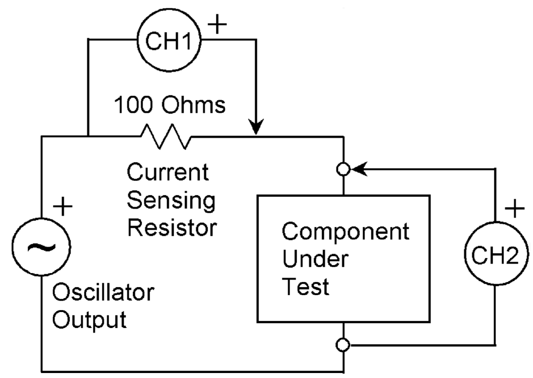
# Measurement of the Impedance of Components versus Frequency

There are two ways to measure impedance of components. We offer an RLC measurement package that has a test fixture and a special menu to correct for measurement fixture parasitics after the component measurement is complete. This is the first and easiest way to measure the impedance of components.

The second way, the method described here, does not require any additional hardware or software except a single resistor. Although, you can use our RLC text fixture if you have one. It has the same connections as shown in the figure below. The ability to measure and display impedance is a built-in feature of the Venable software package. This includes the ability to measure parasitics of test fixtures. The Do Math on Data window can be used to correct for test fixture parasitics. This procedure is not difficult but it is not automatic the way it is in the RLC measurement menu.

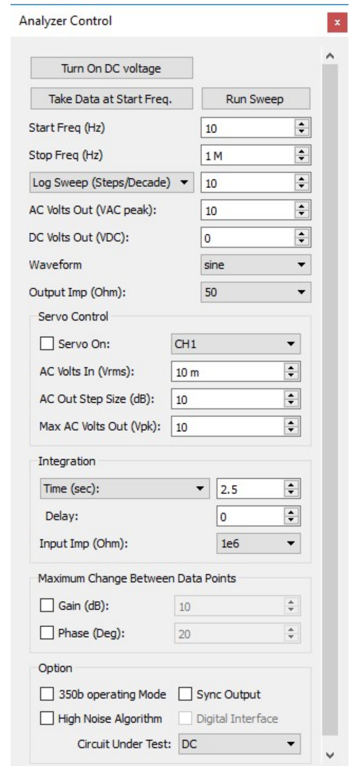
Impedance is voltage divided by current. We use the oscillator output of the FRA as a signal source. We connect the oscillator to the component under test, usually through a series resistor. You can measure the current with a current probe, but it is usually easier to take advantage of the floating inputs of the analyzers (except the 43xx) and measure current by measuring the voltage across the resistor in series with the component under test. For the 43xx, you can use a differential amp or an analyzer with floating inputs to measure current by measuring the voltage across the resistor in series with the component under test. There is about 200 pF of stray capacitance from return to chassis and about 50 pF of capacitance from input to return of the analyzer inputs. For this reason, we usually connect the current measuring channel (CH1) “backward”, so the return is connected to the oscillator output as shown in the figure. This minimizes the parasitic capacitance across the component under test.



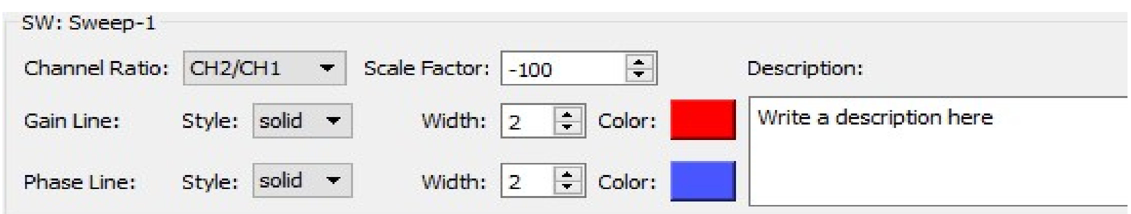

Let’s measure the impedance versus frequency of an electrolytic capacitor as an example. The first thing to do is find a good resistor to sense the current. It should be non-inductive, such as a film resistor. The value is not critical but a value around 100 ohms will give a good balance between the impedance being tested and the open circuit and short circuit parasitic impedances. Although the particular value is not critical, it *is* important to know the absolute value of the current measuring resistor. You should measure the value with a good ohmmeter before you start or use a resistor with a tight tolerance.

Connect the oscillator output, channel 1 input, and channel 2 input as shown in the figure above or connect the RLC test fixture to the analyzer. Open the Venable System software and adjust the settings to match the sample screen on the previous page the Analyzer Control window. . We used the maximum output voltage (10 V peak for

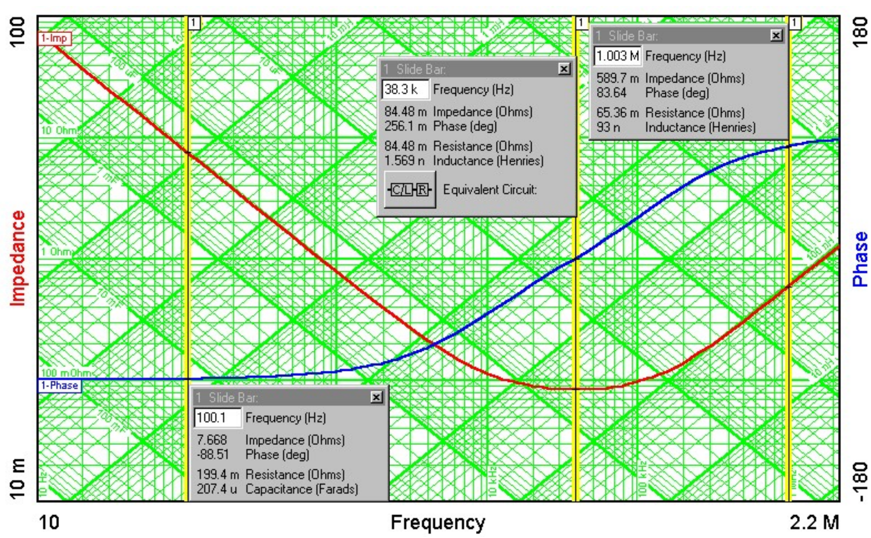
Venable models) to get the best accuracy and Medium integration time for the best speed (2.5 sec for 63xx). Before starting the sweep, make sure the graph screen displayed is a blank impedance plot. You can open a new one when you click the File-New and then click on Impedance and Phase plot. Then, after adjusting the Analyzer Control settings, click the “Take Data at Start Freq.” button. When the analyzer has taken a few data points, click the “Run Sweep” button.




At the bottom of the plot is a sub-window displaying the Channel Ratio and Scale Factor. You can only change this setting if data has already been plotted on the graph or after the sweep has started. If you made the same connections as the test setup schematic on the previous page or are using the RLC test fixture, the Channel Ratio will be CH2/CH1 (the default value), but the Scale Factor has to be changed to match the value of the current sensing resistor. In this case, with the current measuring channel connected “backward”, the polarity of CH1 will be “backward” also. You correct this by entering the current sense resistor value as negative. If you used 100 ohms to measure the current, enter the Scale Factor as –100 in the Data Set Properties sub-window as shown above. If you are using a current probe, the Scale Factor is the Volts/Division divided by the Amps/Division of the current probe amplifier.




The graph does not automatically auto-scale. When the sweep is complete, you can change the scale manually by left-clicking or right clicking and dragging the mouse on any axis of the graph to get the desired minimum and maximum values. In the example shown, we were testing an aluminum electrolytic capacitor with a rated

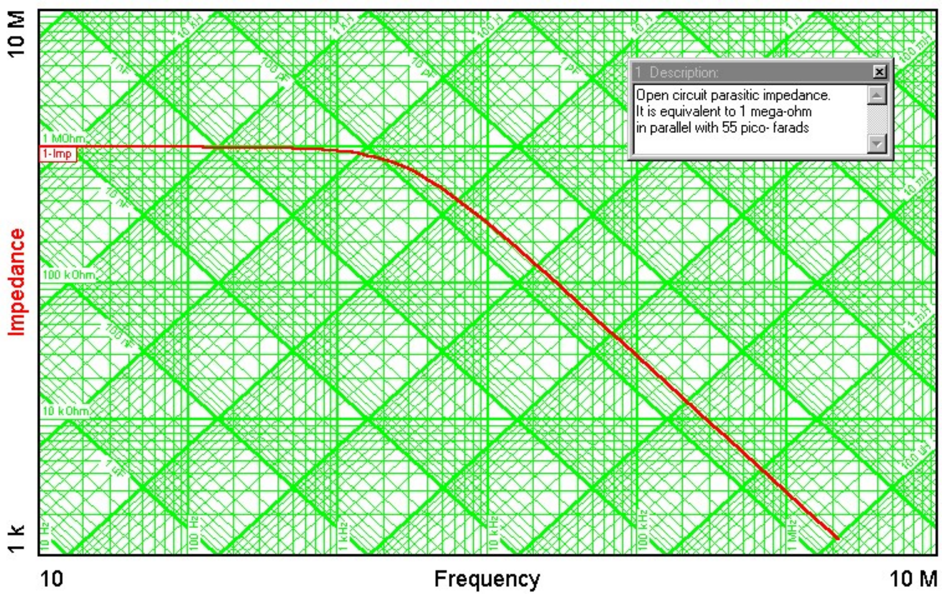


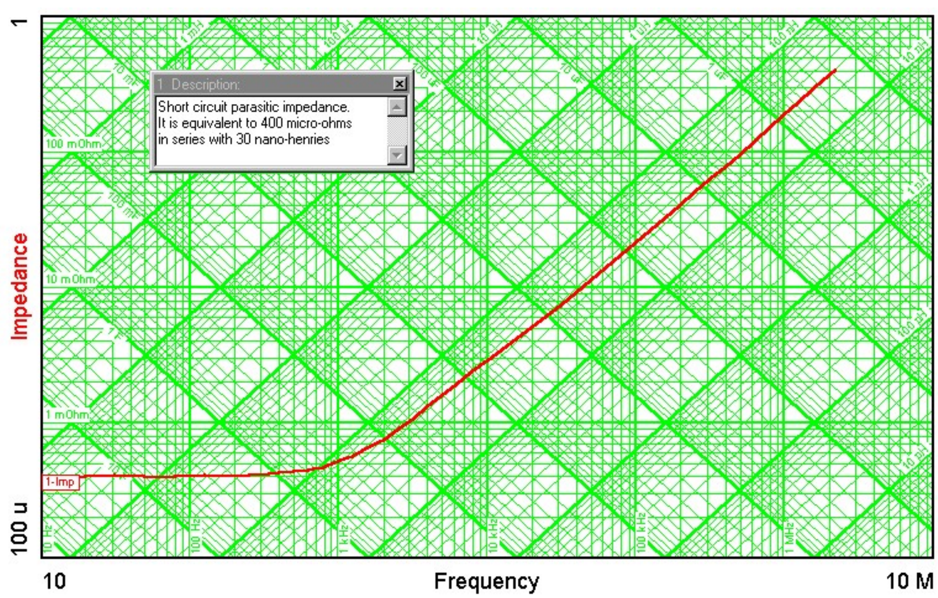

05/24/18

voltage of 35 VDC and a nominal capacitance value of 200 μF.  We added slide bars to show the capacitance at 100 Hz (207.4 μF), the ESR when it is purely resistive (84.48 milliohms), and the inductance at 1 MHz (93 nH).

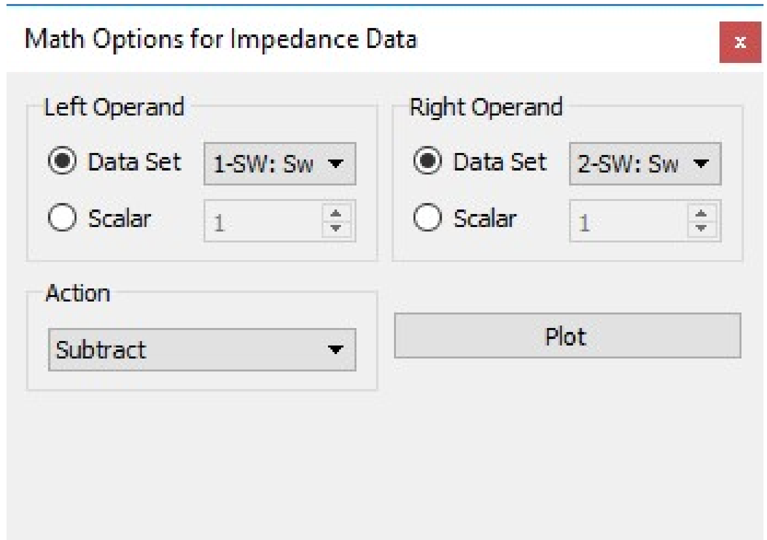
The only problem with the graph on the preceding page is that the parasitics of the test setup are not taken into account and may be significant at low or high impedance levels. To check on this, let’s measure the parasitics.  To do this, simply make the same measurement as before, except do it with the Component Under Test being first an open circuit and then a short circuit.  Here are the results of those two measurements.

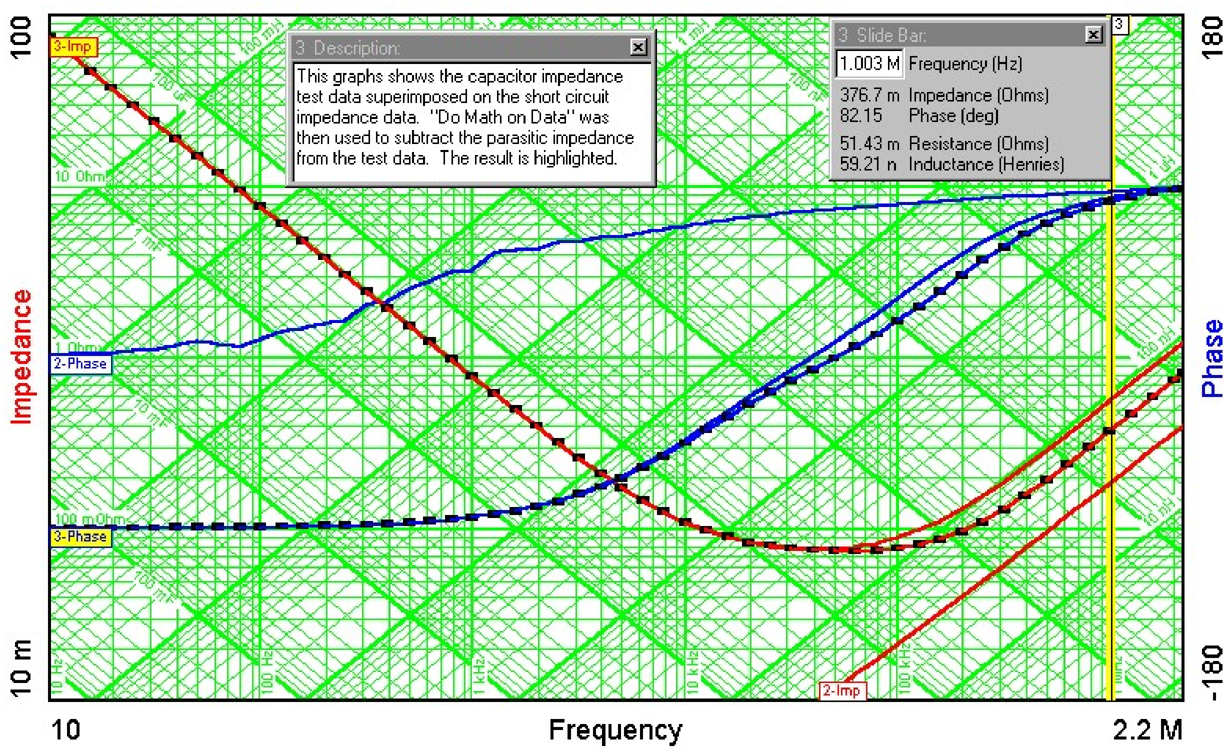
For clarity, the plot type below is impedance only.



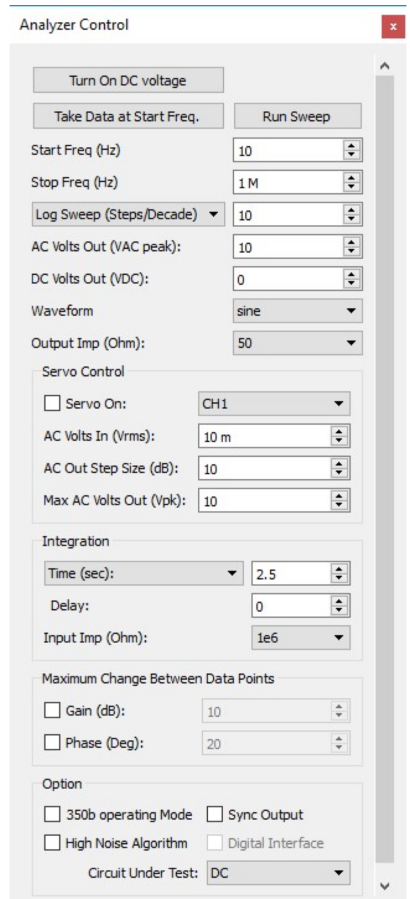



The graph below shows the result of using “Math Options for Impedance Data” to subtract the parasitic short circuit impedance from the capacitor impedance test data. The impedance is too far below the open circuit impedance to require compensation for open circuit parasitics. The true inductance of the capacitor can be seen in the text box near the slide bar to be 59.21 nH instead of the 93 nH we measured without correcting for short circuit parasitic impedance.



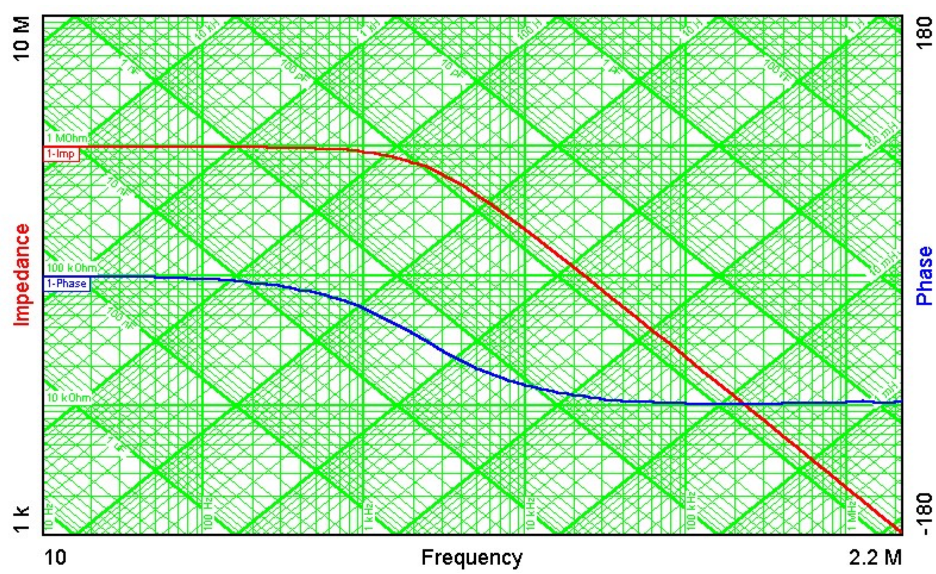



The example on the previous pages was for measuring a low impedance and correcting for short circuit parasitics by subtracting the short circuit impedance from the test data. The same concept can be used for measuring high impedances and correcting for open circuit parasitics, except it is a little trickier because the open circuit parasitics are in parallel with the test data instead of in series.




The best way to illustrate the difference is with an example. Let's say we want to measure a 10 pF capacitor. This is a lot smaller than the parasitic capacitance of approximately 60 pF for an Analyzer and the impedance of a 10 pF capacitor is greater than the parasitic resistance of 1 mega ohm for all frequencies below 16 kHz. To do the test, first connect the 10 pF capacitor as the "Component Under Test" in the test setup on page 36 and run a sweep as before choosing "Impedance and Phase" as the plot type. Use the Analyzer Control settings to the right and the resulting plot with the scales changed to accommodate the data is shown below. Choose "Impedance and Phase" as the graph type and choose Channel Ratio = CH2/CH1, and Scale Factor = -100 if you are using a 100 ohm resistor to measure the current and the connection is the same as the figure on page 47 or if you are using the RLC test fixture.

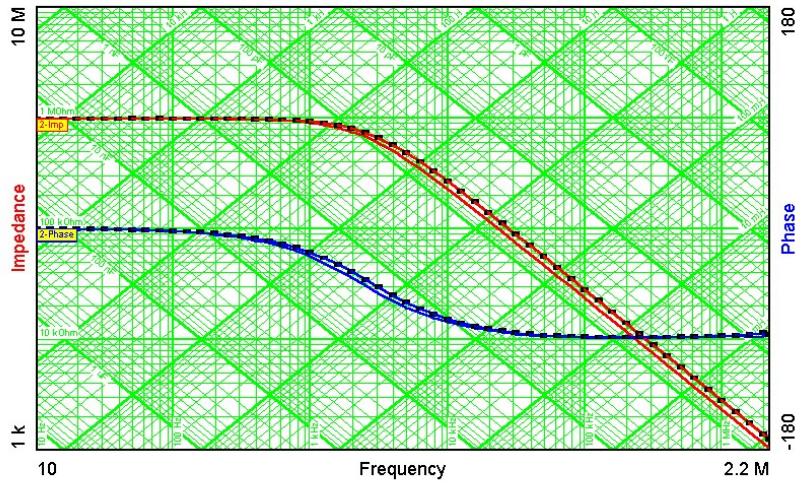
The graph to the right shows the impedance versus frequency plot of the 10 pF capacitor together with the parallel parasitic resistive and capacitive admittance. So far, it just looks like 1 mega ohm in parallel with about 70 pF, but we would like to look at the 10 pF capacitor



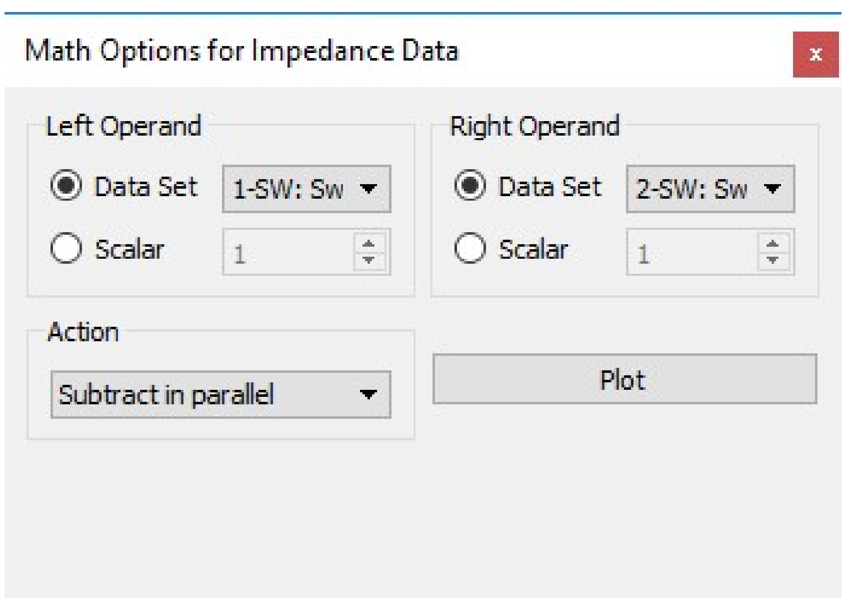

by itself, not in parallel with all those parasitic elements. To do that, we need to run another sweep and then use "Math Options for Impedance Data" to fix the plot.

05/24/18

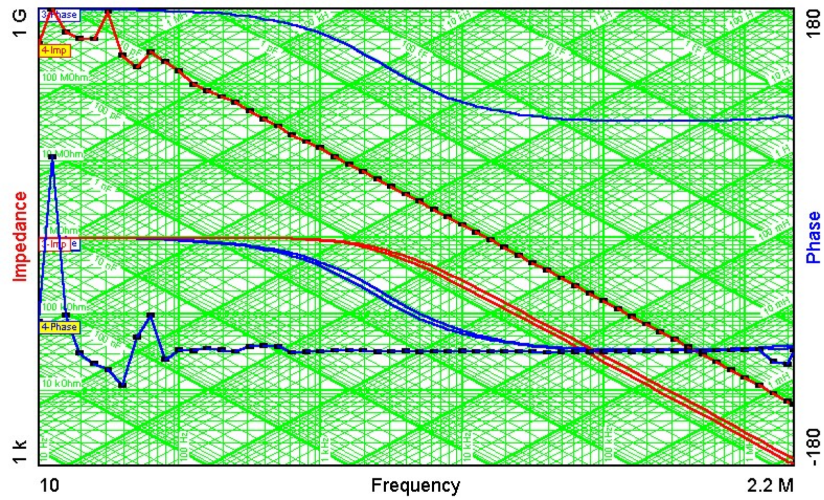
Disconnect the 10 pF capacitor from the test setup but leave the 100 ohm resistor and leave the oscillator and both voltmeters connected as before. Run a second sweep with nothing connected except the voltmeters. This is the open circuit impedance plot. There will not be much difference between the two. The graph to the right shows both sets of data with the open circuit parasitic data highlighted (selected).




Now comes the tricky part. What you want to do is subtract the *admittance* of the open circuit parasitics from the *admittance* of the test data (which includes the impedance of the component under test in parallel with the parasitic open circuit impedance). We have a feature in “Math Options for Impedance Data” called “Subtract in Parallel”. This will put the negative of the parasitic impedance in parallel with the test data, effectively canceling out the open circuit parasitic impedance and yielding only the impedance of the component under test.

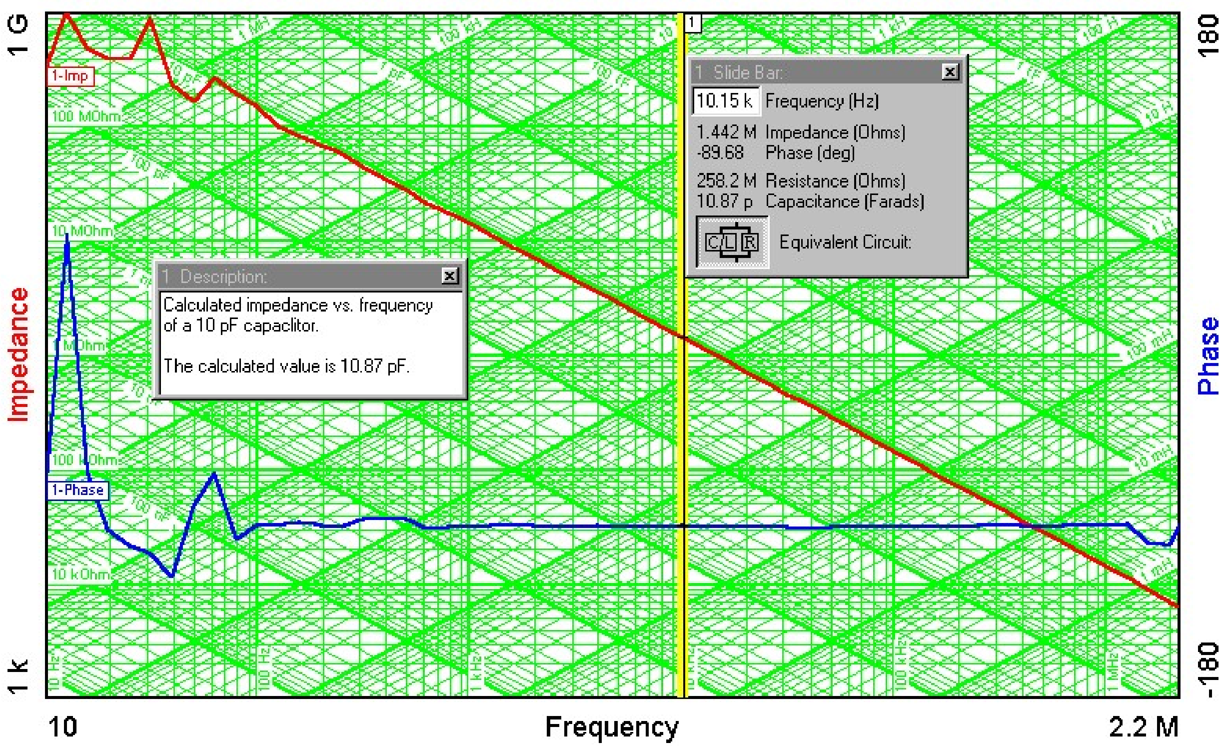



05/24/18




The plot on the upper right shows the results of the step on the previous page. The highlighted curve is the result of doing a "Subtract in Parallel" of the test data with from the parasitic data.

The graph below is the final impedance versus frequency graph of the 10 pF capacitor.
The impedance data is accurate up to about 100 mega ohms. Beyond that, the data is noisy because the parasitic resistance is only 1 mega ohm. At the upper left corner of the graph we are trying to resolve the difference between 1 mega ohm and 1 giga ohm in parallel with 1 mega ohm, and understandably the result has a little variance because we are approaching the limits of measurement resolution.




05/24/18