Impedance measurements with the E5061B ENA

Accurate impedance measurements often require specialized equipment and involve different measurement methods.

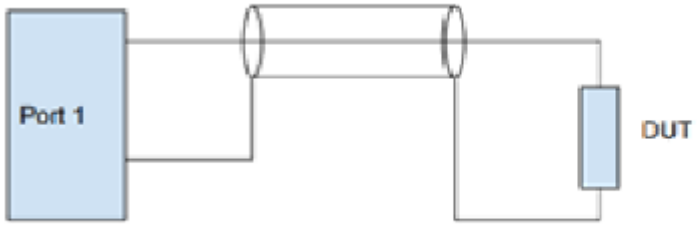
Fortunately, the E5061B is a hybrid Vector Network Analyzer (VNA) / Gain Phase Impedance Analyzer, that covers the 5 most common impedance measurement methods.

Measurements over a wide frequency range require a VNA. Measurements at lower frequencies (up to 10s of MHz) can be performed with a Gain Phase Impedance Analyzer.

There are 3 possible impedance measurements with a VNA:

For each method described below, look at the ENA ports 1 and 2 and think how would the DUT connection be done. What type corresponds to the setup currently in place?

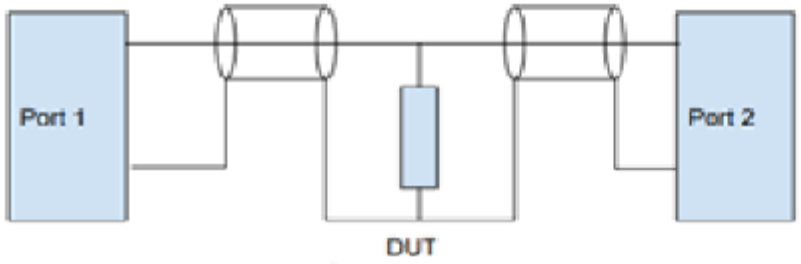
1. Calculating the impedance from a one port reflection measurement (typ, S11)



Configuration 1

Shunt Measurement

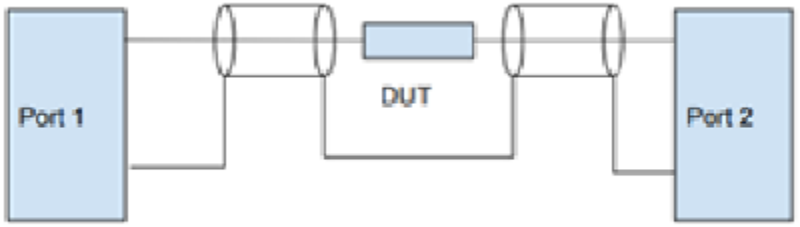
2. Calculating the impedance from a transmission measurement (typ. S21) with the DUT connected in shunt to Port 1 and Port 2



Configuration 2

Shunt-Thru Measurement

3. Calculating the impedance from a transmission measurement (typ. S21) with the DUT connected in series between Port 1 and Port 2



Configuration 3

Series Measurement

(Diagrams are from: Make Accurate Impedance Measurements Using a VNA, Microwaves & RF, June 21, 2019)

For each method the relation between the calculated impedance Z and the measured parameters is different, thus the measurement uncertainty of each method is different too.

Shunt

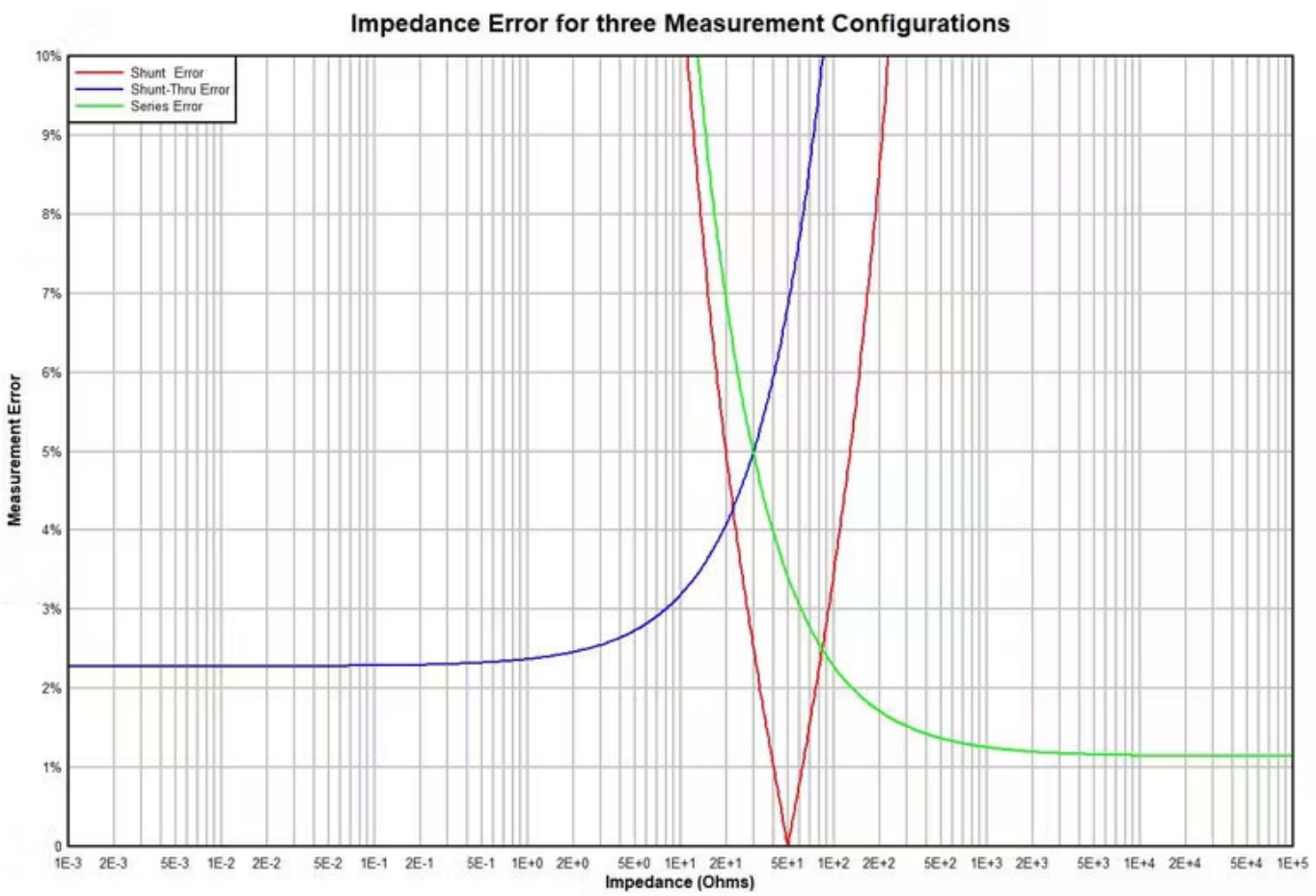
$$z = \frac{Z0(1+S11)}{1-S11}$$

Shunt-Thru

$$Z = \frac{Z0*S21}{2(1-S21)}$$

Series

$$z = \frac{2(Z0-S21)}{S21}$$



Measurement error of the Shunt, Shunt-Thru, and Series methods

(from: Make Accurate Impedance Measurements Using a VNA, Microwaves & RF, June 21, 2019)

For the VNA on the graph the shunt method is the most accurate for impedances between 20 and 80 ohms. The shunt-thru is better for lower Z <20, and the series method for Z > 80. The exact Z thresholds vary with the type of VNA.

Measuring a 100pF 0805 surface mount capacitor using the Shunt / Reflection method

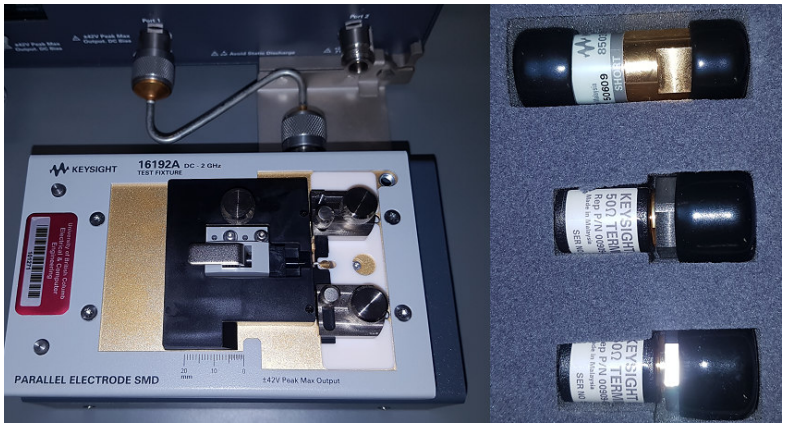
The measurement setup is already connected and calibrated. The fixture was calibrated with a 1 port Short-Open-Load (SOLT) calibration kit.

- Preset the instrument
- Load a previously saved instrument state and calibration:

  [Save/Recall] Recall Sate > State 1

  [Trigger] Trigger Source > Internal
- What is being shown? Does it make sense?

  Using the maker find the ESR frequency of this capacitor.



- Add a second trace to plot the phase:

  [Display] Number of traces > 2

  [Trace Next] (to Select the blue trace Tr2)

  If the instrument beeps it is warning you that the 2 traces are on different measurement modes (VNA and Gain-Phase)

  [Meas] Meas Port > Gain-Phase Return

  Impedance Analysis > θz >

  [Display] Allocate traces > x2 

  [Scale] Scale/Div > 20

  Does the phase trace makes sense?

- Analyze the results and display the equivalent circuit

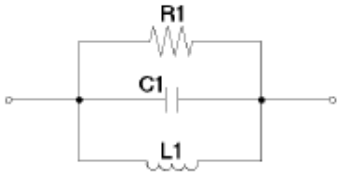
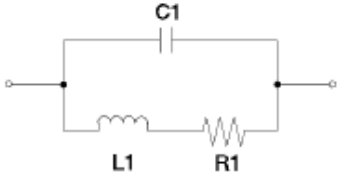
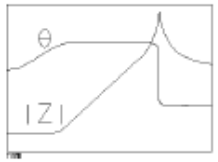
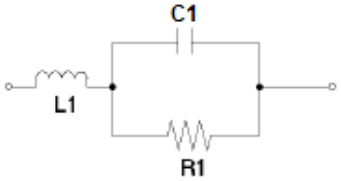
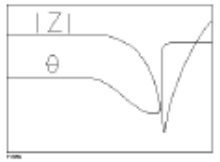
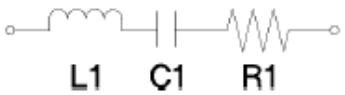
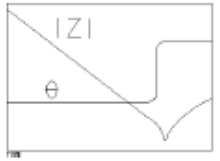
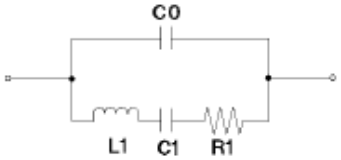
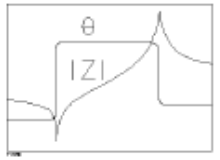
  [Analysis] Equivalent circuit

  Select Circuit D

  Calculate

  set Display OFF to ON

Notice the small equivalent circuit at the bottom of the screen.

Equivalent Circuit Model		Typical Frequency Characteristics	
A		 *1	Inductor with high core loss
B		 *1	Inductor Resistor
C		 *1	High-value resistor
D		 *1	Capacitor
E		 *2	Resonator