classical devices.

Classiq/NTT

Late in 2021 Classiq announced a collaboration with NTT DATA to implement novel credit risk analysis algorithms using quantum computers. Credit risk analysis is vital in determining the

creditworthiness of borrowers or vendors to quantify and limit the risk of loss to the lender. As Shunichi Amemiya, Head of R&D for NTT DATA noted "we are interested in applying quantum computer technology to financial engineering…Classiq's platform enables us to effectively generate and run quantum algorithms for the issues in applying to our use case." This is important in that it represents a collaboration between a QC company and industry, with very specific use cases in mind. As more and more companies consider QC applications for their industries, I expect to see more of these types of collaborations and believe Classiq offers a unique value proposition for accelerating QC engagement by industry.

Classiq/Fraunhofer Institute

Classiq has joined the Sequoia project which will focus on software engineering of industrial, hybrid quantum applications and algorithms. The project is coordinated by the Fraunhofer Institute for Industrial Engineering IAO with additional partners including Fraunhofer Institute for Applied Solid State Physics IAF, Fraunhofer Institute for Manufacturing Engineering and Automation IPA, University of Tübingen, Chair of Embedded Systems, FZI Research Center for Information Technology, University of Stuttgart, High Performance Computing Center Stuttgart, and the University of Stuttgart, Institute of Architecture of Application Systems (IAAS). The project is funded by the Ministry of Economic Affairs, Labour and Tourism Baden-Württemberg and will last from 2021 to 2023. Classiq will be working on two main problems within this project including solving mixed-integer linear programming (MILP) problems with state-of-the art (gate-based) quantum computers and solving coupled partial differential equations with the Harrow Hassidim Lloyd (HHL) quantum algorithm. This is an excellent opportunity for Classiq to increase its inclusion in, and exposure to, various academic institutions.

Others

Classiq is participating in the QC access programs of IBM, Amazon and Microsoft and has other collaborative arrangements with Hewlett Packard Enterprise, Sumitomo Corporation, Israel Aerospace Industries, Ltd, The Hebrew University of Jerusalem and Keio University of Tokyo. Some of these arrangements add commercial value, some add academic exposure and some provide broader industry access.

As can be seen, Classiq has been very active in its collaboration pursuits, and given their agnostic and broad approach to improving quantum algorithms, this is a wise move enmeshing them throughout the QC industry as it continues to grow and evolve.

Learning More

For quantum enthusiasts and investors seeking to learn more about Classiq and their platform I encourage you to visit their website and sign-up for updates. They offer frequent webinars (including one next week on optimization, which you can sign-up for here) and informal demonstrations and other ways to learn more about their products. They are also very active in the various quantum conferences held throughout the year, so you can learn more by speaking with them at any of those in-person and/or on-line events. They also host "The Qubit Guy's

Podcast," an excellent weekly discussion led by CMO Yuval Boger, which you can access here or wherever you listen to your podcasts.

For prospective customers, the best way to learn more would be to contact the company and inquire about a paid proof-of-concept around a chosen problem. That will enable you to see how easy it is to model the problem on your chosen platform, what sort of customer support Classiq provides and how flexible the solutions are.

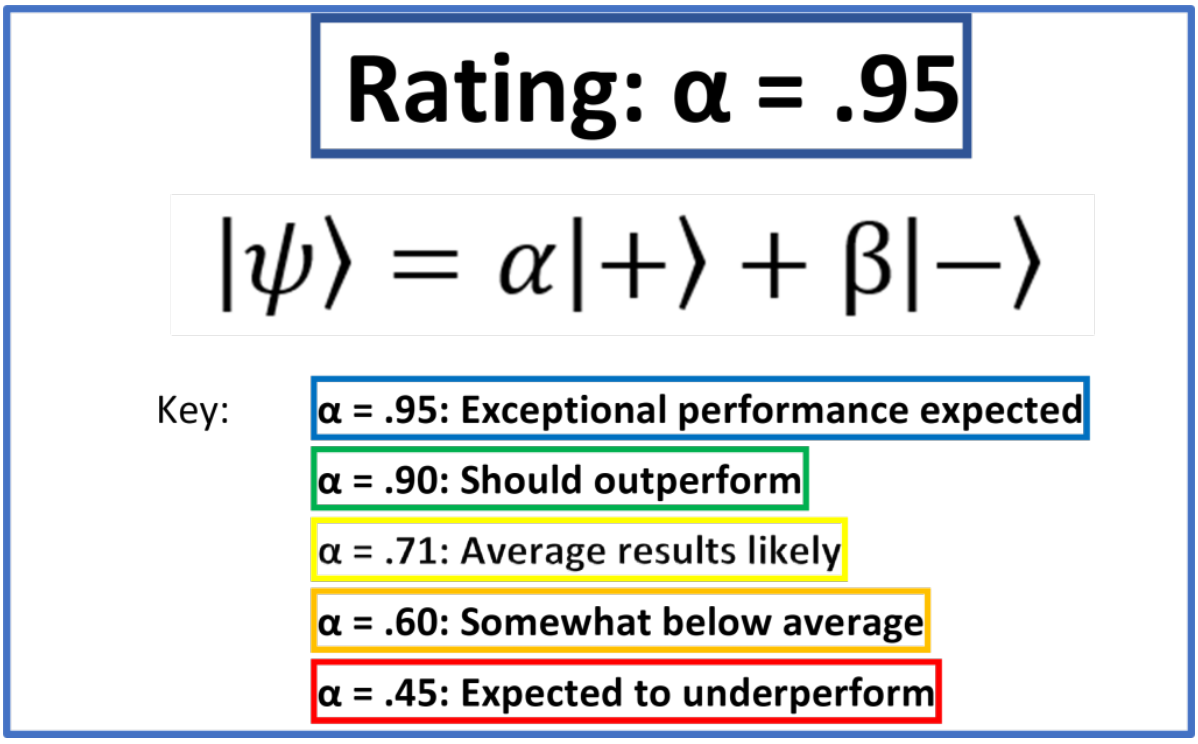
Summary

Classiq has a solid team, strong balance sheet, and highly regarded product. It has entered into a meaningful number of collaborations and partnerships with a wide variety of players. And its business model provides value-add to customers in an agnostic way vis-a-vis quantum hardware and software. And while there may some increasing competition, they appear to have a solid first-mover advantage. Some counterweight to those strengths includes being perhaps a bit early to the market (given that most QC's today are modest, and the performance improvements that Classiq can offer, may not yet move the needle) and it is likely that many prospective customers are still getting up the curve on basic QC access. However, these counterweights should be quite short-lived as QC's scale into the 100's of qubits this year. Smart QC users will engage Classiq now, to ensure they are always optimizing the capabilities of whatever hardware is available at the time. If Classiq can continue its current momentum and become the go-to provider for customers seeking to optimize their quantum algorithms, their customer base should expand quite rapidly and consistently. The following table highlights some of the key attributes of Classiq:

Strengths:	**Opportunities:**
• Being agnostic to both hardware and software platforms enables the Company to be a value-added provider to nearly all participants in QC. • Well capitalized having raised nearly $50m from a diverse group of over a dozen investors. • Solid IP portfolio with 9 issued patents.	• As the roadmaps announced by leading quantum providers reach fruition, with 100's of qubits expected over the next year, the Classiq platform will become increasingly valuable. • Enabling customers to maintain their own IP is a subtle but important feature to leverage. • Establishing a stronger presence in educational institutions (a la Sequoia) should solidify future customer awareness.
Weaknesses:	**Threats:**
• A somewhat concentrated business model. • Their value-add may not be obvious to early QC users dealing with a modest number of qubits.	• Horizon recently closed on $12m in funding from Tencent so may become more of a competitor. • While well capitalized, will need to raise additional future funds which can be challenging.

Rating

Apropos of the probabilistic nature of quantum algorithms, I wanted to leverage the nomenclature to create a company rating system and assign a scale to my overall assessment of a company's potential. Accordingly, I am going to use the formula below when reviewing companies, whereby the "alpha" coefficient correlates with "positivity" (and the formula adheres to the Born rule). Given my overall assessment of Classiq including its strong position as a value-added resource to others working to advance Quantum Computing, the strengths, and capabilities of their Quantum Algorithm Design platform, and their go-to-market strategies, I am assigning the highest rating to Classiq at this time, with an **Alpha of 0.95** which equates to an "Exceptional performance expected".



***Disclosure**: The author has no beneficial positions in stocks discussed in this review, nor does he have any business relationship with any company mentioned in this post. The views expressed herein are solely the views of the author and are not necessarily the views of Corporate Fuel Partners or any of its affiliates. Views are not intended to provide, and should not be relied upon for, investment advice.*

References:

Boger, Yuval. Interviewed by Russ Fein, April 14, 2022.

"CLASSIQ and ColdQuanta Partner to Provide a Complete Solution to Creating and Executing 100-Qubit Quantum Circuits and Beyond," *Businesswire*, January 25, 2022.

"CLASSIQ Collaborates with NVIDIA to Accelerate the Path to Quantum Advantage,"*Businesswire*, March 24, 2022.

"CLASSIQ, NTT Data Collaborate on Quantum Algorithm Design for Financial Modeling," *Businesswire*, December 1, 2021.

Siegelwax, Brian, "Demo: Classiq's QAD Platform," *Medium: Level Up Coding*, November 24, 2021.

"Classiq Unveils Groundbreaking Capabilities for Its Quantum Algorithm Design Platform," *Businesswire*, November 16, 2021.

"Classiq to Collaborate with the Fraunhofer Institute and Other Leading Universities on New Methods for Industrial Quantum Use," *Businesswire*, November 12, 2021.

Boger, Yuval, "Why Is It So Difficult to Write Software for Quantum Computers? And What Can Be Done About It", *Quantum Computing Report*, accessed April 10, 2022.

Naveh, Amir, "Podcast with Amir Naveh, Co-Founder Classiq," *The Qubit Guy's Podcast*, February 16, 2022.

Swayne, Matt, "TQD Exclusive: A Classiq Solution to a Current Quantum Challenge," *The Quantum Insider*, September 1, 2021.

Preimesberger, Chris J., "Quantum circuits automation gains attention and funding," *VentureBeat*, February 21, 2022.

Shaw, David, "Quantum Software Outlook 2022," *Fact Based Insight*

If you enjoyed this post, please visit my website and enter your email to receive future posts and updates: http://quantumleap.blog

Russ Fein is a venture investor with deep interests in Quantum Computing (QC). For more of his thoughts about QC please visit the link to the left. For more information about his firm, please visit Corporate Fuel. Russ can be reached at russ@quantumleap.blog.