

# NanoVNA Tweezers Component Measurement Examples

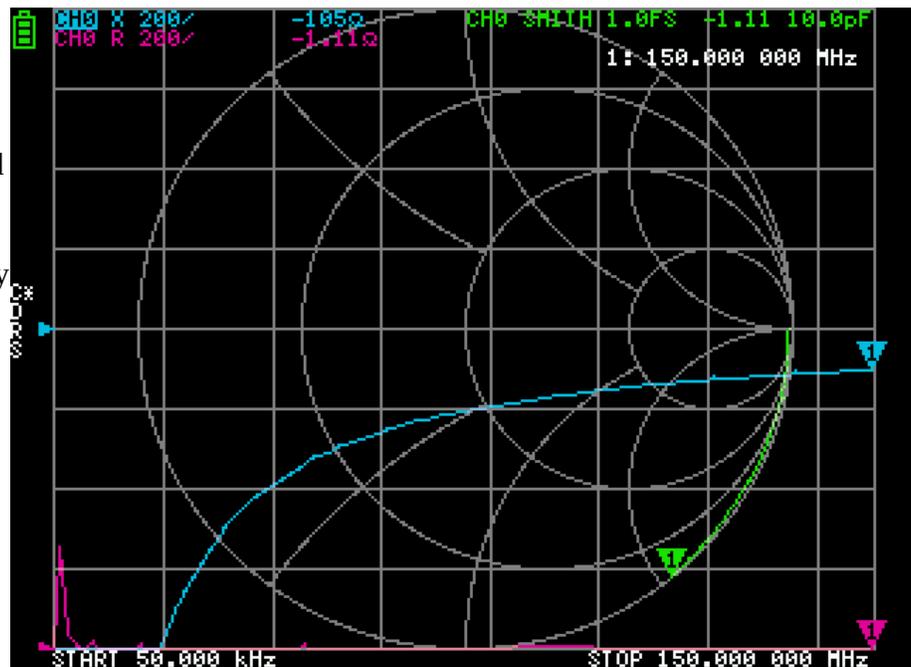
Once the calibration is successfully confirmed the tweezers can be used for measuring SMD passives. To prepare for LRC measurements disable trace 0, Yellow (LOGMAG) to reduce screen clutter and enable traces 1(blue), 2(green) & 3(red) to display the reactance, Smith chart and resistance traces only.

The first examples presented here will be based on the results obtained by the measurement of some of the 1%, COG/NPO ceramic 0805, SMD capacitors installed in the tweezer test reference box shown in photo 12. Fortunately the high quality capacitors that were installed are quite inexpensive and the values remain very accurate throughout the frequency spectrum up to UHF thus they provide a good calibration confirmation reference for the tweezers.

Figure 3 is a *nanoVNA* screen capture enhanced view[6] that illustrates the measurement of the 10pF reference capacitor. As shown the value at 150 MHz was measured as 10.0pF and the capacitive reactance  $X_c$  was -105 Ohms. Figure 4 shows a similar measurement accuracy for the 100pF, 1% capacitor. Both measurements were extremely accurate, well within 1% which might leave the impression that the *nanoVNA* tweezers measurements are always precise. However it will become apparent that this is not always the case and that accuracy depends somewhat upon user skill.

**Figure 1: 10 pF Capacitor Measurement Example**

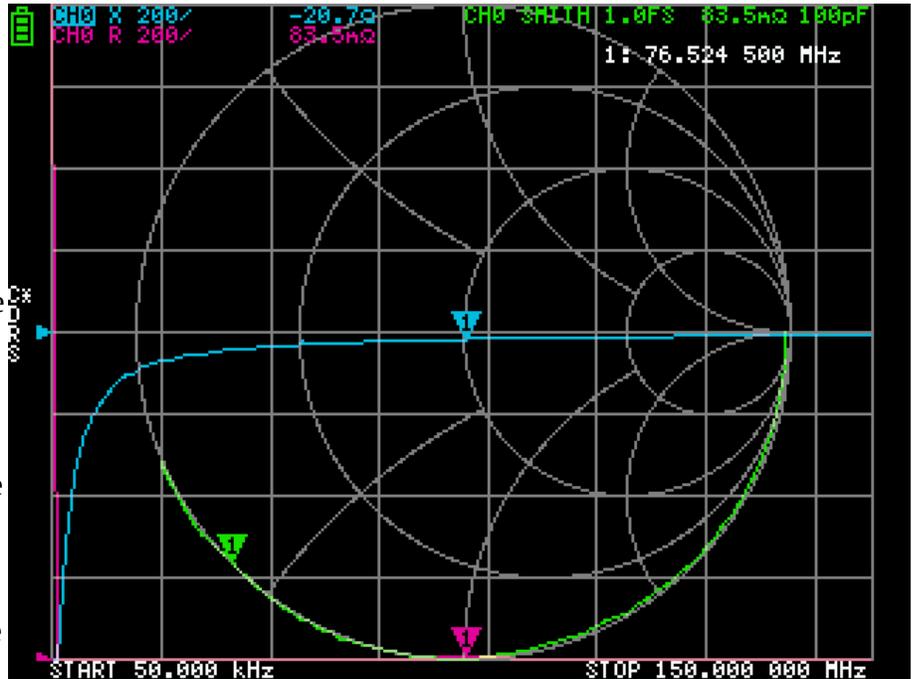
As shown in figure 1 notice the exponentially curved reactance trace in the foreground. It shows the decrease of  $X_c$  as the frequency increased. Note that the zero reference for the reactance trace is the center horizontal grid line which permits the display of both negative and positive values for capacitive and inductive reactance respectively. Since real resistance impedance values should always be positive[7] the whole vertical scale is used for the resistance trace. Thus the bottom grid line which in this case is covered by the R trace is very close to zero Ohms for R which is quite typical for a hi Q ceramic capacitor. Also note that the displayed range for reactance is +/- 1000 Ohms and 0 to 2000 Ohms for resistance as the scales were set to 200/div.



As shown in figure 1 the reactance trace comes into view as it decreases to -1000 Ohms as the sweep reaches about 15 MHz. As the sweep frequency continues to increase the negative reactance continues to decrease reaching -105 Ohms at 150 MHz. It is important to notice that at the point of the #1 triangular measurement marker the reactance was still decreasing towards the zero center line when the sweep ended at 150 MHz. Also note that the reactance value is a moderate -105 Ohms when the stop frequency of 150 MHz was reached.

**Figure 2: 100pF Capacitor Measurement**

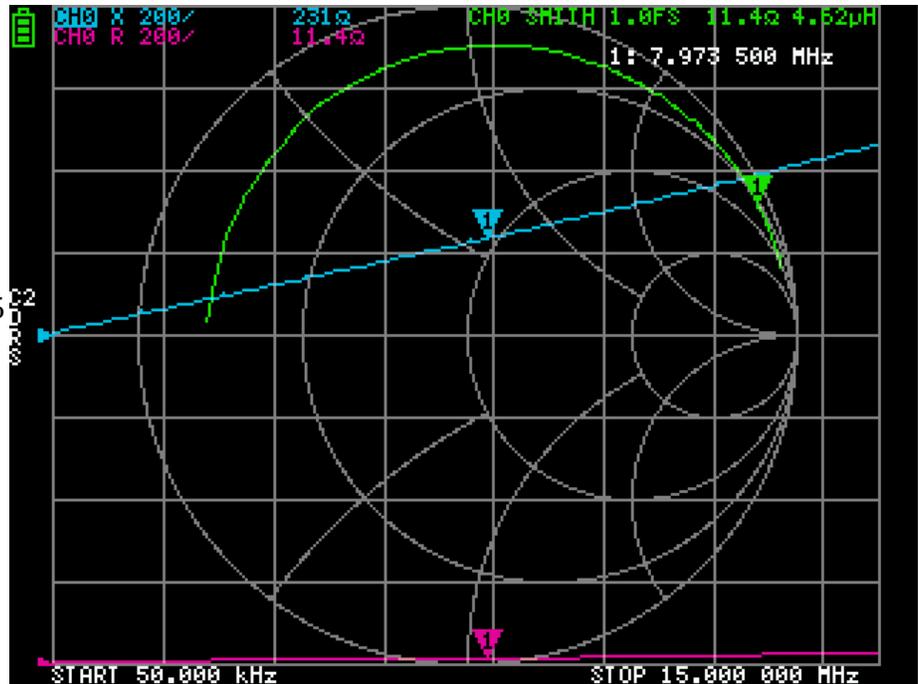
Of significance is that in both figures 1 & 2 the very accurate capacitance value measurements were taken on the slope of the reactance curve where the  $X_c$  value changed noticeably with a fairly small change of frequency and the reactance value was greater than about 20 Ohms. Generally when measurements are taken within this part of the reactance curve the best accuracy is achieved. But notice that in the figure 4, 100pF example the curve becomes very flat as  $X_c$  became a



low value as the sweep reached about 50 MHz. At this point of the sweep the reactance had diminished to a low value as indicated by the flat  $X_c$  trace line that plotted just below and parallel to the center zero grid line. Measurements made at frequencies on this flat portion of the reactance trace tend to be less accurate. Not shown here was a measurement that was made with the marker placed at 150 MHz where the reactance was roughly 10 Ohms. With the measurement done at 150MHz an inconsistent result was obtained that varied from about 102 to 107pF. The accuracy suffers a bit when the reactance drops below roughly 20 Ohms and the reactance trace is flat. Generally the tweezer measurements are consistently accurate when taken on the slope of the reactance trace where there is significant reactance change with a small change of frequency.

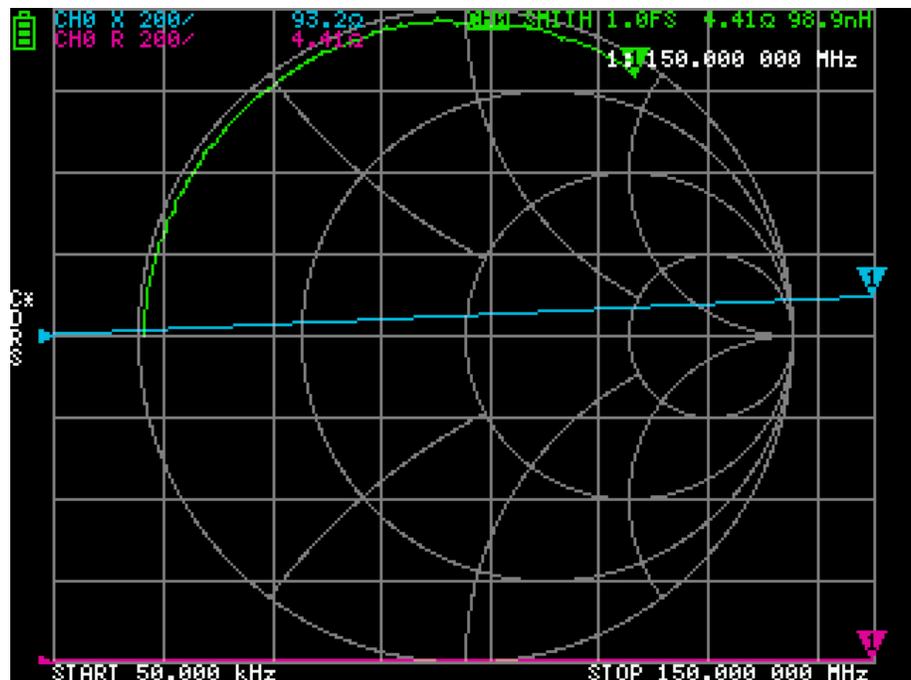
### Figure 3: 4.7uH Inductor Measurement Example

Figure 3 is measurement results for the 4.7uH, +/- 2% tolerance reference box inductor measured with a 50 KHz to 15 MHz sweep. As shown the inductance measured 4.62uH at the manufactures specified test frequency of 7.9 MHz which is about 1.5% on the low side of nominal value but nicely within the 2% spec. Note that unlike capacitive reactance which varies indirectly with frequency the inductive reactance from a good quality inductor increases directly with frequency creating a straight reactance trace across the grid screen that increases linearly in value with frequency. For a good quality inductor the line typically remains straight until the sweep approaches the self resonant frequency which in this case is specified as 40MHz, which is well beyond the 15 MHz sweep stop frequency.



### Figure 4: 100nH Inductor Measurement Example

Figure 4 is measurement results for the 100nH, 2% tolerance reference box inductor with a specified test frequency of 150MHz and a self resonant frequency of 1.2GHz. As shown it measured 98.9nH@150MHz which is also nicely within the 2% specification.

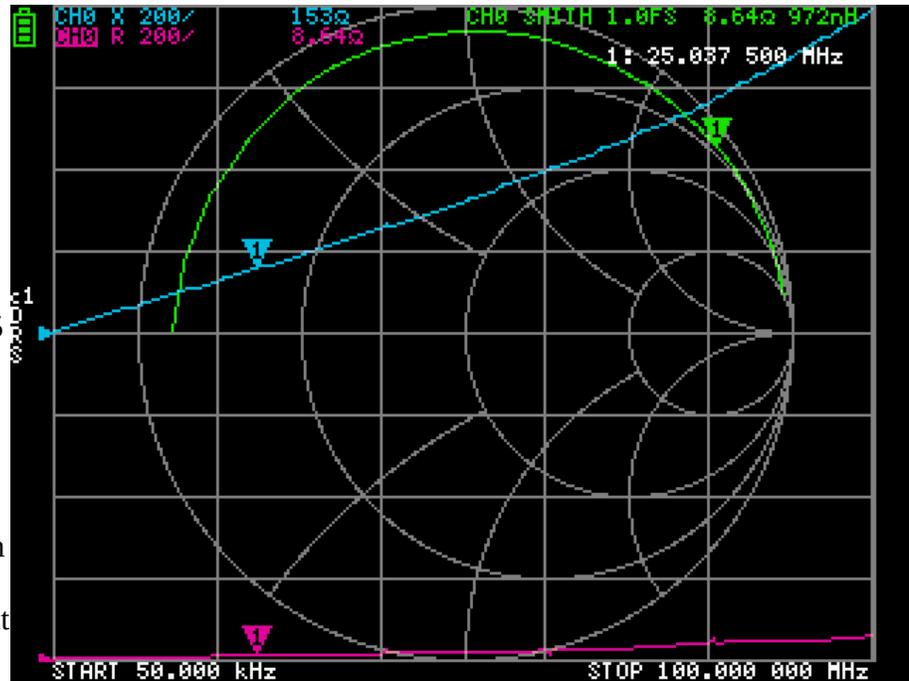


Not shown here was a measurement of the 10nH reference inductor which measured 10.6nH. The results were slightly out of spec probably due to slight measurement error. The reactance line was near zero thus essentially flat across the full width of the screen. The reactance at the 150 MHz stop frequency had only reached about 10 Ohms. This low value of inductance is below the range of high accuracy

measurement for the tweezers but was still sufficiently accurate for determining the approximate value to within about 10%.

### Figure 5: 1uH Inductor Measurement Example

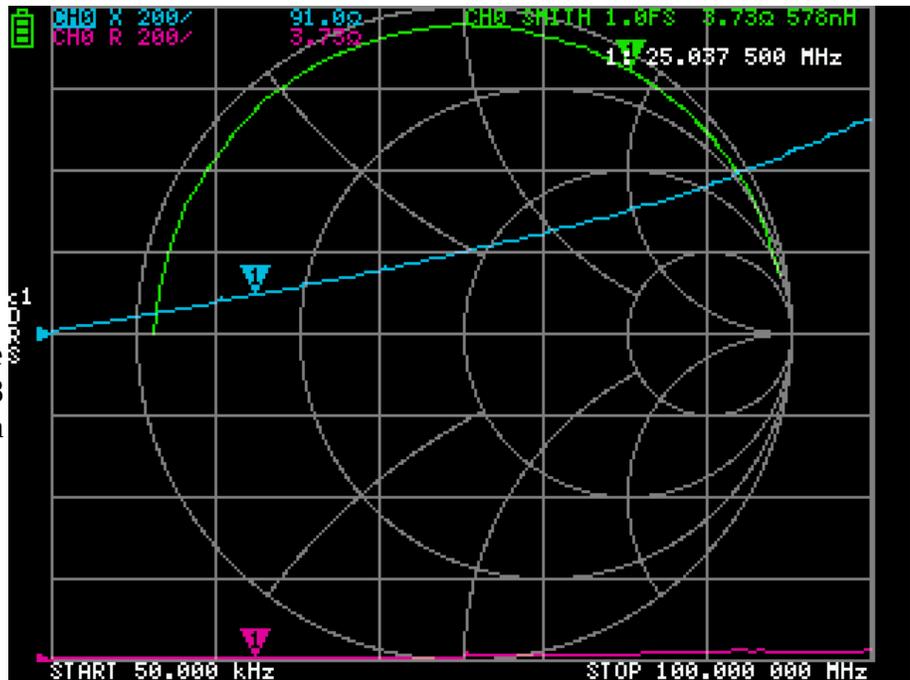
Figure 5 shows a 50KHz to 100MHz measurement response of the 1uH, 2% reference box inductor which has a specified test frequency of 25 MHz and self resonant spec of 290 MHz. Note that the reactance trace is quite straight up to about 50 MHz then starts to curve up slightly due to influence from the self resonant region. This chip appears to be slightly out of spec at 25 MHz as it



measured 972nH which is about 2.9% lower than the specified value. At 100 MHz the inductance measured 1.25uH about 25% higher than the specification limit at 25 MHz. This increase was caused by influence from the self resonance region. Although the inductor self resonance frequency is specified as 290 MHz it was measured at about 160 MHz, about half of the self resonance specification. Considering the value of inductance and the 290 MHz specification the stray capacity of the inductor chip alone must be minuscule, about 1/3rd of a pF. It is presumed the stray capacity contribution from the rather large PCB pads could possibly add another 1/3rd pF which would explain why the in-circuit self resonance was found to be about half the specified value for the inductor. It is important to understand that the influence of self resonance can impact the inductance value measurement. The measurement needs to be made on the straight portion of the inductive reactance trace for best accuracy.

**Figure 6: Poor Quality 1uH Inductor Measurement Example**

Figure 6 is a comparison view to a low quality 1uH chip that came in a low cost Asian inductor kit. Note the reactance trace is, in comparison, quite curved. The inductance measured only 578 nH at 25 MHz which although measured on the straight portion of the reactance trace is about 40% below nominal value. A second chip from the same clearly marked 1uH batch measured only slightly better at 624 nH. This comparison clearly reveals how SMD inductor quality can vary significantly.



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**Figure 7: Ferrite Bead Measurement Example**

Figure 7 is an interesting and rather complex example of tweezer measurement capability. It is test results from a 1-150 MHz sweep of a ferrite bead specified to have a 1K Ohm impedance at 100MHz. Note that the inductive reactance and the real resistance are both on the rise at the start of the sweep at 1 MHz. The inductive reactance continues to rise to a peak of about 450 Ohms around 30 MHz. The real resistance rises steadily from near zero up to about 1050 Ohms where it levels off around 90 MHz. The reactance drops down to zero around 75 MHz. The bead impedance starts to become capacitive above 75 MHz thus its decoupling effectiveness would start to slowly diminish for frequencies higher than 75 MHz. However as the impedance (Z) vector sum was 1046 Ohms at 100 MHz it met the minimum impedance spec of 1K @ 100 MHz OK.

