Soluzioni elettroniche e Innovazione

QCMagic R3

User Manual

The ultimate Quartz Crystal Microbalance System

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Introduction

The QCMagic set-up has been designed to directly drive piezoelectric transducers. It consists of single/multiple measuring units, driven by a USB Base Unit, suitable for:

biosensor development
affinity reaction studies
association/dissociation and kinetic constants determination
monoclonal antibodies characterization
binding site mapping
DNA hybridization
analysis of electrochemical deposition, polymers coated on electrodes, corrosion, adsorption and electrochemical reaction mechanisms
multi-probing detection

Inspection and warranty

QCMagic was carefully inspected, both electrically and mechanically before shipment. After unpacking all items from the shipping box, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to ElbaTech srl.
The item is warranted for two years, according to the European laws; any removal of the protection lable will void the warranty. When returning the instrument for repair, be sure to contact ElbaTech srl for the service form.

Power-up

QCMagic is powered through the connection to a +12VDC external power supply. This must be connected at the rear panel of the Base Unit.
The Base Unit must be also connected to a PC running the QCMagic software by means of a standard USB cable:

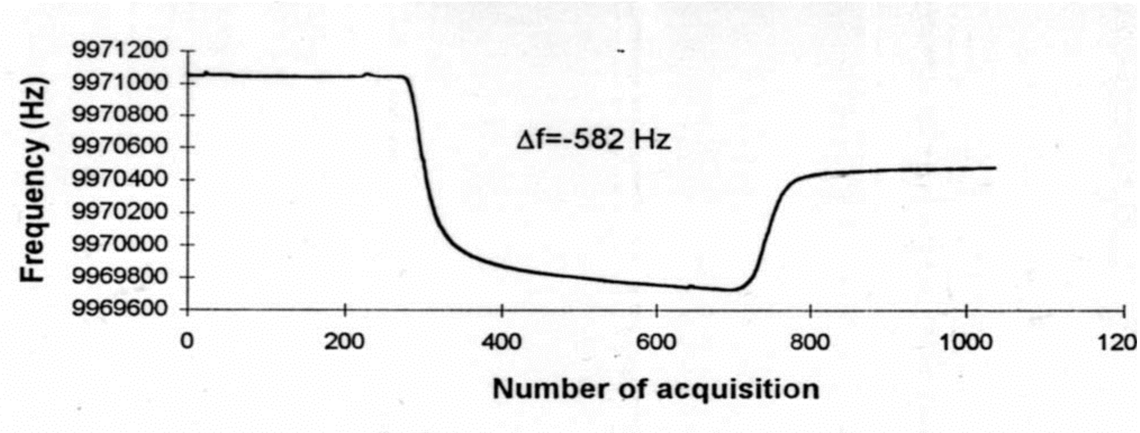
Technical description

Features	Values
Max resolution (gate dependent)	±0.05 Hz
Gate interval	0.01 to 10 s
Frequency stability	100 ppm/°C
Counter logic	32 bit
Air oscillator	TTL compatible
Liquid oscillator	TTL compatible
Interface	USB
Instrument output	Δf (proportional to electrode mass)
Biochemical output	analyte concentration
Transducer	quartz crystal AT-cut, 9.5 MHz (standard) 1 to 10 MHz (optional)
Units	1 to 4
Crystal port	standard 125 mm
Warm-up interval	25-30 min (only after first power-up to meet above stability specifications)
Software	Real time frequency data via dedicated software (windows application running Under Win 2000, XP and Vista)
Physical dimensions	Base unit: 165 x 35 x 105 mm (L x H x W) Oscillator: 115 x 35 x 65 mm (L x H x W)
Operating temperature	0° to 55°C
Power supply	External +12VDC

The instrument

QCMagic is a high precision measuring instrument featuring excellent performance in the recovery of the oscillation frequency of a working quartz crystal.
The system is interfaced to the driving PC by means of the USB port. One single Base Unit can drive up to 4 oscillator modules, thus allowing to operate with up to 4 independent quartz crystals (or with two pairs of working/reference crystals).
QCMagic can be equipped with low-volume static or flow-through reaction chambers, which house the oscillating crystal; fitting the transducer into the different type of cells is rapid and convenient.
QCMagic makes use of a precision internal reference crystal, used as a timebase comparator. Depending on the frequency of this internal timebase, each Unit can be tuned to work with a specific working crystal, choosen between 1 and 10 MHz.
The Oscillator Modules are connected to the Base Unit by means of a RJ45 cable carrying both power supply and signals. The following picture shows a typical system setup:

QCMagic is interfaced with a personal computer for data acquisition and storage. The system is driven by an extremely user-friendly software running under MS-Windows™.
It consist of a lower level kernel which implements the necessary data transfer between the computer and the unit(s), and of a high level set of routines which drive the user through an easy to perform data acquisition and analysis. In addition to the data acquisition service



routine, an useful data display has been implemented by which the user can easily retrieve the acquired signal values. Oscillating frequency versus time measurements can be performed following the data acquisition in real time on the computer screen, by means of strip chart plotting.

Getting started

To set up and use QCMagic you will need the following:

1. CD-ROM with QCMagic R3 software and related drivers
2. one QCMagic R3 Base Unit
3. one to four QCMagic Oscillator Modules
4. one or more static or flow-through measuring chambers (optional)

Installation and configuration is very easy, simply follow the procedures indicated in the next chapters. Please notice that the first step is the installation of the software drivers. Only after this step the device interfaces with the host personal computer. Next you may proceed with the QCMagic software installation.

Installation and configuration - *Step 0: system requirements*.

System requirements for the drivers and software package are:

- Personal Computer equipped with a CD- or DVD-ROM drive
- 20 Mb of free hard disk space
- 256 Mb RAM or more
- graphics adapter with 800 x 600 resolution and 256 colours or better (resolution of 1024 x 768 recommended)
- Operating systems: Win2000™, WinXP™or Vista™.

Installation and configuration - *Step 1: software drivers*.

To install the device software drivers:

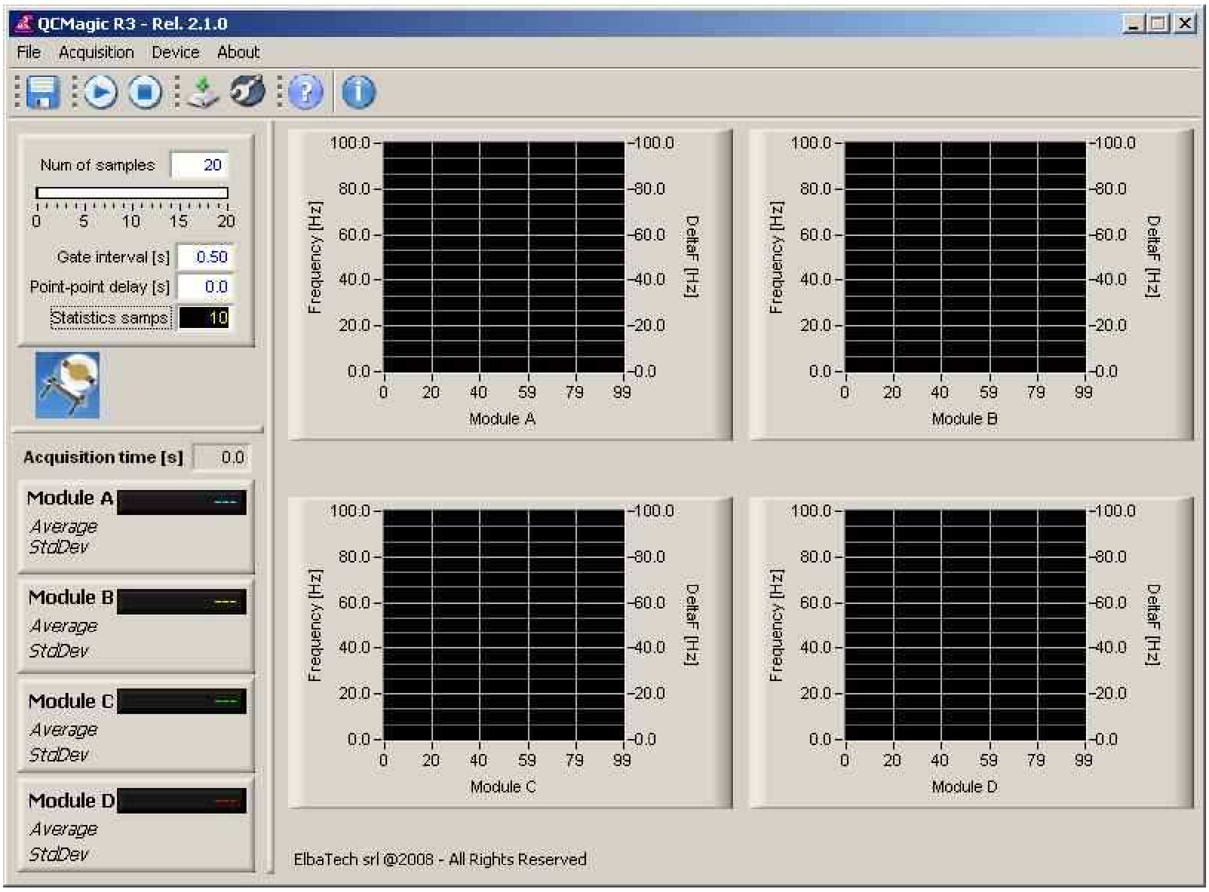
- turn on your computer and start Windows;
- insert the copy of your installation CD into the CD player;
- power the QCMagic R3 Base Unit and connect it to the computer by means of the USB cable
- when the operating system alerts to install the driver, select to specify a path manually and locate the drivers directory in the CD-ROM
- wait until Windows has finished installing the drivers and pops up a message indicating that "QCMagic R3 is installed and ready to use"

Installation and configuration - *Step 2: QCMagic application*.

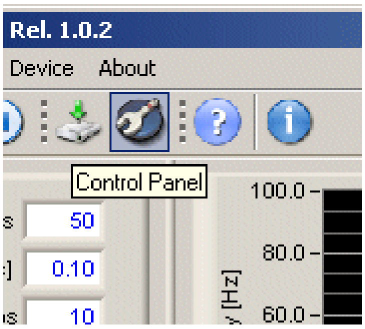
The next step is installing the application software which will manage data acquisition and plotting.
After inserting the the copy of your QCMagic R3 Application Software CD into the CD player start the installation program "Setup.exe" and follow the indications for a successful installation.

Running the application program

After program startup, the User can perform data acquisition. The system is “Plug & Play”, therefore it automatically verifies the number of oscillator units connected and organize the relative channels and digital data pathways in the electronics. This check is performed at every acquisition start.
The data acquisition panel appears as in the following picture (this example shows the case of a system equipped with four units, all connected):

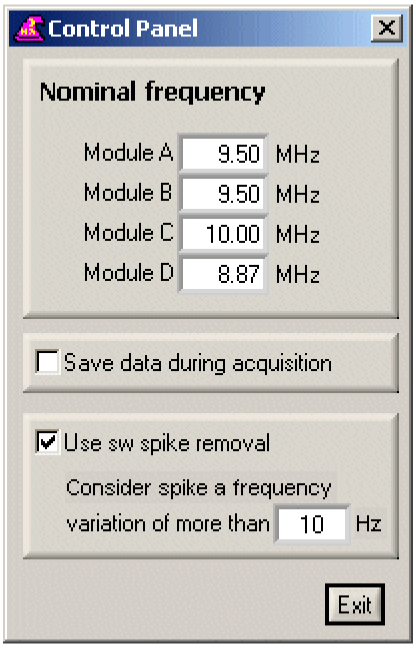


The menu is quite simple and each menu item is also available as a corresponding toolbar icon just below the menu. Holding the mouse pointer on an icon shows its meaning and function:



The icon above calls a Control Panel, by means of which it is possible to set some device parameters.
Each oscillator unit is equipped with a local time base optimized for a certain range of quartz crystal frequencies. These information are always reported on a label on the base unit of the device. You are therefore free to connect quartz crystals of different base frequencies to the

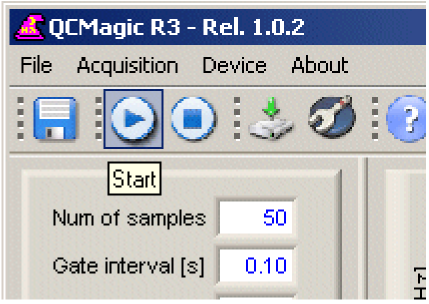
same Oscillator Unit, within a certain range specified on the label. For example, you may use crystals with base frequencies from 9.5 MHz to 10.5 MHz or so.
In order for the software to target the numeric measurements to your crystal, you are asked to set this information in the program. It will retain these values after closing the program, because they are saved automatically in the configuration file. This means that you do not have to specify these parameters as long as you use the same type of crystals at the same Module inputs. In order to set the base crystal frequencies, just click on the Control Panel label. The following window will appear, allowing to set the respective base frequencies for all Modules:



Normally the program acquires data and save them only at the end of a session, upon User's request by hitting the "save" command button. This is normally performed in order to minimize the amount of elapsed time between two consecutive data points, thus eliminating all the unnecessary overwork. The option "Save data during acquisition" allows to save data on a per-point basis, i.e. every data point is saved as soon as it is acquired. The option is useful mainly for very long acquisitions (overnight) where there is a finite probability that something in the experiment goes wrong and one wants to be sure to get all data until the system was active.
The last option, "Use sw spike removal" optimize the acquired data by means of a specific algorithm implemented in the program, which cuts away all those data points considered undesired spikes. A data point is a spkike if Fr from the previous point more than the value in Hz indicated below.

When you press the Exit button, the indicated values are taken into account and cotemporarily saved into the configuration file.
Before starting a new data acquisition session, you should indicate inside the blue numeric controls the number of data points to be acquired, namely in the field "Num of samples", and set a Gate interval in the field "Gate Interval [s]".

Once this is done you can start a new data acquisition selecting the menu item Acquisition->Start or pressing the respective icon:



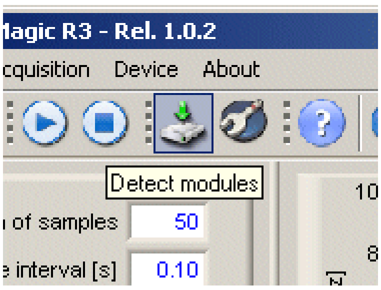
Notice that the Gate interval is the time spent during integration by the internal electronics, i.e. the counting interval. Therefore, small Gate periods increase the sampling rate but decrease the overall system resolution, while higher Gate intervals force samples to be acquired at this slower rate, but increase proportionally the final resolution.
Notice also that the the number of samples is intended “per channel”.

A slider control indicates the progress of the experiment with respect to the total number of data to be collected. This controls is continuously updated during data acquisition.

After toggling the Start/Stop button, the system performs initial steps where a check is made on the frequency oscillation. This procedure takes about 1s, then true data acquisition begins.

Some statistics on the acquired data are calculated during data acquisition. You can choose the number of samples to consider for calculating the average and the standard deviation changing the control Statistics every…. New updated values are displayed regularly, always referred to the last more recent samples.

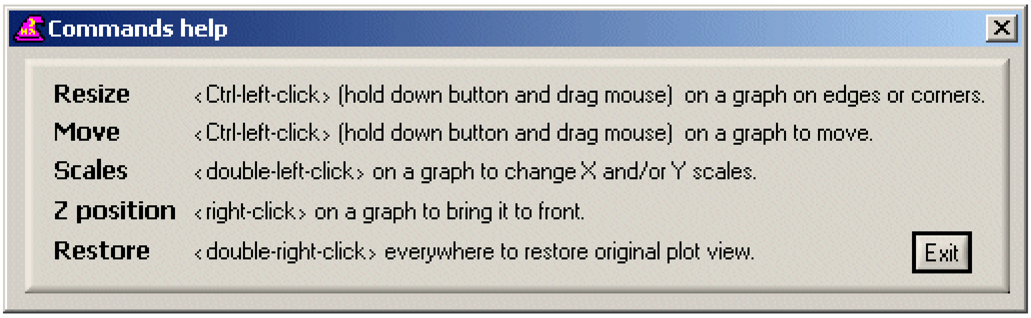
One may have the need to add/remove Oscillator Modules during experiment sessions, or change their location in the base unit. After doing this, QCMagic R3 must be informed of the changes. It detects automatically the modules simply acting on the Device->Detect Modules menu item or onto the corresponding icon:



Point-to-poiny delay is a way to deal with very long data acquisition experiments (i.e. hours). In this case a delay interval of the specified amount of time is inserted after each data point acquisition, thus allowing to widen the overall time and to collect comprehensive data with respect to the experiment timing.

Optimizing data display

As already seen, the program automatically shows a sub-window containing as many plot controls as the the actual number of Oscillator Units connected to the Base Unit. On the bottom-left side of the main panel, last data values together with statistics results are shown.
You have the possibility to customize the plot area as you prefer, by means of several simple mouse commands.
An useful help reminds these commands and is activated either hitting the <F1> key, or clicking on the View commans help label at the bottom right of the plot window.
Either method brings to the following panel:

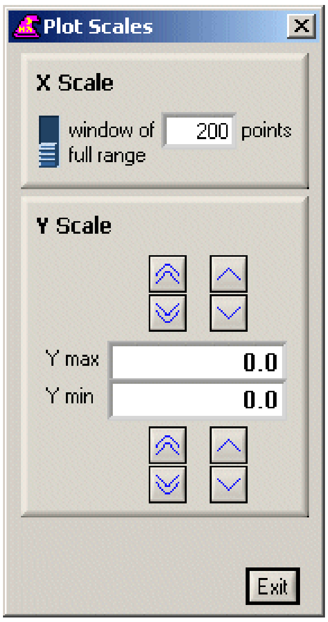


You can move, resize and change the front/back relative position of each plot, as well as restore the original view. In addition, you can change both X and Y scales of each plot, although when a new data acquisition starts, the program automatically sets the Y-axis minimum and maximum limits in order to center the plot and the X range to accommodate the desired number of samples.
Here is a summary of the available commands:

- *<Ctrl-left-click>* on a graph edge or corner and subsequent mouse motion causes the plot to resize. Resizing can occur either horizontally, vertically or diagonally (use the top-left corner in the latter case)
- *<Ctrl-left-click>* on a graph body and subsequent mouse motion causes the plot to be moved

(Notice: *<Ctrl-left-click>* is a short form to indicate “hold the <Ctrl> key pressed while clicking with the left mouse button onto a given region of a graph”).

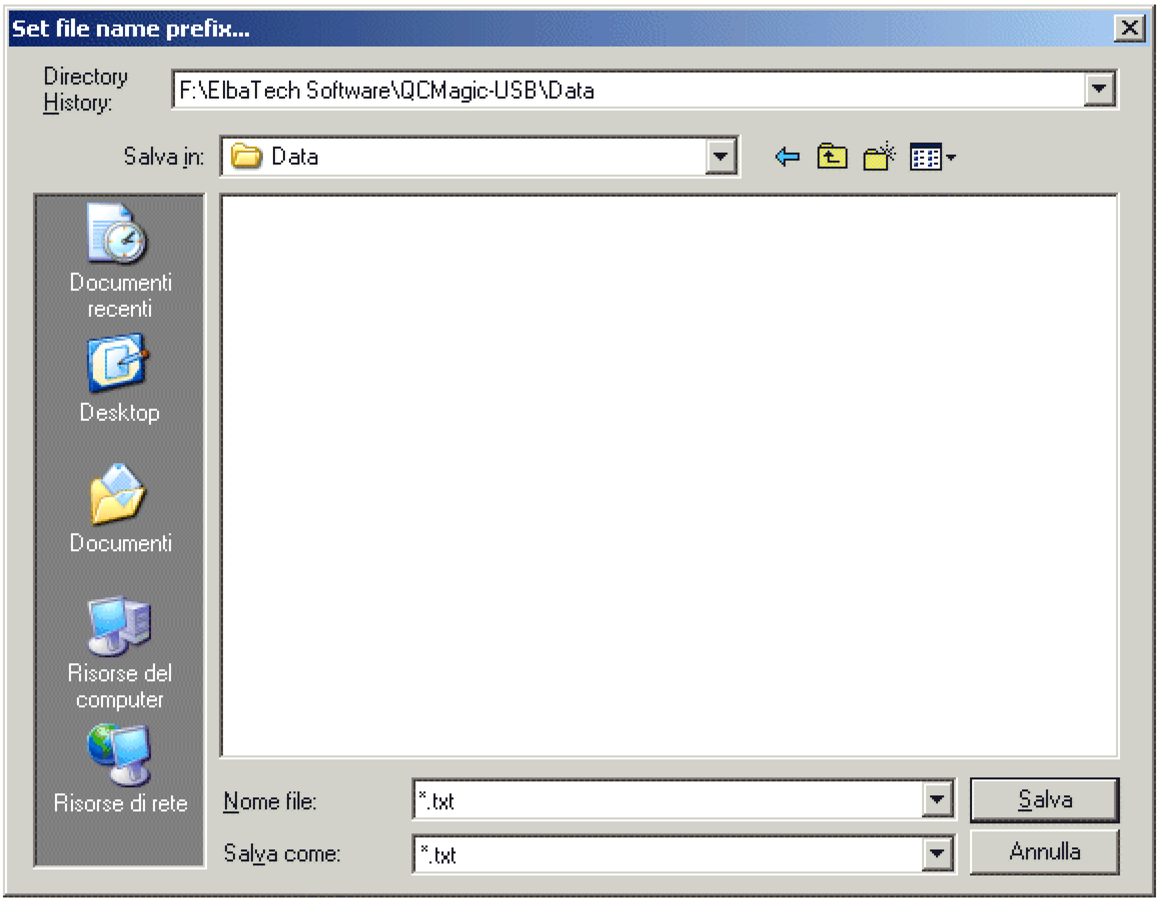
- *<right-click>* on a graph brings it to the front
- *<double-right-click>* within the window restores the original view
- *<double-left-click>* on a graph body allows to set new X, Y scales:



You can manually set new numeric values of Ymin and Ymax to magnify the plot and to shift it within the graph, thus focusing and zooming on particular regions of the data.
One easier way to achieve the same result is to use the arrow buttons respectively to enlarge and to restrict the axis scale. Double arrow buttons have agreater imnpact on scaling than single arrow buttons, which allows fine tuning of the axis.
Instead, on the X axis you can either choose to view a given number of points at a time or to set the window for the number of samples previously indicated.

Acting on the Save acquired data button allows to store the acquired data on a file on disk. The system however alerts the user in case he would exit the program without saving data, thus preventing undesired data loss.
After clicking the control, you will be asked to select a “file name prefix”. This is intended as the root of the final file name, which will be automatically completed with a suffix indicating the device to which the file is referred (this is important in the case multiple Units are connected to the system).
For example, if the indicated prefix is “myquartz” and oscillator modules A and B are connected, then the saved files containing the last acquired data will be named:

myquartz_MOD_A.txt
myquartz_MOD_B.txt



When selecting the file name, the user is free to change, select and even create a new directory where the data will be stored.

Annex A: theoretical Foundation

The QCMagic modular set-up belongs to the Quartz Crystal Microbalance-based (QCM) instruments.
QCM consists of a thin quartz disk with electrodes plated on it: it is a shear mode device in which the acoustic wave propagates in a direction perpendicular to the crystal surface.
The minimum impedance occurs when the thickness of the crystal is a multiple of a half wavelength of the acoustic wave; the resonant oscillation is achieved by including the crystal into an oscillation circuit where the electric and mechanical oscillations are near to the fundamental frequency of the crystal.
The fundamental frequency depends on the thickness of wafer, its chemical structure, its shape and its mass; oscillation frequency is influenced by thickness, density and shear modulus of the quartz and physical properties of the adjacent medium like density and viscosity of air or liquid.
As shown by Sauerbrey in 1959, changes in resonant frequency are simply related to the mass accumulated on the crystal by the following equation:

$$\Delta f = -2 \Delta m \, n \, f_0^2 \Big/ (\eta_q \rho_q)$$

where:
η_q and ρ_q are the density and the viscosity of the quartz, n is the overtone number, f_0 is the basic oscillator frequency of the quartz and Δm is the mass adsorbed on the surface per unit/area.

For an AT-cut quartz crystal $\Delta f = -2.26 \times 10^{-6} \, f_0^2 \, \Delta m$

Case I:

- **GAS phase (solid film):** ***$\Delta f \propto k \, \Delta m$***

The coupling of the crystal surface to a liquid drastically changes the frequency.
When a quartz crystal oscillates in contact with a liquid, a shear motion on the surface generates motion in the liquid near the interface. The oscillating surface generates plane-laminar flow in the liquid, which causes a decrease in the frequency, depending on the liquid density and viscosity:

$$\Delta f = f_0^{3/2} \left(\rho\eta \big/ \pi \eta_q \rho_q \right)^{1/2}$$

For a 10 MHz crystal with one face exposed to diluted solutions, near room temperature, Δf is about 2 KHz.

Case II:

- **LIQUID phase (soft or viscoelastic film): $\Delta f \propto k\ (\rho\eta)^{1/2}$**

If the liquid is flowing, major problems are: viscous damping of oscillations, medium temperature fluctuations and non-specific adsorbtions.
So, an empirical equation has been proposed:

Case III:

- **Application in FLUIDS (solution)**

Empirical equation:

$$\Delta f = a\rho^{1/2} + b\eta^{1/2} - c$$

where:
a,b and c are constants; ρ is the density and η is the viscosity of the solution.