Date: 2020-07-01	**CEN-CLC/FGQT N 010**
Status: FOR DISCUSSION	**Supersedes: -**

Focus Group on Quantum Technologies (FGQT)

Chair:

Dr Oskar van Deventer
TNO – Netherlands Organisation for applied scientific research
Anna van Buerenplein 1
2595 DA Den Haag
Netherlands
Telephone: +31 88 866 7078
E-mail: oskar.vandeventer@tno.nl

Secretary:

Marius Loeffler
DIN - German Institute for Standardization
Saatwinkler Damm 42/43
13627 Berlin
Germany
Telephone: +49 30 2601 2353
E-mail: marius.loeffler@din.de

TITLE **Proposal for TOC on gated quantum computing**

PROJECT FGQT / Gated Quantum Computing

SOURCE Delft Circuits
The Netherlands

CONTACT Rob.F.M. van den Brink
Delft Circuits,
Circuits.com
Lorentzweg 1
2628 CJ Delft, The Netherlands
www.Delft-Circuits.com
tel: +31 6 22529101
mail Rob.vandenBrink@Delft-

ABSTRACT Proposal to split-up the documents on “Quantum Technologies” in smaller parts (separate documents, separate Editors), and further details on how the part on Gated Quantum Computing” can be filled with content

---

The aim for creating consensus documents on quantum computing is to produce a Technical Report with Recommendations to give guidance on how products from different vendors/teams can interwork with each other. This involves all the hardware and software for building a working quantum computer.
The present proposal for a “Roadmap” is a good start, and very useful for describing developments about the entire field of quantum technology. It could become a useful white paper describing for a wide audience what is going on in the field of quantum technology.
However, a Roadmap alone is too broad and cannot handle all the details that are required to let different components interwork well witch each other. Therefore we propose the following:

1. Proposal for a split-up in multiple parts

- [A] Keep the present Roadmap structure to produce a kind of generic overview document for a wide audience.
- [B] Split-up the various topics into smaller stand-alone documents, and allow for each of these documents their own timelines, so that output on (sub)topics become visible more rapidly then others.
- [C] The topic Quantum Computing is often understood as “Gated Quantum Computing” only and sometimes referred to with a very biased name: Universal Quantum Computing. However an “Annealing Quantum Computer” is quite a different machine, which may have very different requirements, and it is NOT the opposite on “non-universal” quantum computing.. Therefore we propose to keep the following topics strictly separated in different documents:
  - “Gated Quantum Computing”
  - “Annealing Quantum Computing” *(in case someone proposed content for that)*
- [D] Below, we offer further detail on a TOC about “Gated Quantum Computing”

2. Proposal for a TOC on "Gated Quantum Computing"

- **Scope and objectives**
  The aim is to develop all kinds recommendation for a modular gated quantum computer, where different vendors create hardware and software modules that can interwork with each other into a reliable quantum computer

- **References**

- **Definitions and Abbreviations**
  - *Defines the usual terminology stuff*
  - *Defines various role models, for instance what we mean with a quantum hosting provider offering computing services to different quantum clients*

- **Quantum Control Stack - QCS**
  This involves recommendations for all low-level software for controlling and read-out a quantum computer within a single quantum hosting environment, but in a manner that is common for different quantum hosting providers.
  - *Defines a functional description of the Quantum Control Stack and associated naming.*
  - *Defines recommended protocols for interfacing with a quantum control unit from a remote location (both nearby and from "the cloud").*
  - *Defines low-level methods for billing and separating quantum jobs, so that when complex piece of (classical) software requires a call to a quantum-specific algorithm, it can automatically set-up a connection with a quantum host to perform the quantum calculation*
  - *Defines low-level messaging in some ASCII or binary format, to send all kinds of instructions to the quantum host, to perform quantum calculations, but also to inquire the capabilities of a quantum computer in terms of supported QASMs, primitives, gate topologies, etc. These instructions may be a mix of Quantum assembler and/or micro code.*
  - *Defines a common list of systematic names and definitions, so that different QASM languages can use the same naming for commonly used gates.*
    - *Think of common names for single qubit gates like phase shift (PH?, Rs?), arbitrary gates (U?, UU?, U3?, ARBI?), S or sqrt(Z) gates, V or sqrt(X) gates, etc*
    - *Think of common names for dual qubit gates like Ising gates (IS, 'ising'), molmer-sorensen gates (XX?, MS?)*
    - *Think of common names for compound gates like QFT (quantum Fourier Transform), etc*
  - *Defines a common syntax for the micro-code to instructs the Qubits in terms of pulses, timing, read-out, etc. This allows the development of innovative QASM languages to translate a set of parallel QASM instructions into a common micro code.*
  - *Defines a recommended interfacing with (a stack of) Quantum Control Units*

- **Quantum Control Unit - QCU**
  This involves all room-temperature electronics capable of generating and receiving signals (pulses, carriers, ..) for controlling and read-out the Qubits
  - *Defines a functional description of the Quantum Control Unit and associated naming.*
  - *Defines desired functionality, modularity and scalability*

- *Defines signal levels, shapes, noise floors, connectors, timing requirements*
- *Defines receiving requirements and associated signal processing*
- *Defines how a digital (local) computer interfaces with the Quantum Control Unit, and the level and syntax (ascii and/or binary) of the micro instructions that are directly understood by the QCU*

- **Quantum Control Highway - QCH**
  This involves the full interconnection between room temperature and cryogenic temperatures for interconnecting a Quantum Control Unit with thousands (or more) Qubits
  - *Defines a functional description of the Quantum Control Highway and associated naming.*
  - *Defines functional requirements, desired footprint/size, desired modularity, scalability of the cabling, requirements on passive and active (microwave) components inside and outside the fridge, connecting methods, max distance between QCU and fridge,*
  - *Defines desired external connector types, mechanical requirements inside and outside the fridge, grouping blocks of connectors for hundreds or thousands of signals, recommended color coding*
  - *Defines all kinds of signal transmission requirements through the cabling, like bandwidth, loss, crosstalk, phase stability, filtering, signal splitting, signal amplification, etc*
  - *Defines desired internal connection between near zero-Kelvin components such as quantum processor chips and units.*
  - *Defines all kinds of thermal requirements to obtain an adequate trade-off between (conflicting) thermal, electrical, and mechanical requirements. This includes a maximum heat-flow per channel for given signal loss, thermal clamping, and associated mechanical recommendations.*
  - *Defines all kinds of vacuum requirements for a vacuum feed-through of cabling into the fridge, as well as associated mechanical recommendations.*
  - *Defines robustness requirements, like minimum number of in/out connections before wear-out*
  - *Defines testing of above requirements like minimum number of temperature cycles between room temperature and near zero Kelvin,*

- **Quantum Processor Unit - QPU**
  - *Defines a functional description of the Quantum Control Highway and associated naming.*
  - *Defines desired internal connection with the QCH*