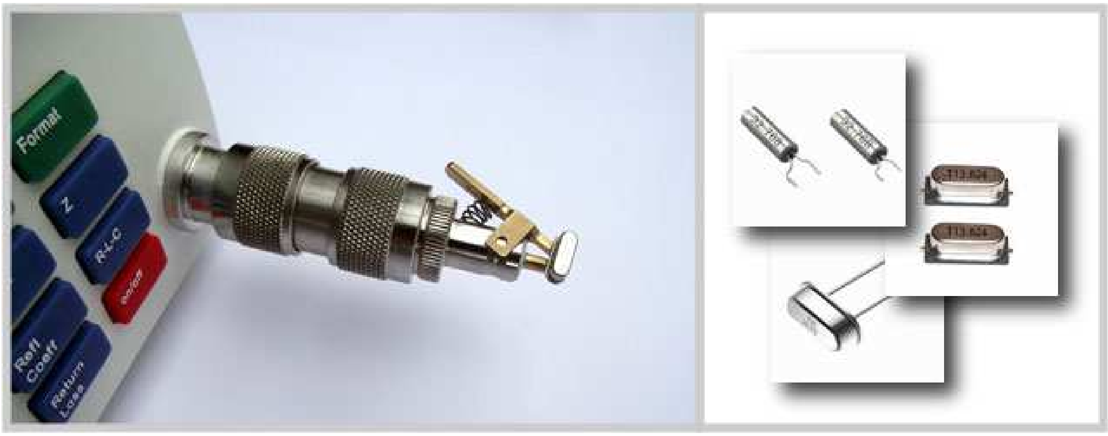
# Crystal Characterisation with the TrewMac TE3001 Analyser




The TrewMac TE3001 Analyser is an excellent tool for the measurement and characterization of quartz crystals and resonators. With 1Hz resolution, a range of display formats and a purpose built holding fixture, crystal behaviour can be explored by manual scanning, frequency sweeping, or by using the fully automated utility. This article demonstrates how to use the TE3001 and software to measure and calculate the static and motional parameters of an 8MHz quartz crystal.

**Article Contents:**

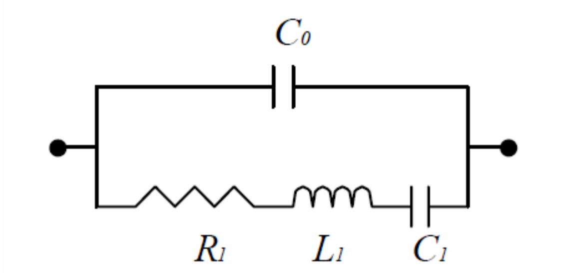
1. Quartz crystal model and behaviour
2. Calibrating the tweezer attachment
3. The automated function
4. Hints for operation

**Equipment Used:**

- An 8MHz quartz crystal
- TrewMac TE3001 Network Analyser
- TrewMac tweezer attachment

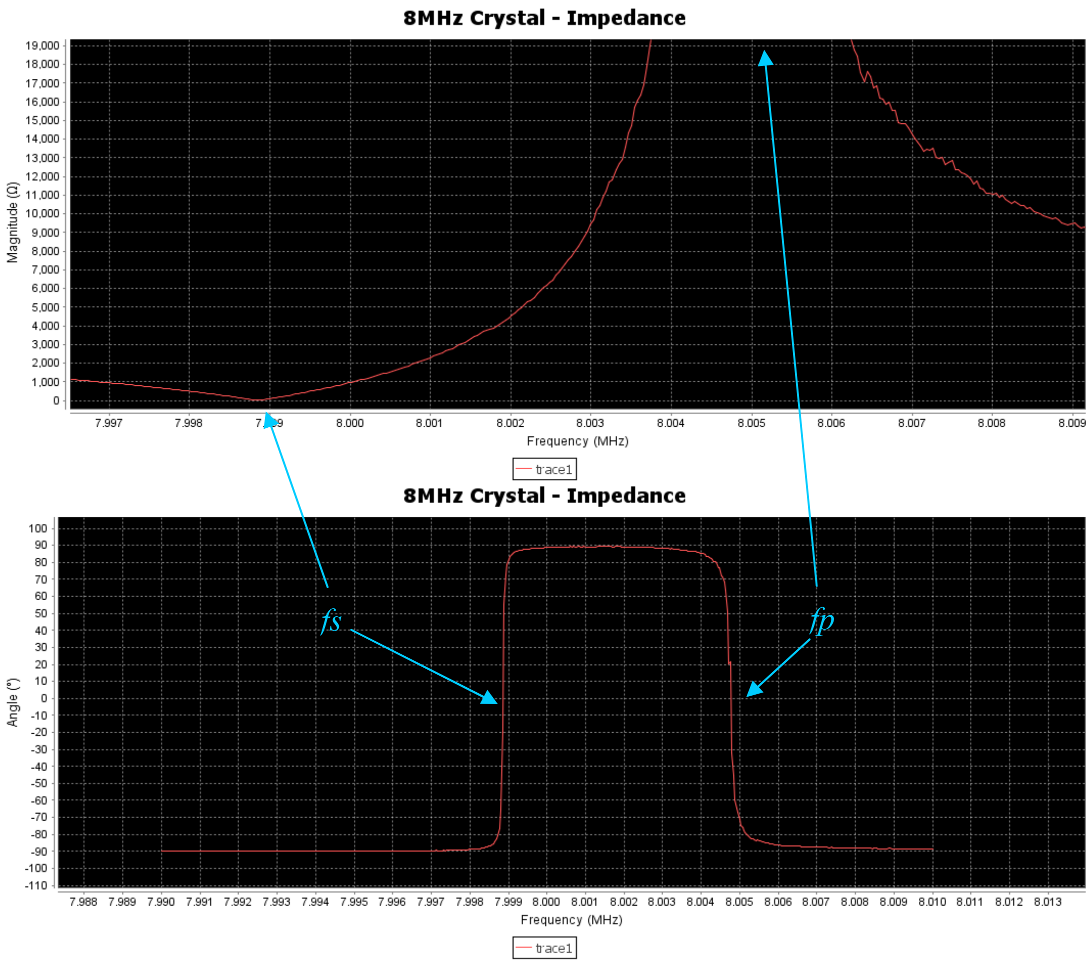
# 1. Quartz Crystal Model

The electrical behaviour of quartz crystals around their fundamental frequency can be modelled by the 4 parameter equivalent circuit shown below.




While this is only an approximate model, it is sufficient for most practical purposes. The model consists of 2 arms in parallel. The 'static arm' consists of a single capacitance *Co*. This includes the bare crystal capacitance and the packaging capacitance. The 'motional arm' consists of the series combination of $R_1$,$C_1$ and $L_1$.

An impedance sweep of the 8MHz crystal is shown below.
(taken with the equipment listed above)



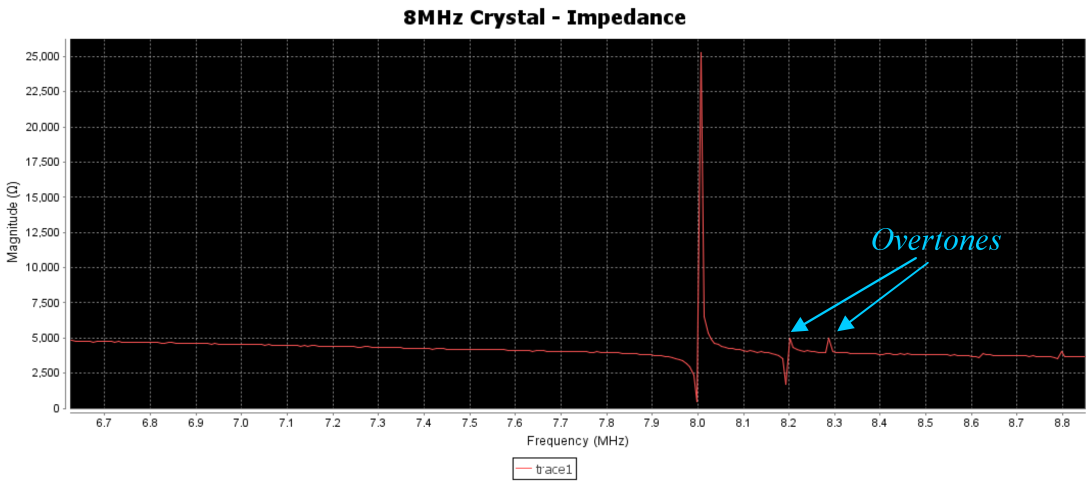
Series resonance occurs at frequency *fs* with the first change in phase and the null in magnitude.

Parallel resonance occurs at frequency *fp* with the second change in phase and the peak in magnitude.

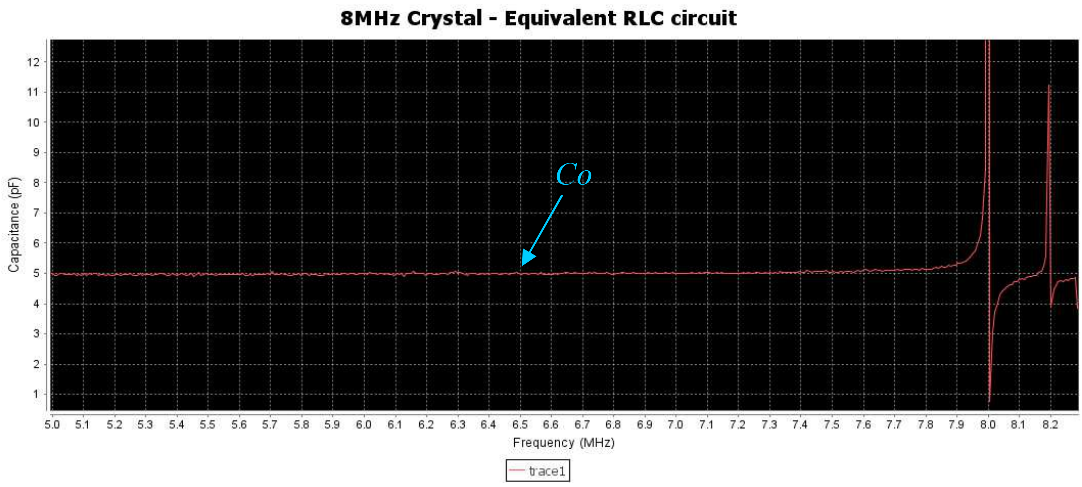
Between *fs* and *fp* is called the 'inductive region' because phase is positive.

Below *fs* the crystal is nearly pure capacitance due to *Co*.

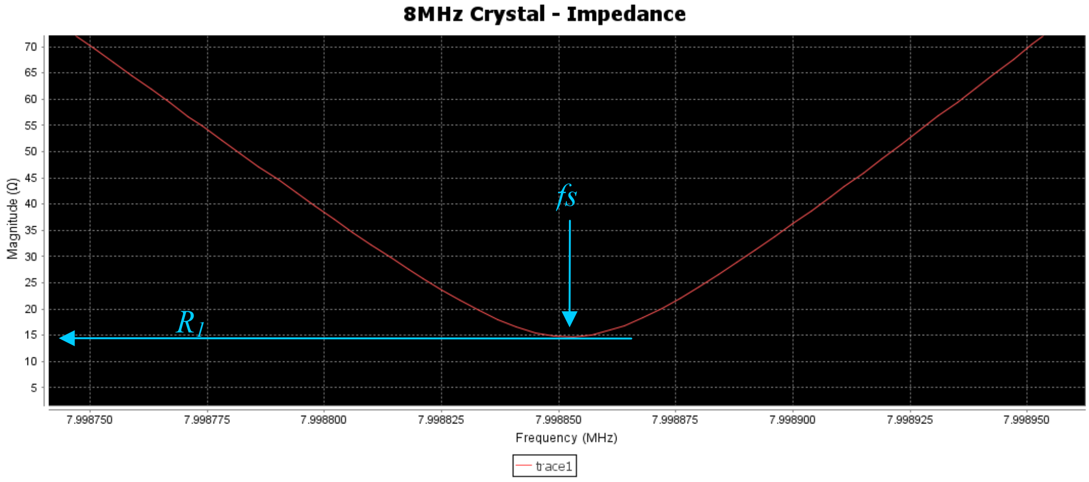
Above fp harmonic overtones can be seen.




Below fs the crystal is dominated by *Co*. If we change the format to equivalent parallel RLC we can see that for this crystal *Co*=5pF.



At *fs*, the reactance of $C_1$ and $L_1$ cancel, leaving only $R_1$. (Co has almost no effect)
Hence $R_1$ can be taken directly as the magnitude of impedance at *fs*.




$C_1$ and $L_1$ are more difficult to obtain by measurement, but can be calculated as:

$$C_1 = 2C_0\left(\frac{fp}{fs} - 1\right) \qquad L_1 = \frac{1}{4C_1\pi^2 fs^2}$$

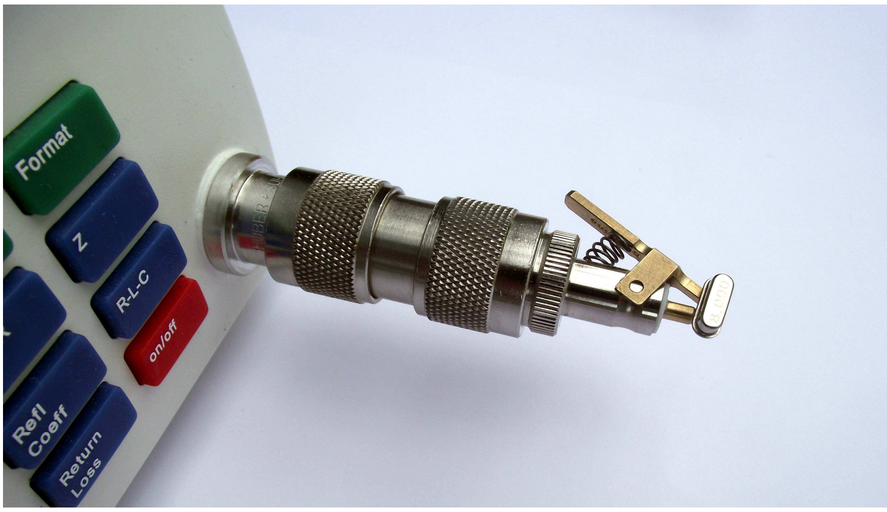
Other parameters for crystal characterisation include quality factor Q, figure of merit M and capacitance ratio r. These can be calculated as:

$$Q = \frac{1}{2\pi fsR_1C_1} \qquad M = \frac{1}{2\pi fsR_1C_0} \qquad r = \frac{C_0}{C_1}$$

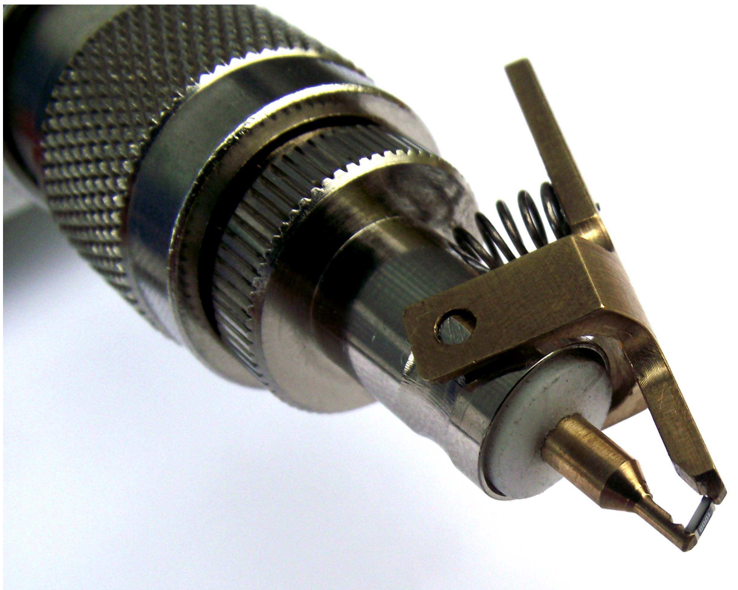
# 2. Calibrating the tweezer attachment.

The tweezer attachment is the easiest way to hold and measure a regular quartz crystal. Before accurate measurements can be obtained, the effect of this fixture must be calibrated out. This is easily achieved using the custom cal routine.

**Step 1**
Connect the tweezer attachment using as short a cable as practical. (any length of cable between the analyser and the point of measure introduces errors that can not be completely removed by even the best calibration equipment!)




**Step 2**
Press ‘System Zo’ and select ‘Calibration’ from the menu. Select CUSTOM as the type, SMD as the kit and I used 0.3 and 100 MHz as the start and stop values.

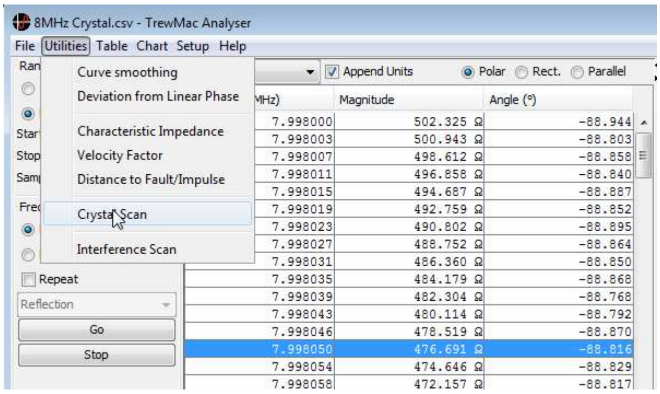


**Step 3**
Select ‘Perform Cal’. You are prompted to measure the SMD calibration standards one at a time with the tweezers. When finished select ‘Done’.

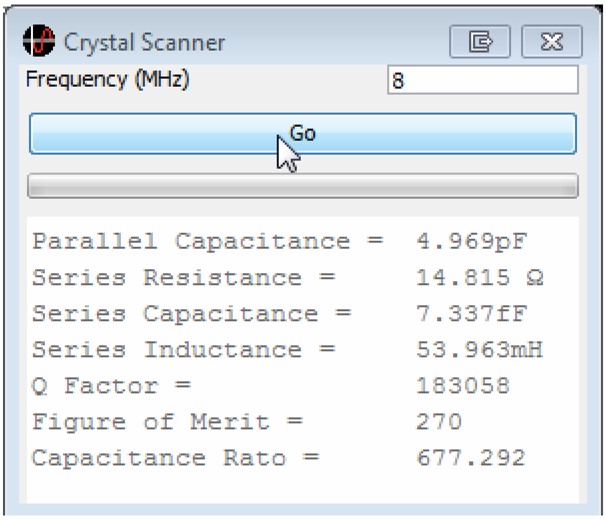
Now you are ready to measure!

## 3. Using the automated function

Select ‘Crystal Characterisation’ from the utilities menu.



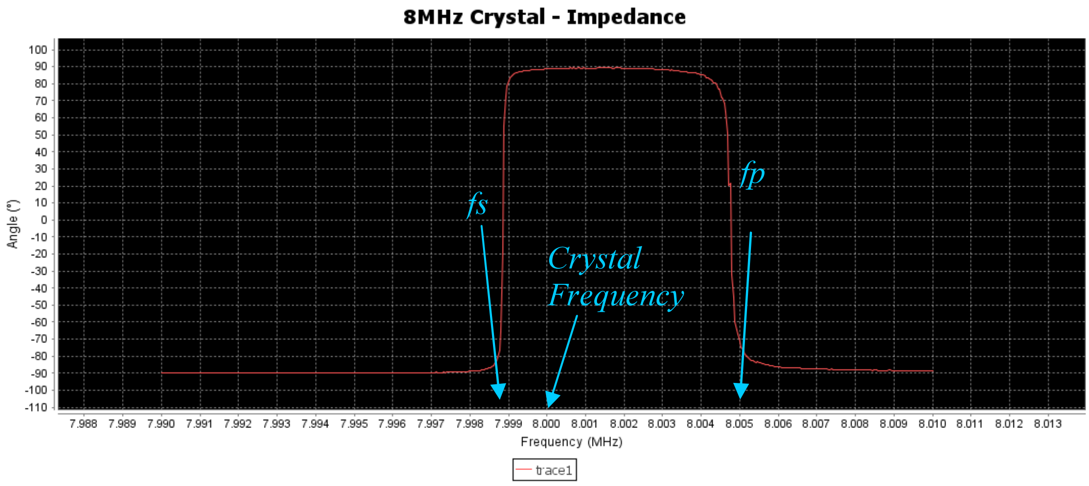

Enter the fundamental frequency of the crystal and press go!



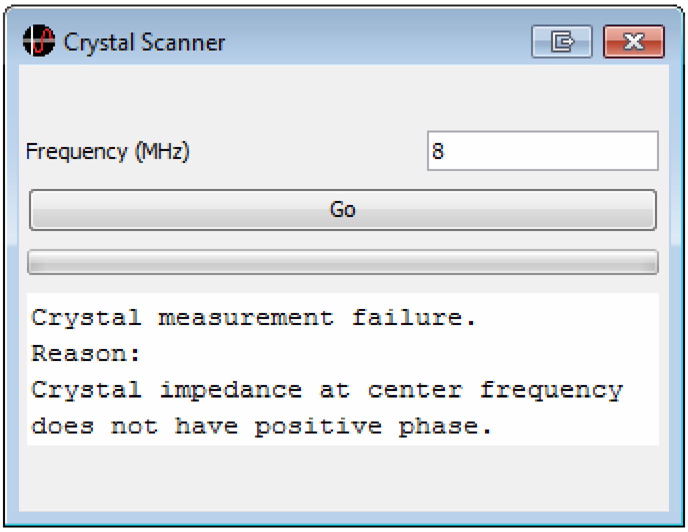

All the parameters are measured and calculated for you.
These values are also copied to the clipboard to paste into a document.
So easy!

# 4. Hints for operation

The crystal characterisation utility expects the crystal frequency entered by the user to be located between fs and fp in the inductive zone. See the diagram below:




If the crystal frequency entered by the user does not return positive phase, the utility displays a warning that it cannot proceed as it has not started in the inductive region.




In this case, try a frequency sweep from 1% below to 1% above the specified crystal frequency. Use the polar impedance chart. Look for the region where phase is positive and choose a new crystal frequency in that region.