Technical Note

Guide to PSM17xx/3750 + IAI Compensation

This document was originally written before the introduction of the PSM3750, this issue uses the term PSM to stand for any of the PSM1700/PSM1735 and PSM3750 instruments and applicable to all. However, all the illustrations are showing a PSM1735 & IAI. Similarly, IAI refers both to the IAI and the IAI2.
Within the document "***PSM17xx + IAI Operating Guide***", the connection and basic operation of PSM1700 or PSM1735 instruments when used in conjunction with the Impedance Analysis Interface is described.

Here, we discuss in more detail the subject of compensation and the importance of this process when making precision impedance analysis.

Why is compensation required?

While it is natural for engineers to recognise the importance of making a good electrical connection when measuring the impedance of a component, it is quite common to underestimate the impact that impedance of the connection system itself may have on the total measurement.

Many high-performance impedance measurement instruments (including the PSM + IAI) reduce the effect of cable impedance by using 4 wire Kelvin connections. Here, two sets of leads are used to connect to the component under test and this enables measurement of the voltage drop across the component under test to be made directly, without including the additional voltage associated with current flowing through impedance of the power leads. However, it must be remembered that while this technique offers an effective solution to DC measurement errors, any phase shift associated with the reactive impedance of the connection leads is not accounted for using this technique.

While the value of parasitic impedance associated with connection leads may often be small relative to a component being tested, connection leads that may be thought to have negligible impact on measurements (for example coaxial Kelvin leads) can in easily introduce significant errors. This effect is particularly evident when measurements are made over a wide frequency range because it is much more likely that tests will be made at a frequency where the parasitic impedance of connection cables becomes a large proportion or sometimes even a greater absolute value than the impedance being measured.

What is the principal of compensation?

Compensation is a process of measuring and recording the impedance of connection cables when no test component is in place so that this value of 'connection cable impedance error' can be removed or 'offset' from the total measured value when a component is being measured with the same cables.

The maximum errors associated with the impedance of connection cables are usually associated with particularly high or low impedance measurements. For example, inductance measurements at low frequency where the sample impedance will be low relative to the cables or capacitor measurements at low frequency where the high sample impedance will be influenced by cable capacitance.

For this reason, 'short circuit' compensation will usually be of greatest importance when measuring inductive components while 'open circuit' compensation is usually of greatest importance when measuring capacitive components. While this can be used as a general rule, the wide range of impedance that can be expected when testing a reactive component over a wide frequency range is such that ‘Short Circuit’ AND ‘Open Circuit’ compensation should be implemented when a wide frequency sweep measurement is made.

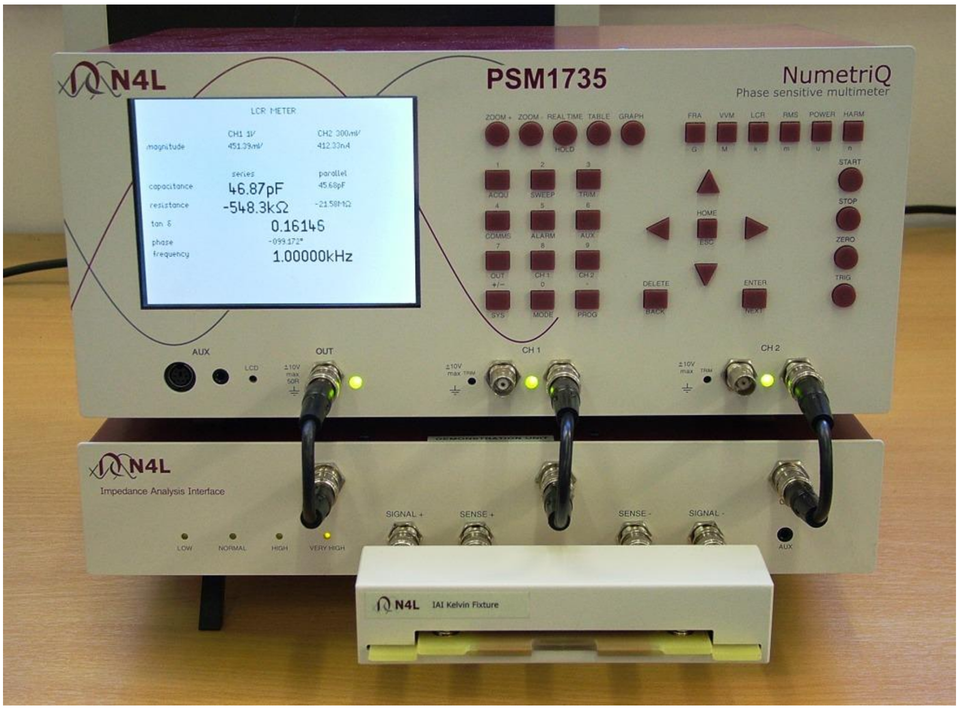
Applying single frequency compensation on the PSM

The following pictures and supporting text illustrate typical measurements without compensation and the process of using the LCR Compensation function to overcome influence of a connection fixture.

Here, a PSM1735 + IAI and Kelvin Fixture are making an LCR measurement with default generator settings, no component in place and no compensation.

The relatively large capacitance shown is caused by two things:

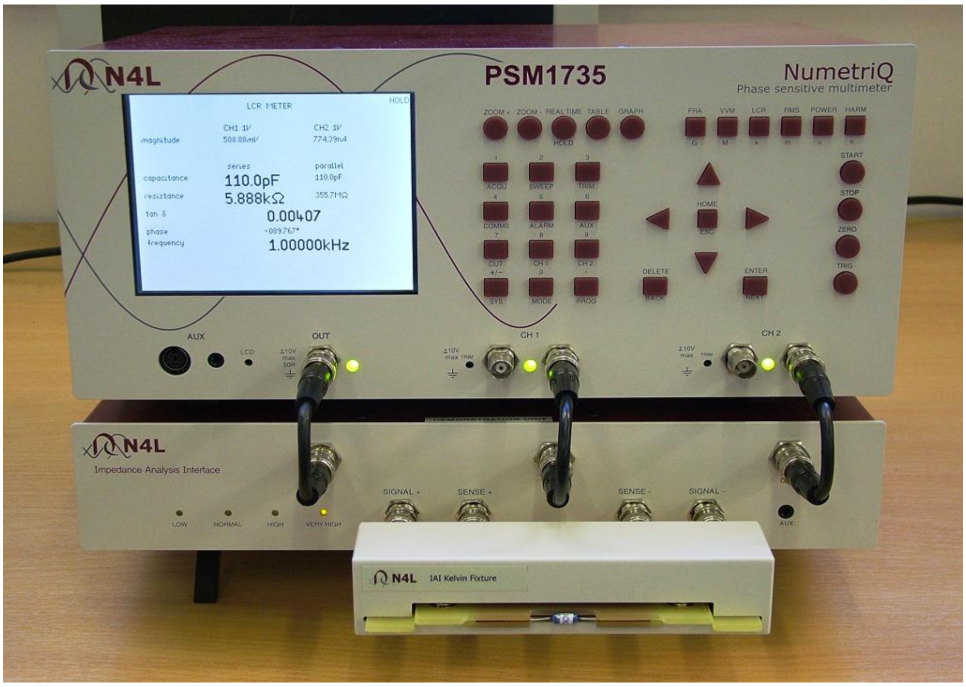
1. A poor Kelvin connection due to no component being in place
2. No compensation



Here, a 100pF capacitor is placed in the IAI Kelvin Fixture. No compensation has been applied.

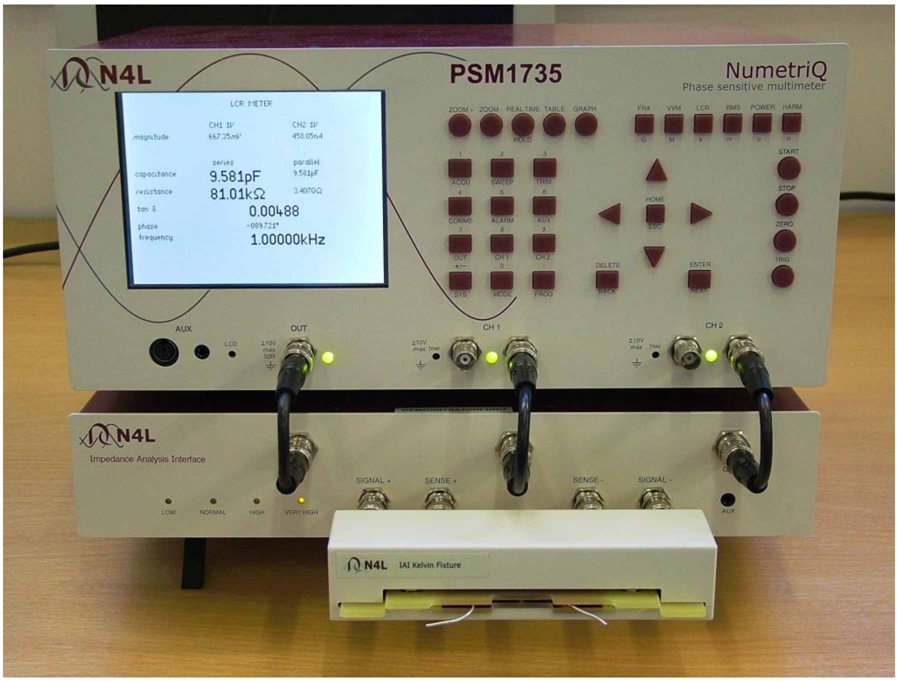
It can be seen that the measurement is 10pF too high giving a measured value of 110pF.

At this point, we do not know if the 10pF error is due to fixture impedance or measurement error.



Here, two pieces of single core wire are placed into the Kelvin fixture, one to each side of the fixture so that a good connection between the power and sense Kelvin pairs is achieved.

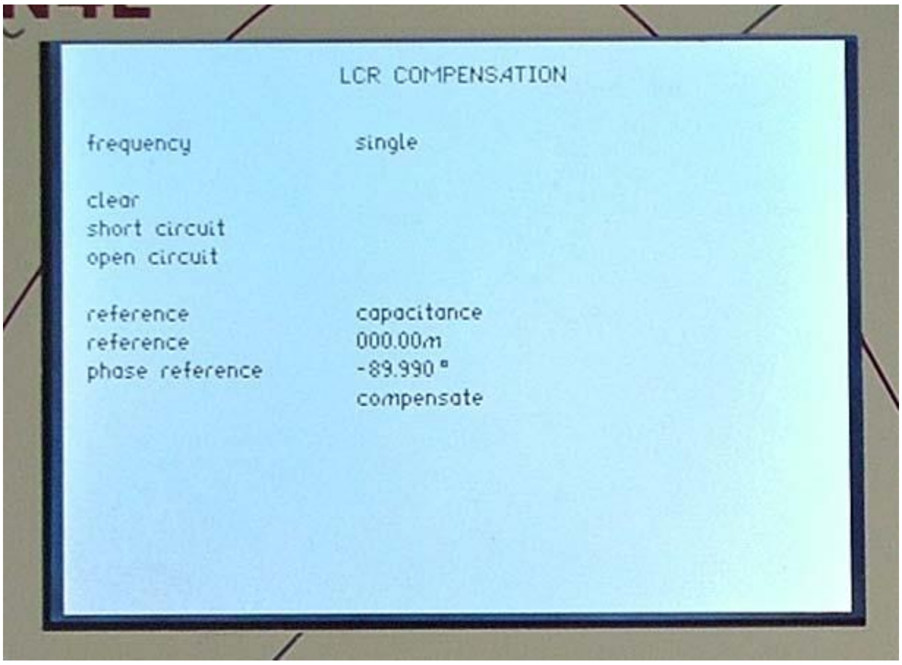
Now the Open Circuit measurement error can be seen, and it is this value that should be removed from the total measurement to obtain the true component value.



Now, pressing the 'ZERO' button on the PSM will open the Compensation menu as shown here.

The first line shows frequency > single, illustrating that compensation will be made at a single frequency. This will be the frequency that is presently selected in the output menu and in this case, it is the default 1kHz.

Using the navigation arrow keys, the frequency option can be changed to 'sweep' but we will discuss this later.



As we presently want to measure capacitance at a relatively low frequency, it should only be necessary to implement 'open circuit' compensation, therefore this is selected using the navigation arrow keys and when a flashing cursor is around the 'open circuit' option, the ENTER button is pressed on the PSM front panel to activate the open circuit compensation process. At this point, the PSM will step through each of the four shunts within the IAI and open circuit compensation will be applied.

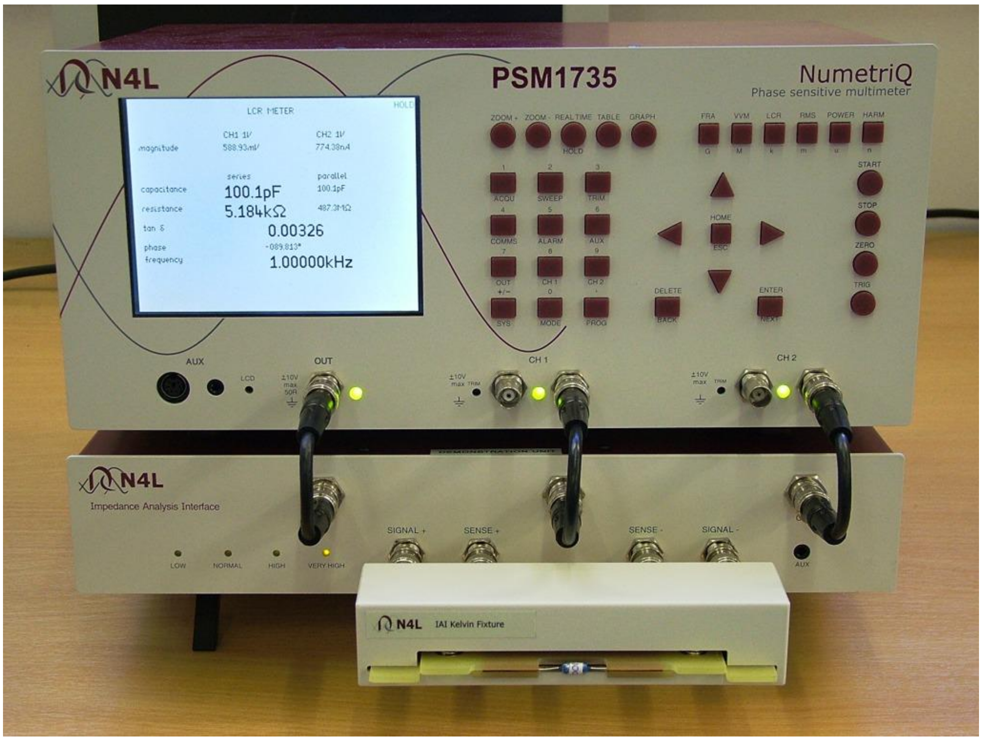
NOTE: For open and short circuit compensation, ENTER is used as above NOT the compensate option that is associated with 'reference' and 'phase reference' options. This will be discussed later.

After compensation, the PSM display will return to the LCR Meter mode and the two pieces of wire that were used for the open circuit compensation can be removed from the IAI Kelvin Fixture.

At this point, it is possible that the PSM is automatically switching between shunt ranges and this is due to low measurements after compensation that are detected by the ‘low blanking function’. Should this occur, simply switch off the low blanking function in the SYS menu.

Here, the 100pF capacitor is placed in the IAI Kelvin Fixture and it can be seen that the open circuit compensation has removed the 10pF open circuit error resulting in the correct measurement.

As this compensation has offset the fixture error, other capacitive components will also be measured correctly.



When measuring components that exhibit low impedance, for example inductors at low frequency or capacitors at high frequency, it will also be necessary to apply short circuit compensation.

The short circuit compensation using a similar process open circuit described above but this time, a single piece of wire should be fitted to the IAI Kelvin Fixture as shown here to ensure that connection between each power and sense Kevin pair is good and also that there is a good short circuit between negative and positive Kelvin connections.

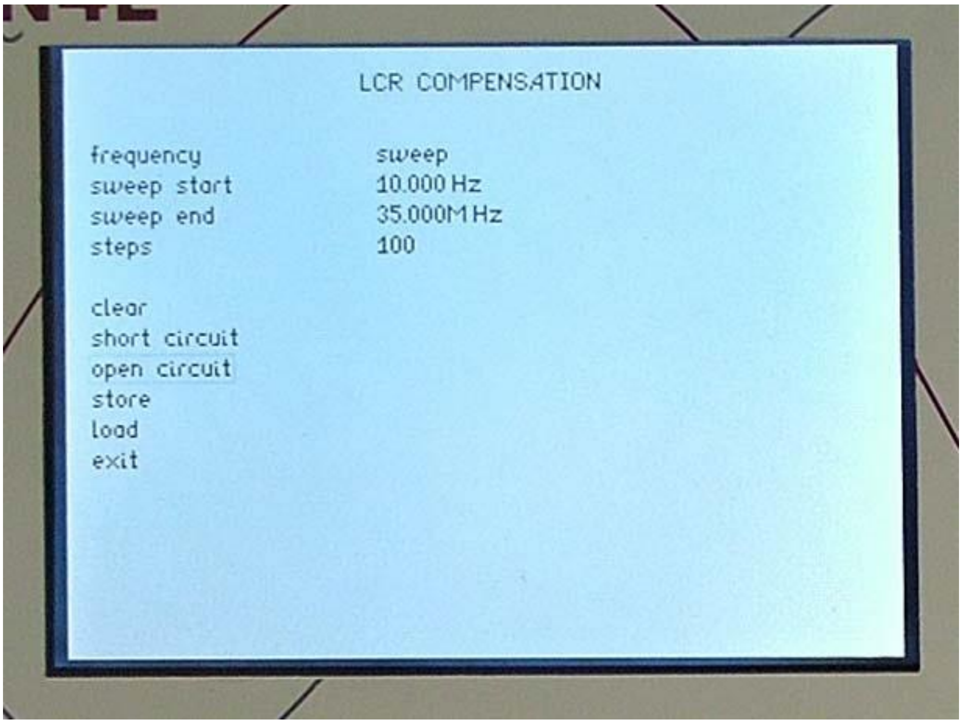
The short circuit link should be short as shown here to ensure that unnecessary inductive impedance is not included at high frequency.

In this case, the short circuit option is selected with the flashing cursor in the compensation menu before pressing the ENTER key to start compensation.

Applying sweep compensation on the PSM

As the PSM range provide the benefit of frequency sweep functions for all measurement modes, it is common to use the instruments to test components over a range of frequencies. In this case, the issues discussed above in relation single frequency compensation now apply to the complete frequency range over which measurements will be made.

Here, the ZERO key has been pressed on the PSM front panel to present the LCR Compensation screen and then by using the navigation keys, the frequency option has been changed form 'single' to 'sweep'.



Here it can be seen that 'sweep start', 'sweep end' and 'step' options are presented. As would be expected, sweep compensation covers a frequency range that is at least equal to the range of measurement frequencies that will be required.

The default number of steps is 32 and the maximum number is 100 steps. By selecting the number of steps, a user has control over the total time required for compensation and the accuracy of compensation throughout a sweep. While interpolation between frequency steps is applied so that the frequency steps within compensation do not have to correlate with the number of steps in a measurement sweep, superior compensation over a frequency sweep range will be achieved when using more steps, especially if a very wide frequency range is being used.

Store

When using single frequency compensation, there is no store function since the compensation of a single frequency is fast. However, sweep compensation can be quite consuming, especially when many steps are selected and for this reason, a store function is provided. The store function should be selected only when the complete compensation has been completed, i.e. if both short circuit and open circuit compensation is applied, the 'store' function should be used when both processes have been completed. A new sweep compensation can be made at any time without effecting the stored compensation but only one sweep store is provided, therefore pressing 'store' after a new compensation has been made will overwrite the previous compensation.

Load

The load function will re-load the stored compensation. As the sweep compensation memory is non-volatile, the stored compensation can be loaded at any time. If no sweep compensation is present in the memory, the 'load' option will not appear.
To ensure that users do not switch on the instrument and inadvertently make measurement with inappropriate compensation, the default power on condition is with no compensation applied. If therefore a user wishes to apply the stored sweep compensation, they should enter the sweep compensation menu and 'load' the compensation. The applied compensation will remain active while the unit remains powered on or until clear function is selected.

Open and short circuit connections

The basic process for open and short circuit sweep compensation is comparable with that of the single frequency mode, therefore it is not necessary to repeat the associated fixturing information. However, it worth noting that when testing over a wide frequency range, particular care should be taken regarding fixture consistency. Should flying leads be used for connection, it is essential that there is minimal physical movement between compensation and measurement stages. This is especially true of measurements above 1MHz where the parasitic capacitance of measurement leads is influenced significantly by movement of cables. It is for this reason that the short Kelvin leads are supplied with the IAI as standard and why the IAI Kelvin fixture is recommended when measurements over a wide frequency range are required.

Clear

The 'clear' function will remove any presently applied compensation such that measurement is made in the non-compensation state. However, this will not delete the stored compensation memory and therefore the clear function can be used to make a quick comparison between compensated and non compensated measurements.

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General LCR measurement advice

- To avoid unwanted zero value measurements or nuisance range changes on low value measurements, set the 'low blanking' option under the SYS menu to 'off'

- When making measurements over a frequency range that may result in component resonance, or when measuring components with a very high tan delta, set the 'parameter' option under the LCR menu to 'impedance'. This will avoid the problem of zero measurements should a specified reactive component go over the expected phase quadrant for that type of reactance (for example, a high tan delta capacitor with a measured phase angle of 90.1 degrees due to a small phase shift would be presented as zero farads when the capacitance mode is selected). Unlike the inductance or capacitance modes, 'impedance' will not limit the phase angle presentation to the expected quadrant for that component. Irrespective of function set in the parameter menu, the PSM will record all impedance values during a sweep. Therefore, after making a measurement sweep in the impedance mode, changing the parameter to a specified reactance e.g. capacitance will show that value from the same measurement data but with no zero applied. Also, when using PSMcomm2 software, the data for all impedance parameters will be included in measurement results.

- To avoid a step seen in a measurement sweep due to a range change, set the 'conditions' option in the LCR menu to 'manual' and then select the shunt under the AUX menu such that the chosen shunt is closest to the expected impedance at the most critical point of sweep.

- Where possible, use the IAI Kelvin Fixture to avoid the variability that is associated with flying leads.

- Reference and Phase Reference options shown in the single frequency compensation menu are intended for use when making measurements against a known reference (or what is sometimes called a golden sample) component. Here, a specified reactance value or specific phase angle associated with a component presently connected to the instrument is defined by the user followed by ENTER. The PSM will then apply the necessary compensation to achieve the specified values. In this way, subsequent components can be measured relative to the golden 'reference' sample. This function is only available in single frequency mode and should be used when open or short circuit compensation is used.

- While single or sweep frequency compensation is not applied at power on, all other instrument settings can be stored into non-volatile memory buy using the program store function. 99 configurations can be stored and referenced by number and name.

- Program memory number '1' is always loaded at power on. If memory '1' remains empty, the factory default settings will be loaded at power on. However, by storing any instrument configuration into memory '1', this configuration will automatically be loaded at power on.