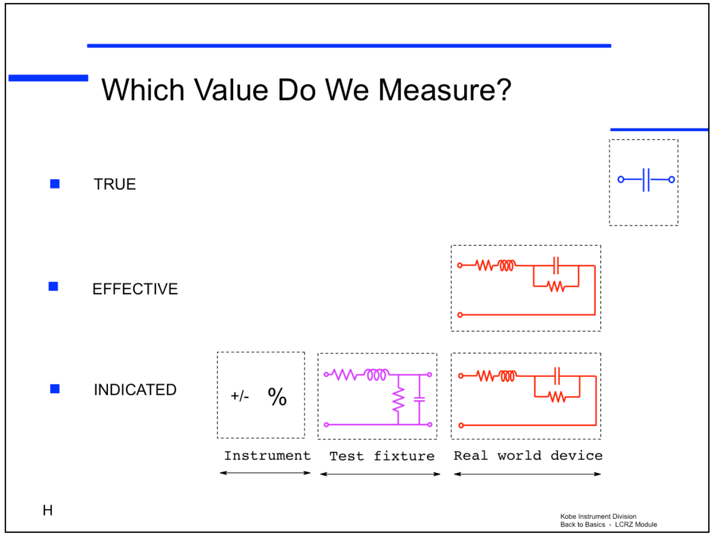
From S parameters to impedance

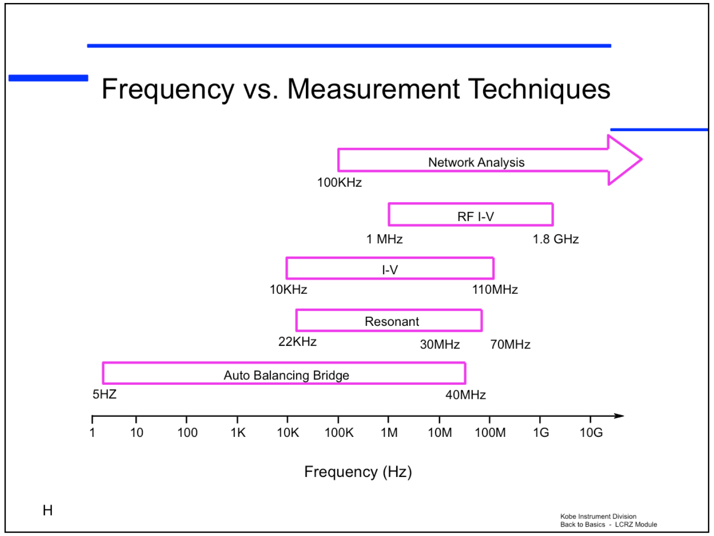
Impedance Measurements



Before proceeding to practical measurements, we need to understand the concept of True, Effective and Indicated values. This is essential since we all tend to forget that the instrument does NOT necessarily measure what we want to measure. By the way, which value do instruments measure?

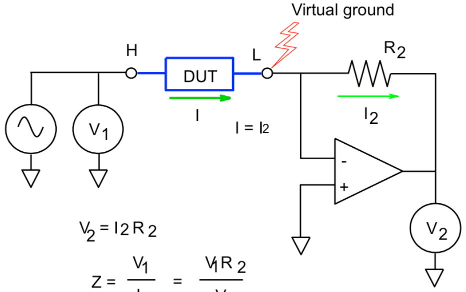
The TRUE value excludes all parasitics and is given by a math relationship involving the component's physical composition. If you think of a 50 Ohm PC board stripline, it is built up assuming that the dielectric constant K is constant. But in the real world this is not true. The TRUE value has only academic interest.

The EFFECTIVE value is what we generally want to measure because it takes into consideration the parasitics and dependency factors, as this figure shows. When designing and simulating circuits, only EFFECTIVE values should be used to reflect the actual circuit behavior. But the INDICATED value given by the instrument takes into account not only the real world device, but also the test fixture and accessories as well as the instrument inaccuracies and losses. What is the difference between TRUE and EFFECTIVE values? The quality of the component. And what is the difference between EFFECTIVE and INDICATED values? The quality of the instrument and above all the quality of the MEASUREMENT. Our goal is to make the INDICATED value as close as possible to the EFFECTIVE value



This chart will help you visualize the frequency range for 5 measurement techniques. The frequency range numbers are a mix of practical and theoretical limits and should be used as a reference only. The autobalancing bridge basic accuracy is 0.05% while the network analysis one is 1.5%. This already uncovers possible trade-offs.

Auto Balancing Bridge
Theory of Operation



$$V_2 = I_2 R_2$$

$$Z = \frac{V_1}{I_2} = \frac{V_1 R_2}{V_2}$$

Kobe Instrument Division
Back to Basics - LCRZ Module

Auto Balancing Bridge

Advantages and Disadvantages

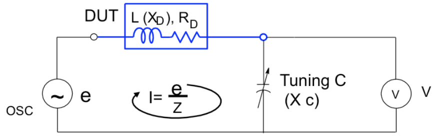
- Most accurate, basic accuracy 0.05%
- Widest measurement range
- C,L,D,Q,R,X,G,B,Z,Y,O,...
- Widest range of electrical test conditions
- Simple-to-use
- Low frequency, f < 40MHz

Let us summarize the advantages and disadvantages of each of the measurement techniques.

The Autobalancing bridge technique is by far the best technique for measurements below 40 MHz. It provides the most accurate measurements possible and has the widest impedance measurement range. Both of these are critical for accurate component analysis. A wide range of AC and DC stimulus can be applied to the component. In addition, because this is a low frequency technique, it is the simplest measurement technique to use.

Resonance (Q - Meter) Technique
Theory of Operation

- Tune C so the circuit resonates
- At resonance $X_D = -X_C$, only R_D remains



$$X_C = \frac{V}{I} = \frac{R_D V}{e} \text{ (at resonance)}$$

$$Q = \frac{|X_D|}{R_D} = \frac{|X_C|}{R_D} = \frac{|V|}{e}$$

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Resonant Method
Advantages and Disadvantages

Very good for high Q - low D measurements

Requires reference coil for capacitors

Limited L,C values accuracy

Vector	Scalar
75kHz - 30MHz	22kHz - 70MHz
automatic and fast	manual and slow
easy to use	requires experienced user
limited compensation	No compensation

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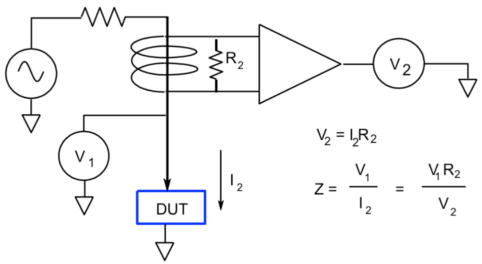
The Resonant technique, or Q-meter, used to be a very manual measurement technique. However, the design of automatically tunable air capacitor standards allows today fast and error free measurement of high Q or low D components. In low D capacitor test, it is still difficult to achieve high accuracy measurements due to the need for very stable reference inductors, which are difficult to design.

Testing chip or SMD capacitors requires specific test fixtures which have strays, essentially stray capacitance, that influence the value of the tuning capacitance. With the new automatic technique, test fixture parasitics can be compensated for by offset compensation. This requires accurate design and evaluation of the stray capacitance of the test fixture.

I - V Probe Technique
Theory of Operation



$V_2 = I_2 R_2$

$$Z = \frac{V_1}{I_2} = \frac{V_1 R_2}{V_2}$$

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I-V (Probe)

Advantages and Disadvantages

- Medium frequency, 10kHz < f < 110MHz
- Moderate accuracy and measurement range
- Grounded and in-circuit measurements
- Simple-to-use

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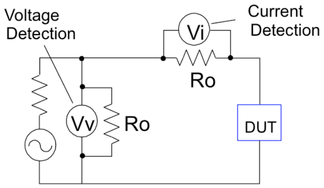
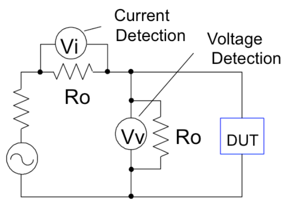
The I-V, or "probe technique", provides very good mid-frequency range performance, extending up to 100 MHz. Another key feature of this technique is that it is a floating measurement technique, thus grounded and in-circuit measurements are very easy.

RF I-V
Theory of Operation

High Impedance Test Head



Low Impedance Test Head



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RF I-V

Advantages and Disadvantages

- High frequency, 1MHz < f < 1.8GHz
- Most accurate method at > 100 MHz
- Grounded device measurement

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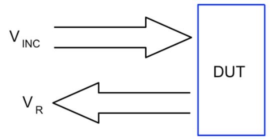
The RF I-V technique provides very good high-frequency range performance, extending up to 1.8 GHz. This is the most accurate technique at frequencies higher than 100 MHz.

Although this is a 50 Ohm system, the technique has a very good impedance measurement range with quite good accuracy

Network Analysis (Reflection) Technique
Theory of Operation



$$\Gamma = \frac{V_R}{V_{INC}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

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Network Analysis

Advantages and Disadvantages

- High frequency
  - Suitable, f > 100 kHz
  - Best, f > 1.8 GHz
- Moderate accuracy
- Limited impedance measurement range (DUT should be around 50 ohms)

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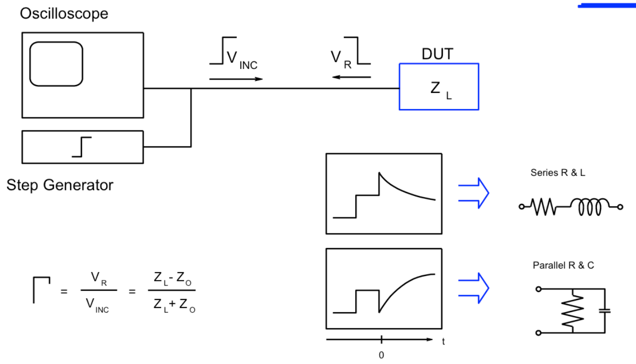
Network analysis is the best solution for very high frequency measurements, extending up to tens of GHz. Measurements as low as 100 KHz are possible with this technique (directional bridge low-end limit). Given the existence of the autobalancing bridge, I-V probe, and RF I-V techniques, it is advised that the network analysis technique be used for measurements above 1.8 GHz. Above 1.8 GHz, the reflection technique is the only measurement technique currently available.

TDR
Theory of Operation



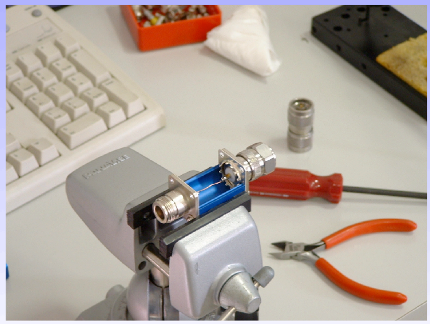
$$\Gamma = \frac{V_R}{V_{INC}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

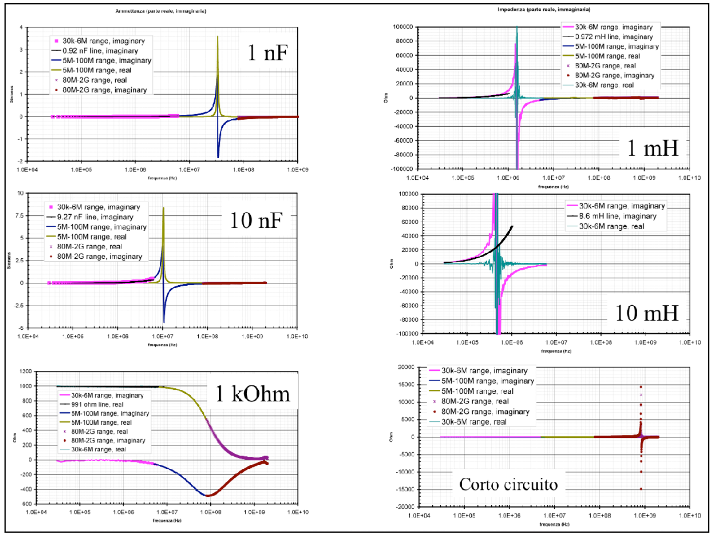
TDNA (TDR)
Advantages and Disadvantages

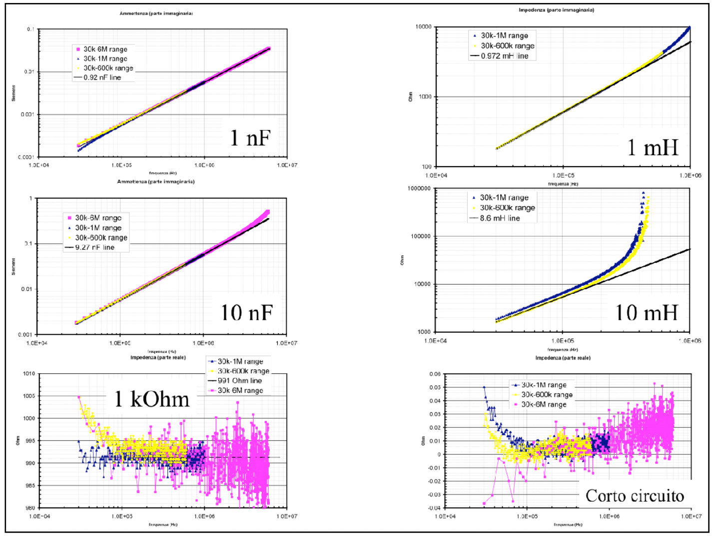
- Reflection and transmission measurements
- Single and multiple discontinuities or impedance mismatches ("Inside" look at devices)
- DUT impedance should be around 50 ohms
- Not accurate for DUTs with multiple reflections
- Good for test fixture design, transmission lines, high frequency evaluations

Although this is a 50 Ohm system, the technique has a very good impedance measurement range with quite good accuracy.

Measurement examples






1 nF
30k 6M range
30k-1M range
30k-600k range
0.92 nF line
1 mH
30k-1M range
30k-600k range
0.972 mH line
10 nF
30k-6M range
30k-1M range
30k-600k range
9.27 nF line
10 mH
30k-1M range
30k-600k range
8.6 mH line
1 kOhm
30k-1M range
30k-600k range
991 Ohm line
30k 6M range
Corto circuito
30k-1M range
30k-600k range
30k-6M range