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openQCM Q-1 User's Guide

openQCM Q-1 Quartz Crystal Microbalance with Dissipation Monitoring based on Scalar Network Analyzer

authors: openQCM Team
version: 1.1
date: OCT-2018

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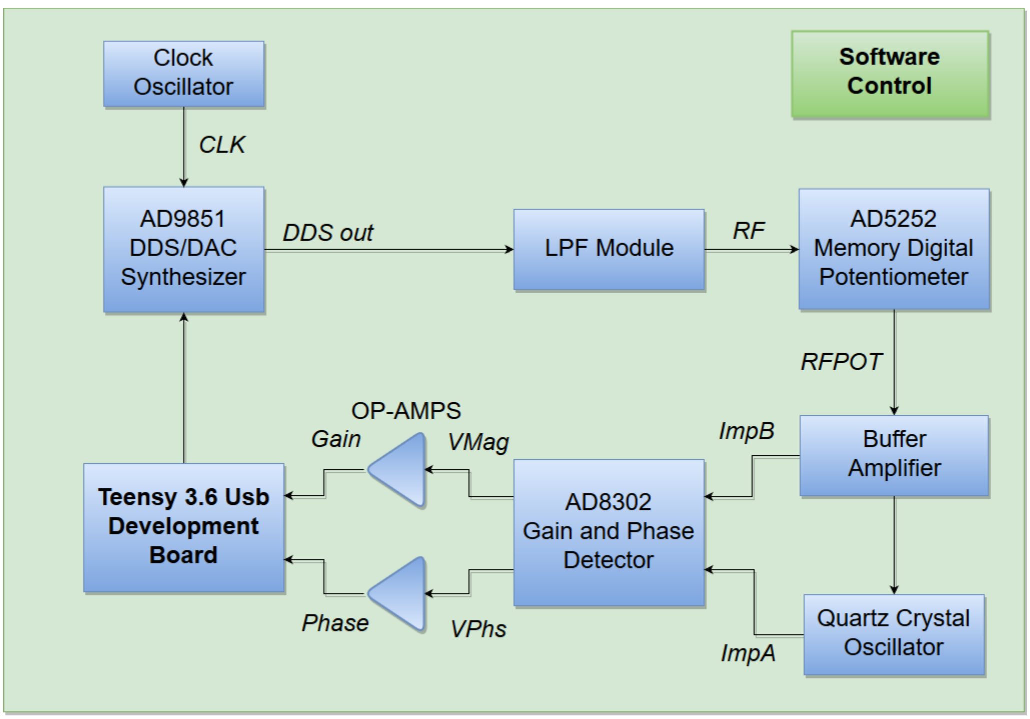
Intro

openQCM device is released as a scientific open source instrument, and it is intended solely for use for **SCIENTIFIC**, **RESEARCH and DEVELOPMENT APPLICATION, DEMONSTRATION, OR EVALUATION PURPOSES** and is not considered to be a finished end-product fit for general consumer use.

Sensing Principle

openQCM Q-1 is the new Quartz Crystal Microbalance instrument capable of measuring simultaneously frequency and dissipation variations. The instrument is therefore capable of measuring both variations in mass and in the viscoelastic properties of the material on the surface of the quartz crystal



Semplified Block Diagram

The electronic mainly consists of a scalar network analyzer, the main block diagram is showed in figure. The scheme of measurement follows the principle of passive interrogation of the quartz sensor by sweeping around the resonance frequency. The actuation signal is generated using the AD9851 DDS/DAC frequency synthesizer and the output signal is read by AD8302 gain and phase detector, which can measure both the magnitude ratio (gain) across the quartz crystal and the phase difference between the actuation and transmitted signal. The analysis of the gain curve allows the characterization of the sensor by measuring simultaneously the resonance frequency and quality factor. The main advantage of the scheme of measurement is the possibility to measure quartz sensor parameters in isolation without an external circuity influence.

openQCM Q-1 electronic consists mainly of two boards: i) the main board features the network analyzer and Teensy microcontroller, and ii) the secondary board which is inserted in the fluidic cell, which features the electro-mechanical connections with the quartz crystal sensor using pogo-pin and also a temperature sensor which is mounted as close as possible to the quartz crystal sensor, in order to measure the temperature inside the fluidic cell.

Electronic Hardware

Teensy

The openQCM Q-1 PCB is designed to use a Teensy 3.6 development board
https://www.pjrc.com/teensy/index.html
which is a powerful arduino-compatible microcontroller, featuring a 32 bit 180 MHz ARM Cortex-M4 processor developed by Paul Stoffregen. The development board has a lot of functionalities, the most interesting one is the analog input ADC with an usable resolution of 13 bits
https://www.pjrc.com/teensy/techspecs.html
It means that over the full-scale range of 3.3 volt it is possible to measure input voltage variations with a resolution 0.4 mV/bits.

Frequency Synthesizer AD9851 DDS/DAC

The AD9851 DDS/DAC frequency synthesizers
http://www.analog.com/media/en/technical-documentation/data-sheets/AD9851.pdf
is an integrated device which uses DDS technology for generating an analog output sine wave when it is referenced to a stable clock source. In this application the AD9851 was connected to a 30MHz standard clock oscillators. The DDS can generate a sine wave with frequency from DC up to 72 MHz, with an output tuning resolution of about 0.04 Hz when clocked at 180 MHz. The output frequency is controlled by the digital pin W_CLK and S_LD using a defined protocol of communication.
The wide – range frequency output capability of AD9851 (0 – 72 MHz) enables to interrogate the quartz sensor not only at the fundamental frequency but also to the higher mode of vibration, which are supposed to be more suitable for biosensing applications, mainly because they have less drift and less environmental effects.

Gain and Phase Detector AD8302

The AD8302 Gain and Phase Detector
www.analog.com/media/en/technical-documentation/data-sheets/AD8302.pdf
is capable of measure simultaneously both the magnitude ratio, defined as gain, and phase difference between two signals, from low frequencies up to 2.7 GHz. The AD8302 measures the gain loss through the quartz crystal, referenced to the input signal, and simultaneously the phase lag between the response and actuation signal.

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How to Setup openQCM Q-1 Sensor Module




1. The sensor module has a pair of pogo pins to ensure connection to the quartz crystal sensor. The first couple is suitable for 14 mm diameter quartz crystal one sided contacting
2. Insert the quartz crystal into the sensor module housing, making sure that the electrodes on the rear surface of the quartz are in contact with both pogo pins
3. Close the sensor module with the cover, while the closing lever is positioned on the min

4. Turn the lever counterclockwise, in the direction of maximum, to ensure the seal of the sensor module

How to Finely Check the Sealing of the Sensor Module

- Connect the tubes to the flow cover.
- Connect one tube to the liquid reservoir (inlet) and the other tube to a syringe / pump (outlet)
- Aspirate the liquid with the syringe / pump and stop before the liquid enters the quartz chamber.
    - if the liquid remains stationary at the same level, the seal of the chamber is guaranteed. Otherwise:
    - the seal of the chamber is not guaranteed: fine turn the lever counterclockwise, in the direction of maximum, to ensure the seal of the sensor module.

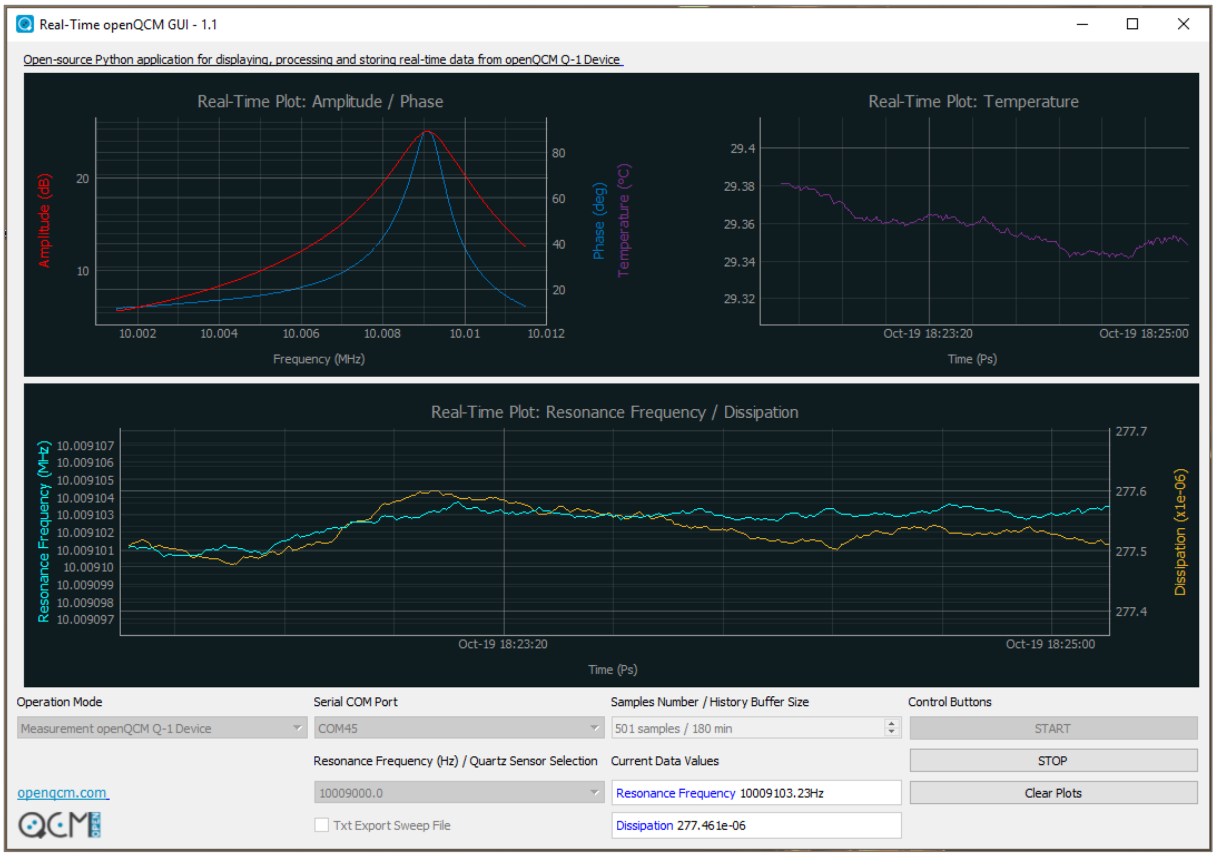
The machining process of the openQCM sensor module is carried out using 3D printing technology, so that the fine adjustment of the sensor module measuring cell can depend on the specific device used.

Once the adjustment lever has been positioned in the appropriate working position, it is recommended to keep its position fixed during the measurement cycle.

It may be possible to observe frequency drifts because the cover presses too much on the quartz surface of the quartz. You can solve this by finely turning the lever clockwise in the direction of minimum.
PLEASE BE CAREFUL ! Turning clockwise the lever too far towards the minimum may cause the cell to be flooded because it loses sealing.

It may be possible to observe tilting of the top cover, which can prevent the measurement cell from being sealed properly. Gently press on the top cover to check that it does not tilt, otherwise sealing may not be guaranteed. If the top cover tilts, it is suggested that you turn the adjustment lever anti-clockwise, in the maximum direction, to prevent the top cover from tilting.

Software GUI Python version 1.1



Version History

Name: openQCM Q^{-1} GUI

Version:1.1

Programming Language: Python

Author: openQCM Team

Supporting and Powering the openQCM project: Novaetech S.r.l

Description:

An open-source Python application, to display, process and store data in real-time from the openQCM Q^{-1} Device. The main functionality is the real-time monitoring of frequency and dissipation variations of a quartz crystal microbalance through the analysis of the resonance curve. The application includes internal and external packages.

Intended Audience: Science/Research/Engineering

Software Development**:** User Interfaces

Requirements**:**

- Python 3.6.5
- Ananconda 4.5.11

Packages:

- PyQt5
- PySerial 3.4
- PyQtGraph 0.10.0
- progressbar 2.5

Other used internal packages:

- multiprocessing, numpy, scipy, setuptools, io, platform, sys, enum, argparse, cvs, time, datetime, logging, pywavelets

Installation Guide

Download openQCM Q-1 Python application version 1.1 here:
https://openqcm.com/shared/q-1/openQCM_Q-1_py_v1.1.zip

Using Anaconda (Windows, macOS, Linux)

1. download and install Anaconda3 for Python 3.6 version Anaconda3-5.1.0
   https://repo.continuum.io/archive/

2. Open anaconda prompt (windows) or terminal (macOS and Linux) and type:
```
conda install pyqtgraph pyserial
python -m pip install --upgrade pip
python -m pip install --upgrade h5py
pip install progressbar
```

Linux

1. Open a terminal and type:
```
sudo apt-get install python3-pyqt5 python3-pyqtgraph python3-serial
```
2. Then, type:
```
sudo pip install progressbar
```

Usage

1. Launch anaconda prompt
2. Browse to the openQCM Q-1 python software main directory
```
…/openQCM_Q-1_py_v1.1/OPENQCM/
```
3. Start the application main GUI by typing the command
```
pyhton – m openQCM
```

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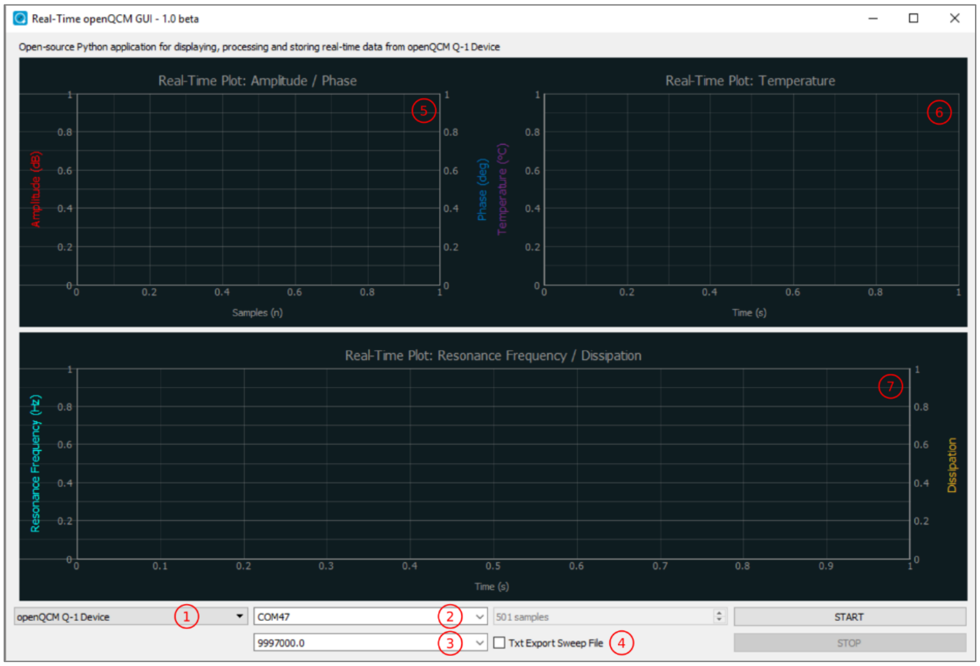
openQCM Q-1 GUI Description



The main GUI of openQCM Q-1 Python software (version 1.0) is showed in figure. The detailed description of the functions is given below:

Button command:

- START: start a continuous measurement procedure OR start the calibration procedure
- STOP: stop the acquisition procedure OR stop the calibration procedure

Drop-down menu

1. Select measurement / calibration mode
2. Available COM port (note the software shows only the port connected to the device)
3. Frequency drop-down menu: select the working frequency (fundamental and overtones)

Radio Button

4. Flag Txt export sweep file radio button to log data for each sweep cycle of the measurement (raw data)

Real Time Plots

5. Amplitude /Phase displays the amplitude and phase curve during the sweep procedure
6. Temperature: displays the current value of the temperature, measured by sensor embedded on the fluidic cell
7. Resonance Frequency and Dissipation real time chart simultaneously displays the current frequency and dissipation value, calculated at the end of each sweep procedure

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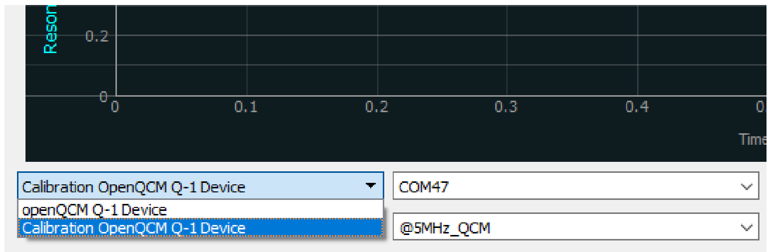
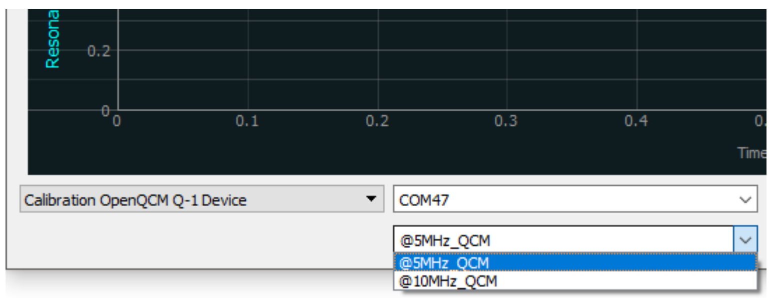
Calibration Procedure

Each time the quartz sensor is replaced, the calibration procedure has to be started.

1. From the main GUI open the #1 Drop-down menu and select *"Calibration openQCM Q-1 Device"*

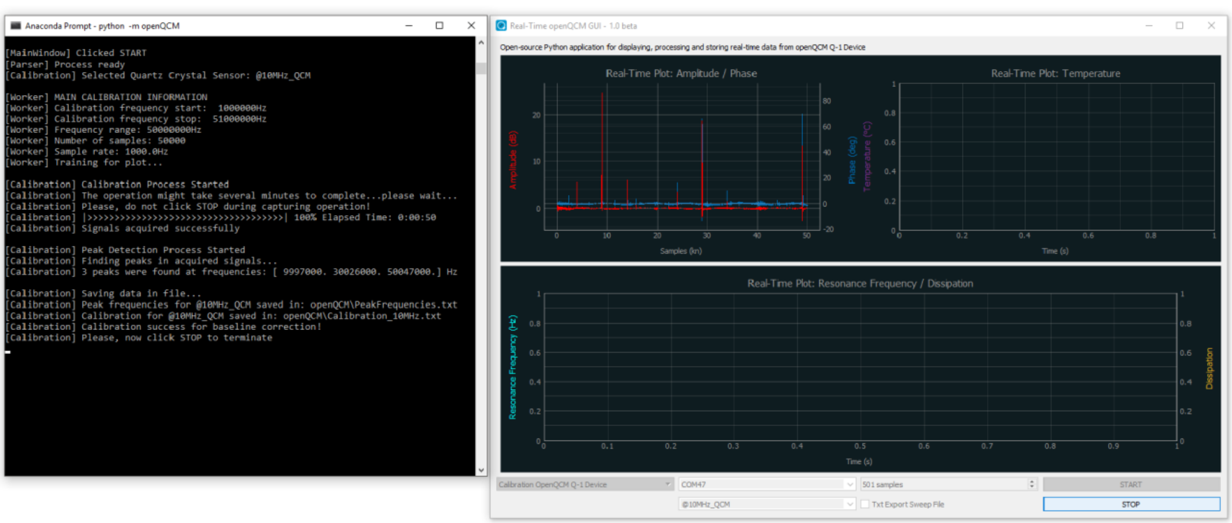


2. Select the quartz crystal type, 5 MHz or 10 MHz fundamental frequency



3. Press "START" button for starting calibration procedure. Follow the indication in the anaconda prompt to check info and progress of the calibration (please note that calibration takes roughly 50 sec to complete. Please do not interact with the GUI during the scan)

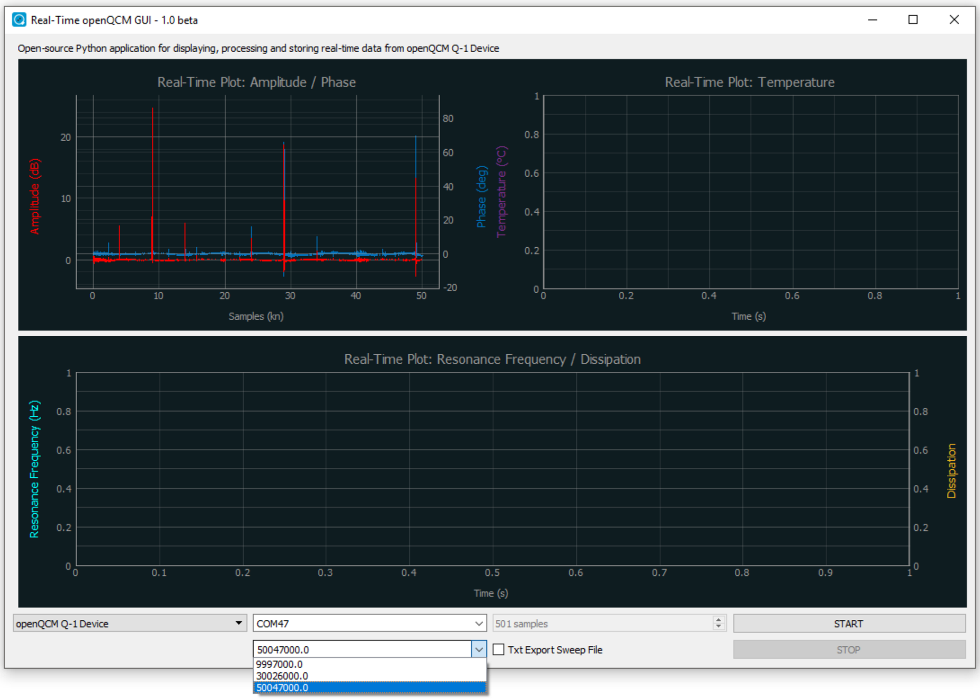
4. When anaconda prompted "Please, now click STOP to terminate" you can now press the STOP button and terminate the calibration procedure.



Measurement Procedure

In order to start a new acquisition and measurement procedure of frequency and dissipation follow the steps below:

1. Select the working frequency, that is fundamental frequency or overtones, from the drop-down menu #3



2. (Optional) Flag Txt export sweep file if you want to store raw data corresponding to each sweep

3. Press start button to initiate a new data acquisition – measurement.

4. Frequency, dissipation and temperature real-time data are automatically stored each time a new acquisition is initiate. Data file is stored in the following directory

   `…\OPENQCM\logged_data`

   Data file extension is .csv a typical saved file is shown below

	A	B	C	D	E
1	Timestamp	Temperature	Resonance_Frequency	Dissipation	
2	16-57-19_24-Sep-2018	29.03041734	9996902.507	0.000276502	
3	16-57-20_24-Sep-2018	29.02943886	9996902.996	0.00027649	
4	16-57-20_24-Sep-2018	29.02842015	9996902.972	0.000276503	
5	16-57-21_24-Sep-2018	29.02736749	9996903.242	0.000276498	
6	16-57-21_24-Sep-2018	29.02827974	9996903.12	0.000276491	
7	16-57-22_24-Sep-2018	29.0272224	9996903.356	0.000276493	
8	16-57-23_24-Sep-2018	29.02892981	9996903.35	0.000276503	
9	16-57-23_24-Sep-2018	29.02685414	9996903.457	0.000276493	
10	16-57-24_24-Sep-2018	29.02650128	9996903.478	0.000276494	
11	16-57-24_24-Sep-2018	29.02628705	9996903.571	0.000276499	
12	16-57-25_24-Sep-2018	29.02784617	9996903.316	0.000276496	
13	16-57-25_24-Sep-2018	29.02543383	9996903.394	0.000276499	
14	16-57-26_24-Sep-2018	29.02728097	9996903.589	0.000276505	
15	16-57-26_24-Sep-2018	29.02523916	9996903.571	0.000276494	
16	16-57-27_24-Sep-2018	29.02715856	9996903.607	0.000276498	
17	16-57-27_24-Sep-2018	29.02522099	9996903.534	0.000276499	
18	16-57-28_24-Sep-2018	29.02731837	9996903.465	0.000276499	
19	16-57-29_24-Sep-2018	29.02713713	9996903.365	0.000276503	
20	16-57-29_24-Sep-2018	29.02692172	9996903.523	0.000276507	
21	16-57-30_24-Sep-2018	29.02705951	9996903.574	0.000276505	
22	16-57-30_24-Sep-2018	29.02721854	9996903.634	0.000276501	
23	16-57-31_24-Sep-2018	29.02538294	9996903.513	0.000276509	
24	16-57-31_24-Sep-2018	29.02755596	9996903.563	0.0002765	
25	16-57-32_24-Sep-2018	29.02789079	9996903.526	0.000276502	
26	16-57-32_24-Sep-2018	29.02787196	9996903.415	0.000276504	
27	16-57-33_24-Sep-2018	29.02781139	9996903.248	0.000276499	
28	16-57-33_24-Sep-2018	29.02809944	9996903.48	0.000276494	
29	16-57-34_24-Sep-2018	29.02800392	9996903.504	0.000276501	
30	16-57-35_24-Sep-2018	29.02821552	9996903.53	0.0002765	
31	16-57-35_24-Sep-2018	29.0284795	9996903.504	0.000276498	
32	16-57-36_24-Sep-2018	29.02841491	9996903.386	0.000276504	
33	16-57-36_24-Sep-2018	29.02838078	9996903.553	0.000276495	
34	16-57-37_24-Sep-2018	29.02837947	9996903.602	0.000276498	

15-38-55_24-Sep-2018_DataLog_fu

Temperature, Voltage and Material Warning Notice

Temperature

The openQCM devide hardware case is 3D-printed using Nylon material. It is heatproof to 80°C and higher temperatures may significantly change material properties.

It is recommended to use openQCM electronics components and device (as a non-restrictive example Teensy microcontroller, openQCM Q-1 shield) in the working temperature range -40°C to 85°.

Using the device at temperatures other than those indicated may significantly alter the materials and components resulting in a malfunction of the device. openQCM device is intended solely for use for scientific, R&D application, demonstration, or evaluation purposes Users handling the device must observe good engineering practice standards**.**

Voltage

openQCM Q-1 device is designed to be powered at a continuous voltage of 5VDC through connection to the USB port.

Power supply different from that indicated will damage the device.
openQCM device is intended solely for use for scientific, R&D application, demonstration, or evaluation purposes Users handling the device must observe good engineering practice standards.

Material

openQCM devices are realized with the 3D printing technique. The 3D printed case is made in Nylon strong and flexible plastic. This material is very adaptable, it is dishwasher safe and heatproof to 80℃ / 176℉ degrees. The material datasheet is available at this link: https://goo.gl/NzkbSG and the material safety datasheet is available here https://goo.gl/abrP8y

The only materials of the sensor module that are in contact with the sample are those of the measurement chamber, consisting of the window cell and the oring. The standard window cell materials are PMMA acrylic glass (Plexyglass®) or PTFE synthetic fluoropolymer (Teflon®) standard oring is made of FKM Viton®.

It is strongly suggested not to use the PMMA window cell with organic solvents
PMMA acrylic glass (Plexyglass®) material swells and dissolves in many organic solvents (such as ethanol); it also has poor resistance to many other chemicals due to its easily hydrolyzed ester groups.

It is advisable to be very careful with aggressive chemical materials.
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FCC Warning

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will be required to take whatever measures may be required to correct this interference

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