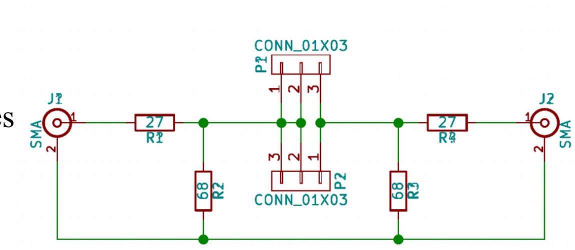
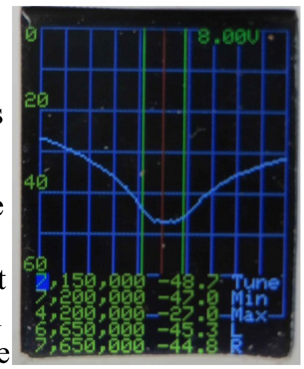
SNA, SNL, SNC ... Measuring Resonance, Inductance and Capacitance
K1TRB (12/12/27)

A parallel resonant circuit presents a high impedance at resonance (i.e. it looks like an open circuit) and a low impedance off resonance (i.e. it looks like a short). In other words, if the tuned circuit is placed between the generator and detector of Yana, there will be a dip in the SNA graph. The bottom of this dip occurs at resonance. This fact can be used to measure resonance, inductance, and capacitance.

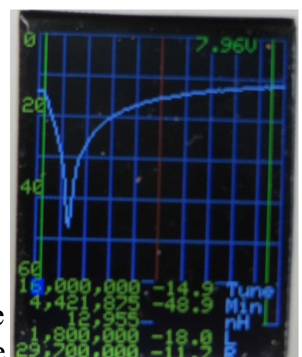
In a tuned circuit, the circuit is really more than just the coil and capacitance that are connected in parallel. Any stray inductance and capacitance in Yana also contributes to resonance. Therefore, an adapter is needed to isolate the tuned circuit from Yana circuitry. The Yana adapter is a modified 10db T network attenuator which provides enough isolation to separate Yana's circuitry from the parallel circuit being tested.

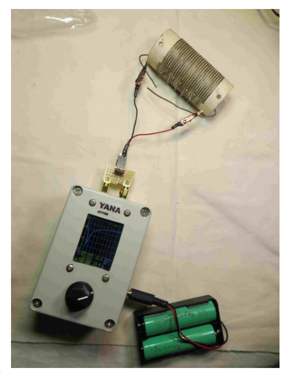


Use the LC measuring adapter described in the Dongles section. The wiring diagram is shown below. Kicad

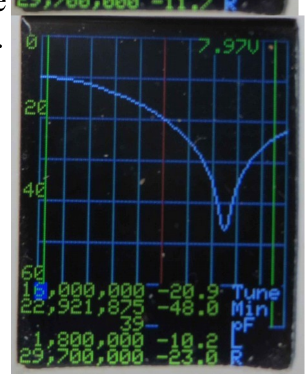


The setup for measurement is shown at the right. There are two female pin headers on the adapter. A capacitor is connected to one and an inductor to the other. It doesn't matter which socket is used since the two sockets are in parallel. The standard is mounted on a 3 pin header. Be sure to plug it in correctly, two pins on the header are shorted together. Plug the standard into one header and make certain Yana knows the value of your standard. The built in standards are 1.2uH and 680pF. While graphing, a push will allow you to change the standard for the current Yana run. Plug the test component into the other pin header.





The first two pictures show Yana in SNA mode with the LC combination tuned approximately to 7.15MHz. The second two pictures show Yana measuring L of the coil. The third two pictures show Yana measuring the C of the capacitor. Yes, the extra clip leads do affect the circuit values. The effect is ignored. I imagine at a 30MHz resonance, ignoring the effect of leads can noticeably affect values. I used my 100pF standard to measure L. Using the 680pF standard gave a result very close to the same.



Computing resonance with the measured values gives 7.08MHz showing the effect of the leads. I found moving the coil or the capacitor slightly changed resonance by up to 100KHz. A carefully constructed jig would be needed to get repeatable close results.

Use a standard inductor to measure capacitance and a standard capacitance to measure inductance. Getting the standard or the instrument (SNL, SNC) reversed will lead to strange wrong answers.

Finding standards

The procedure below was actually performed after the experiment that follows. This procedure is based upon the results of the experiment.

1. Choose a 100pF standard capacitor.

As a percent deviation, the 0805 smd C0G (NP0) 100pF capacitor seems best according to the VNA readings. In measuring 10 samples I found variation among values to be smallest. Finally the values were closest to the nominal value of 100pF. Therefore, I decided that the best way to obtain standards is to bootstrap from a 0805 C0G 100pF capacitor. These are inexpensive on eBay.

Pick a 100pF capacitor and call it your 100pF standard. Short two pins of a 3 pin pin header and solder the 100pF capacitor between the remaining pins.

2. Choose a 1.2uH standard inductor.

In SNL mode, set the C standard to 100pF. Plug the 100pF standard into the adapter. Then plug 1.2uH inductors into the adapter's second port and write down the values for a collection of 1.2uH inductors. The dip on Yana will be about 14.3MHz. Select the inductor with value closest to 1.2uH and record the value given by Yana.

Short two pins of a 3 pin pin header then connect the 1.2uH standard between the end two pins of the pin header. Measure the inductance of the 1.2uH inductor in its mounting on Yana and record the inductance. This number (in nH) is the value of the 1.2uH standard.

3. Choose a 680pF standard capacitor.

I used a 0805 smd 680pF capacitor. Mount it on a 3 pin pin header just like the way the 100pF standard is mounted. Measure the 680pF standard using the standard L value recorded in step 2. Write down the value of capacitance measured by Yana.

You now have three standards: 100pF, 680pF, and 1.2uH. The values to the left are nominal. The values used in Yana are the ones you wrote down. I don't think my 680pF is C0G (NP0). If you can, choose that type ceramic because it will be more stable.

Using this method, my standard values are: 100pF, 617pF, and 1234nH. I entered C_STD 617 and L_STD 1234 into the Yana code so that these would be the default standards. During a run, it is easy to change the standard value to whatever you have.

Values measured before standards were set

The values used in this experiment are best detected between 1 and 31 Mhz: Yana's startup frequencies. However, a couple measurements required going outside this frequency range. Measurements work outside this range, but some care is needed to make sure readings are meaningful. A very shallow wide dip at resonance indicates low Q and values computed may be have large errors. Once there is a graph, click to go into tuning mode where the component value is computed.

When measuring L or C, Yana is just in SNA mode. The only change is the computation of the component value in tuning mode. You will note this when you go back to the home screen and change the instrument. The knob behaves as if Yana is in SNA mode.
That's because it is in that mode.

To measure capacitance, an inductance standard is needed. To measure inductance, a standard capacitance is needed. It is possible to buy 1% tolerance inductors and capacitors, and that might be the best approach. But for sake of economy, I used standard tolerance parts.

A good range of values useful for high frequency work (3 to 30 Mhz) are obtained by using a 680pF standard capacitor and a 1.2uH standard inductor. The inductor is a small molded coil and the capacitor is a 0805 smd capacitor. I measured my standards on meters I had. Capacitors of type C0G are most likely to make the best standards. Generally a 100pF 0805 smd capacitor is made of C0G ceramic. Measuring a bunch of 100pF capacitors with various meters, I found them to be pretty close to 100pF.

For the measurements in the table below, I set my "680pF" standard value to 650pF and my 1.2uH standard to 1200nH. The bottom three rows of the table show how I readjusted those values by the bootstrap method described above.

The table below gives some measurements using an AADE LC Meter II/B, an eBay LC100A and Yana. I also measured parts using an N2PK VNA. VNA graphs are appended to the end. If you believe our components have actual standard values, constant over frequency, then don't use a VNA. It will reveal how variable our "fixed value" components really are.

Yana computes the value at the minimum on the SNA graph (the dip). Therefore, these frequencies are also listed in the table. The least significant digits for frequency and value should not be considered exact. I think RF heating of the component changes its value. While measuring capacitance, the value will slowly drift and the frequency of measurement will change. Yana is not continually recomputing a value so the listed value looks deceptively stable compared with the LC100A and LC II/B.

Label Value	Standard	LC100A	LC II/B	Yana
10 pF	1.2uH	9.34pF@759432Hz	9.21pF	11pF@43100625Hz
100pF	1.2uH	100.5pF@728526Hz	99.28pF	103pF@14312500Hz
680pF	1.2uH	650.0pF@597360Hz	680pF	638pF@5750000Hz
1nF	1.2uH	1004pF@545700Hz	996.3pF	1014pF@4562500Hz
1.2uH	650pF	1.263uH@752188Hz	1.206uH	1.179uH@5750000Hz
18uH	650pF	18.14uH@635524Hz	18.18uH	18.065uH@1463750Hz
100uH	650pF	89.87uH@429400Hz	90.47uH	89uH@661713Hz
Sample	617pF	2.514uH@739600Hz	2.543uH	2.606uH@3968750Hz
Sample	1.234uH	180.5pF@702068Hz	177.5pF	194pF@10281250Hz
1.2uH	100pF	See above	above	1234nH@14328125Hz

680pF	1234nH	See above	above	617pF@5765625Hz
100pF	1234nH	See above	above	100pF@14328125Hz

My sample inductor is a ceramic coil I had in my junk box. The coil is tapped so I took the 2-tap gap in the middle. My sample capacitor is a polyvaricon I have in the junk box. I resonated the capacitor and inductor at 7.149960MHz using the SNA mode. Then I measured L and C. The computed resonance from these is 7.078MHz. Clip leads ran to the components from Yana and their configuration changed when moving among resonance, L, and C measurments. The variation in measurements show why a timmer capacitor is usually included ina tuned circuit at high frequency. Circuit configuration changes L, C, and resonance. Further, the vna scans show that component values are not constant across frequency. The polyvaricon was so unstable and difficult to adjust, for the pictures I switched to an air variable.

I tried measuring a 10nF capacitor with Yana, but the dip was so broad and shallow that there was no meaningful value.

Comparing values in the table, it looks like Yana is doing a quite reasonable job. Yana works as follows. In scanning from 1 to 31MHz, the frequency steps are 250KHz. Therefore, the initial minimum (dip) is possibly a long way off the actual resonance being checked. The Yana program refines this dip. Further, a scan is an "on the fly" measurement. The DDS is set and the ADC is read once. The ADC has a certain amount of noise. For the refinement, the ADC is read eight times and the result is averaged. The frequency steps are made much smaller when Yana searches for a minimum.

If you play with the power meter, you will find that the ADC steps are about 0.2db for each count of the ADC. In other words, if a value stays within 0.2db of another value, the two are indistinguishable.

For example, with 250KHz steps, taking a reading of inductance at 5.75MHz will lead to an error of as much as 8%. Refining the step size will lead to a much smaller error. If you switch to tuning mode and hunt for a minimum, there will be a range of frequencies where all minimum values are equal. Yana finds the lowest frequency among these equals. Then the search continues upward until the dip is passed. There is then a range of frequencies where the ADC values are all equal. Yana takes the average of these frequencies as the minimum value.

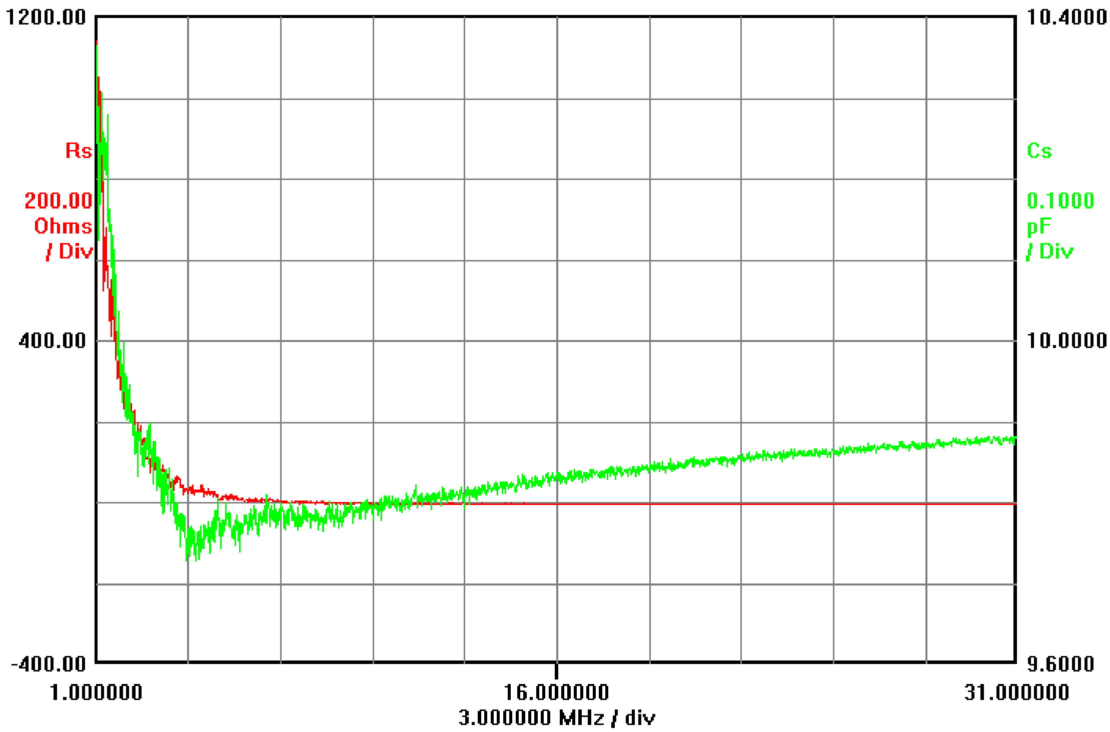
The N2PK VNA values are more interesting. The red curve in each graph is equivalent series resistance. Ideally this should be zero. The green curve is the component value. My standard inductance value (1.2uH) varies between 1.24uH and 1.3uH, a 4.8% variation. My standard 680pF capacitor varies from 640pF to 680pF, a 6.2% variation. I have it entered into Yana as 617pF. I also use a 100pF capacitor which varies from 106.2pF to 106.6pF, a 0.4% variation which I just take to be 100pF in Yana. Yana only allows standards of integral value.

We live in an imprecise world. It is probably best to measure tuned circuits for resonance rather than to measure each component and compute resonance.

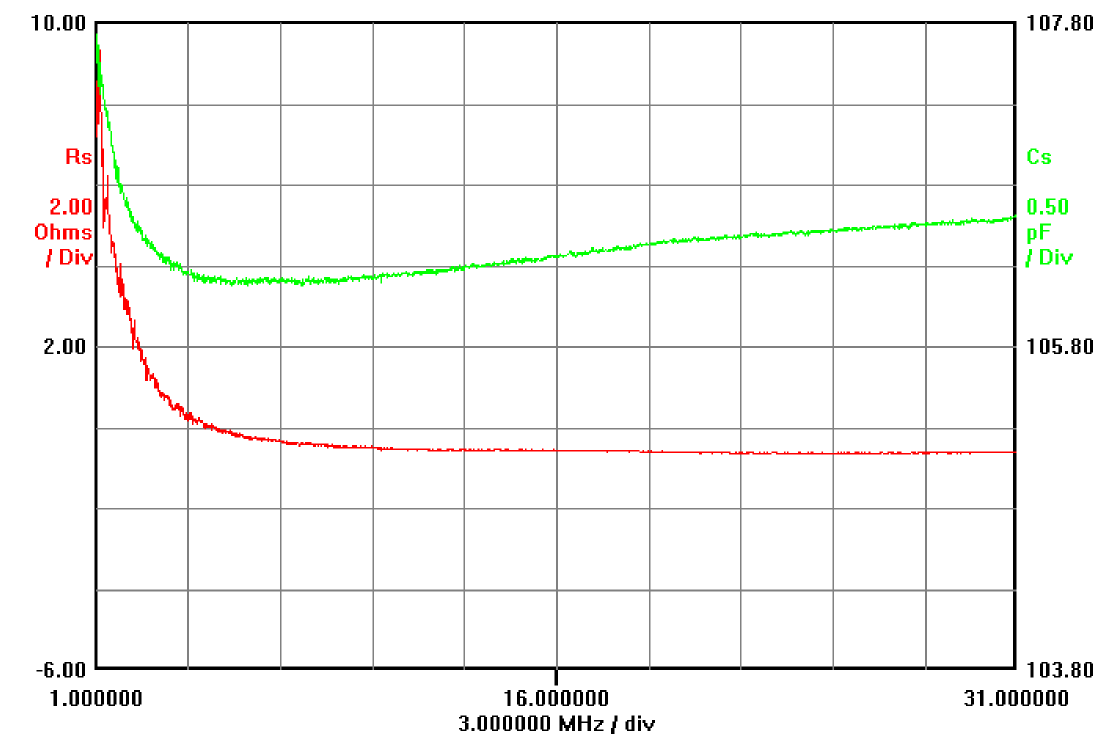
Look at the vna graph of the 18uH inductor. It has a gottcha. Imagine winding a coil on a round form. The wire goes around and comes back almost where it began the turn. The two ends are close together and form a capacitor. Further, the turn around the form is an inductor which is in parallel with this capacitance. Aha! A parallel resonant circuit. Coils have a parallel self-resonance caused by the inductance and interwinding capacitance. In data sheets this is called SRF or self resonant frequency.

Above self resonance, the inductor looks more capacitive than inductive. In the vna graph of the 18uH inductor, self resonance occurs at about 13MHz. The conclusion here is: Use inductors well below their self resonant frequency. Yana's SNA makes it easy to find the SRF of an inductor. Just scan the inductor in the adapter with no standard in SNA mode.

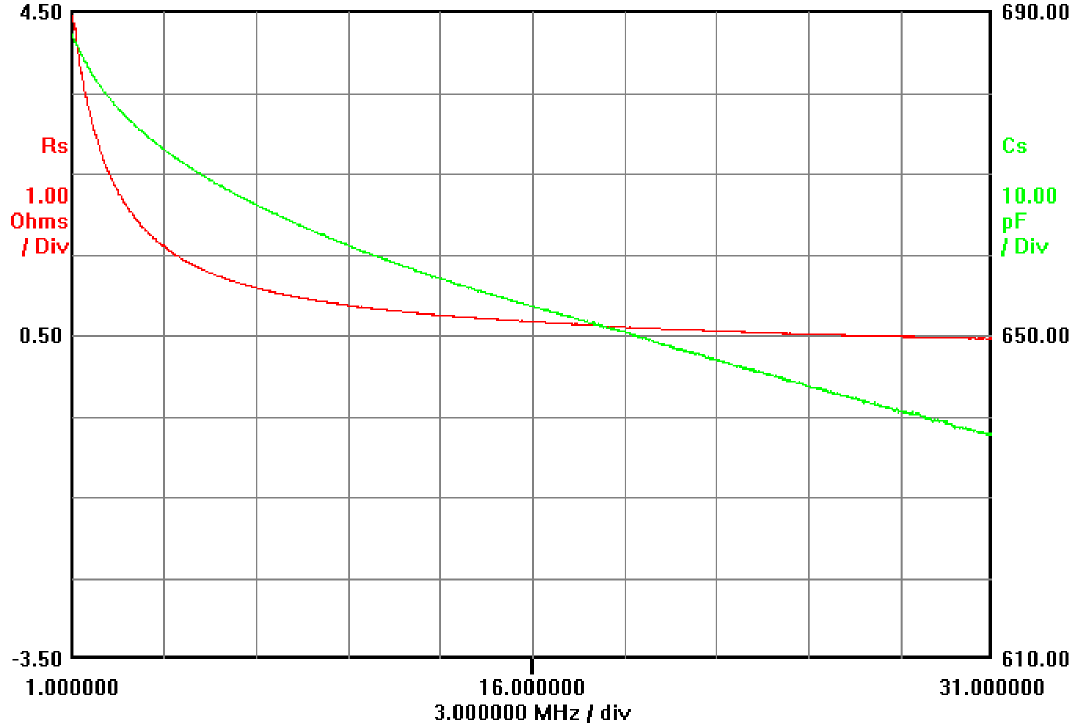
10pF disk



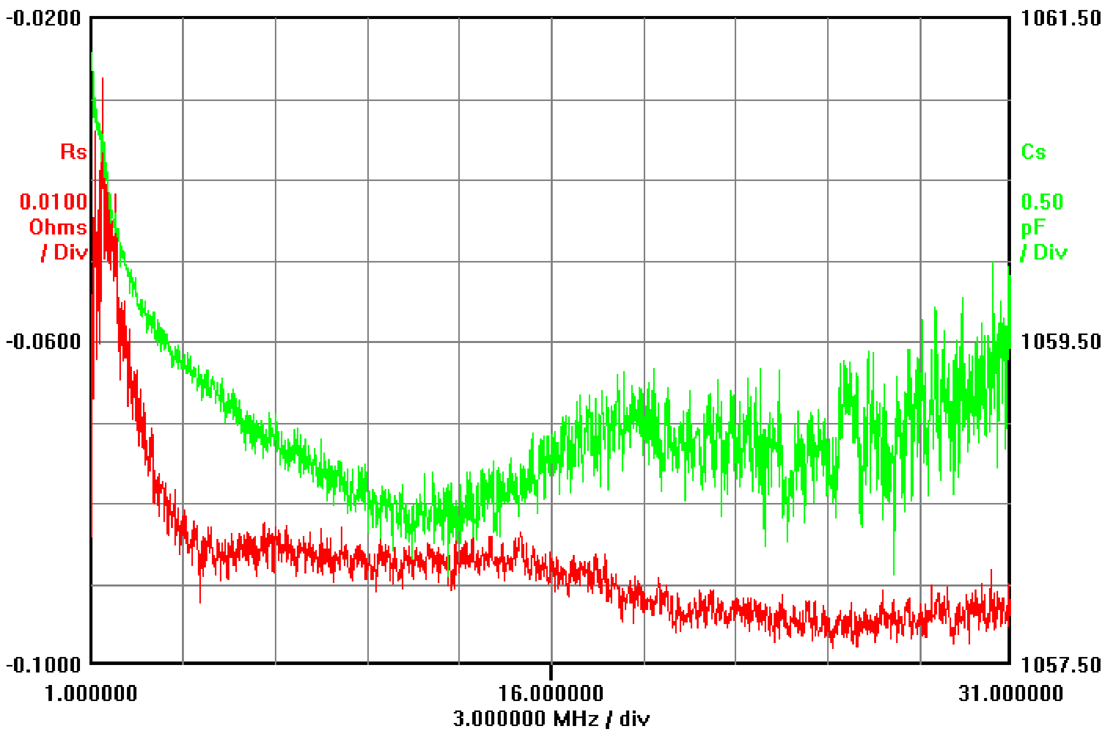
100pF 0805 Standard



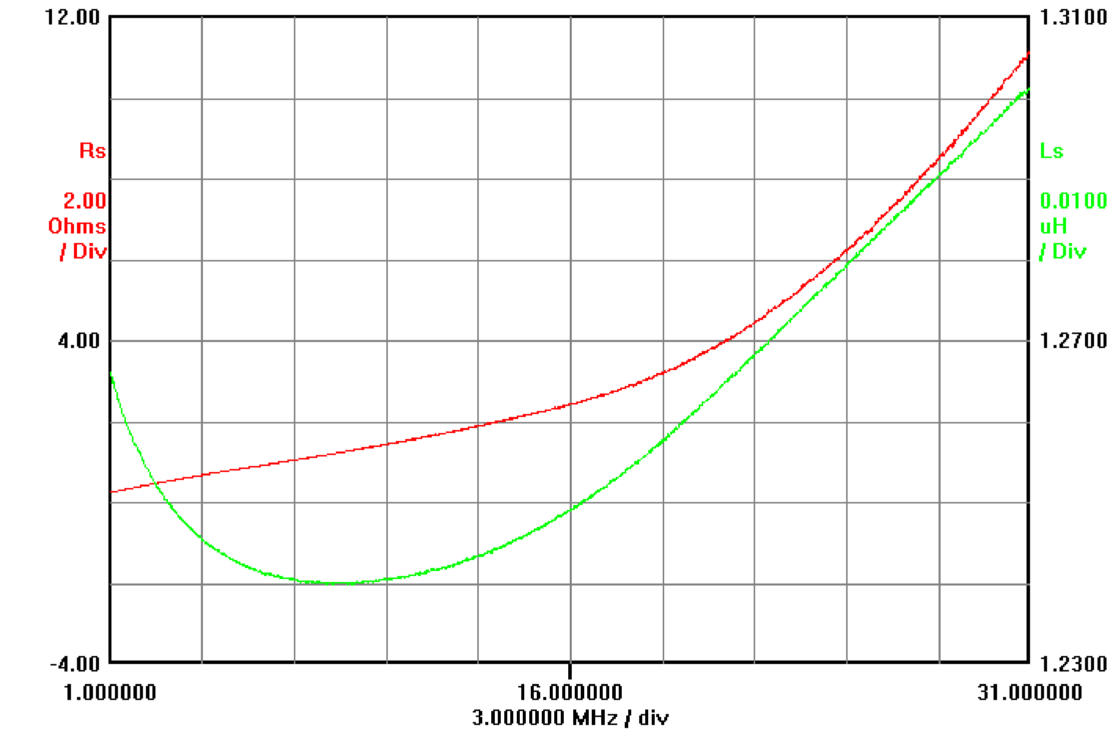
680pF 0805 Standard



1000pF Disk



1.2uH Standard



18uH