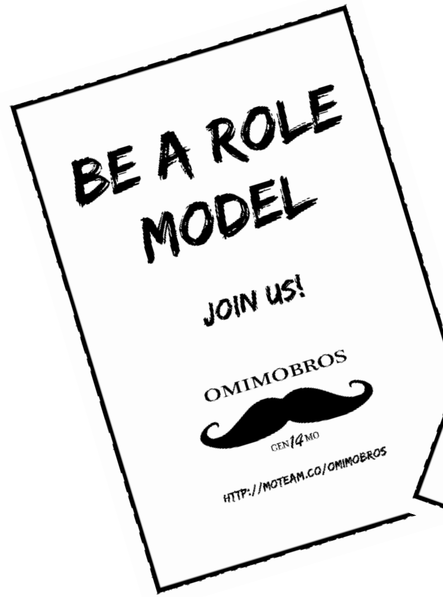
Measuring Impedance with the Bode 100

OMICRON Lab Webinar Nov. 2014

Let‘s start with a question

- Why do the presenters wear moustaches?



http://moteam.co/omimobros

Agenda

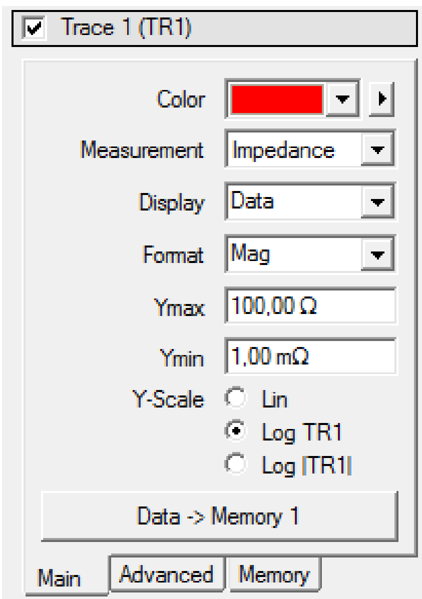
- Direct Impedance measurement methods
- Indirect Impedance via Gain
- Measurement examples
- Time for discussion
- Wishes & feature requests

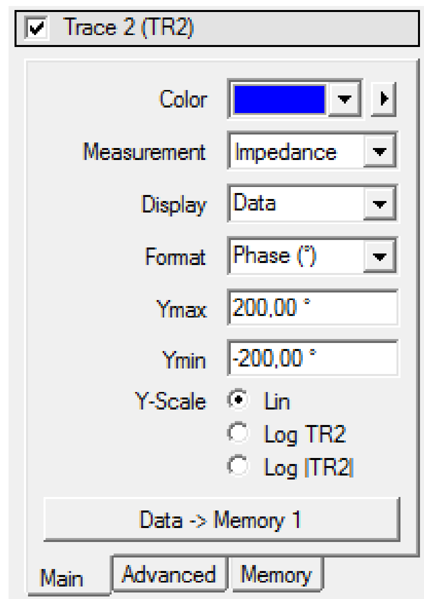
Impedance Measurement Methods

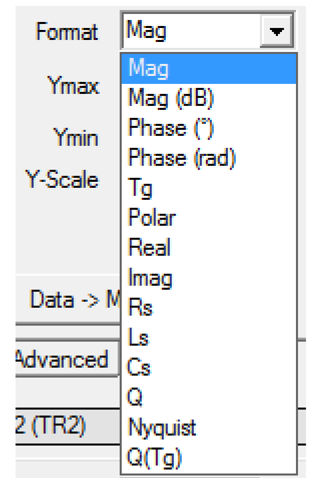
- Direct Measurements
  - One-Port
  - Impedance Adapter
  - External bridge (e.g. High Impedance)
- Indirect Measurements (via Gain)
  - Two-Port shunt-thru
  - Two-Port series-thru
  - Voltage-Current Gain

Direct Measurement Methods

- Support full impedance calibration (open/short/load)
- Directly displaying impedance, reflection and admittance
  - Ls, Lp, Rs, Rp, Cs, Cp, Q, VSWR

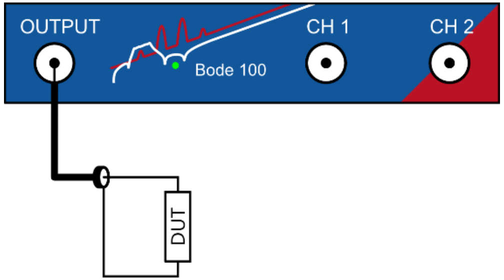




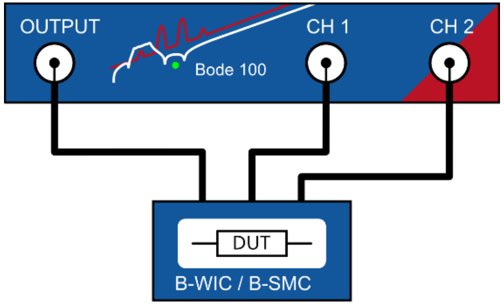


Direct Measurement Methods

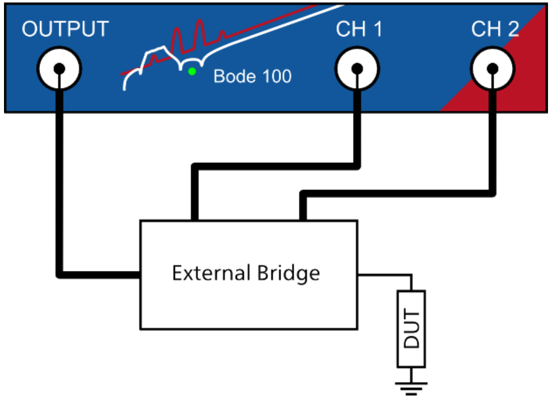
One-Port



Impedance Adapter



External Bridge

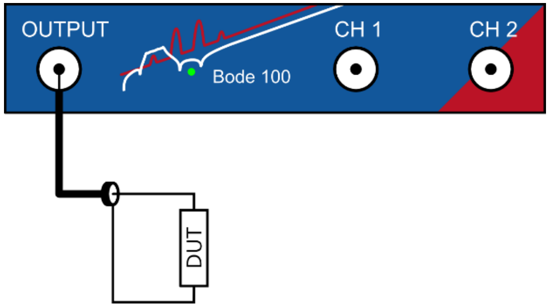


One-Port Method (Overview)

- Standard VNA impedance measurement via S11
- As with any VNA most accurate around 50 Ω
- Recommended from 0.5 Ω - 10 kΩ
- Full frequency range 1 Hz – 40 MHz
- Uncalibrated measurement is possible
- Full impedance calibration possible to remove influence of cable or measurement setup

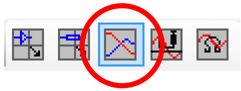
One-Port Method (Setup)

Measurement setup



Bode Analyzer Suite

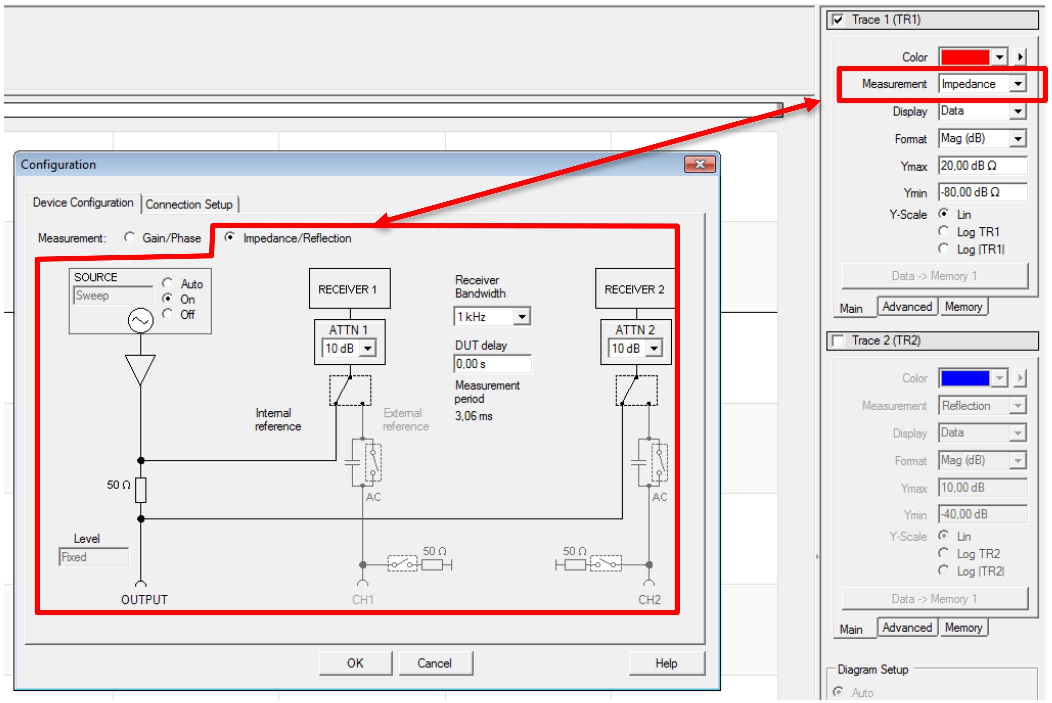
1. Frequency Sweep Mode



2. Trace Settings
   - Measurement: Impedance
   - Format: e.g. Mag & Phase or Real & Imag...
3. Frequency Settings
   - Start Frequency
   - Stop Frequency
   - Sweep Mode, Number of Points

One-Port Method (Device Configuration)

If **Measurement** is set to Impedance, the **Impedance/Reflection** configuration is used for the measurement



One-Port Example

Measure inductance and self resonance of a power inductor (uncalibrated)

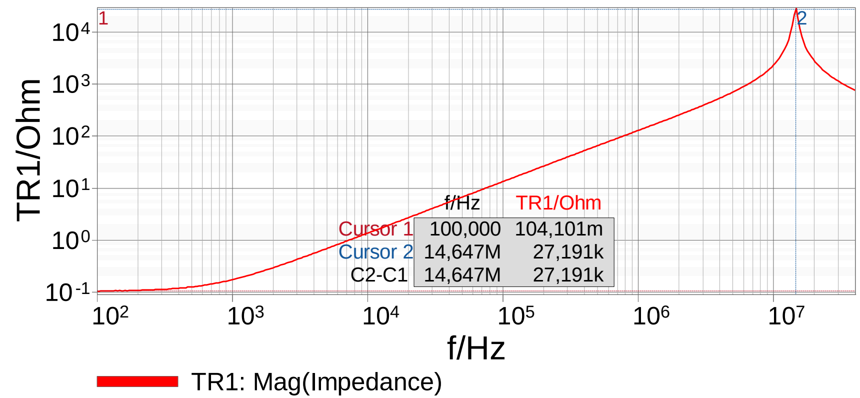
DUT: 22 µH shielded power inductor (WE 744 77 912 2)

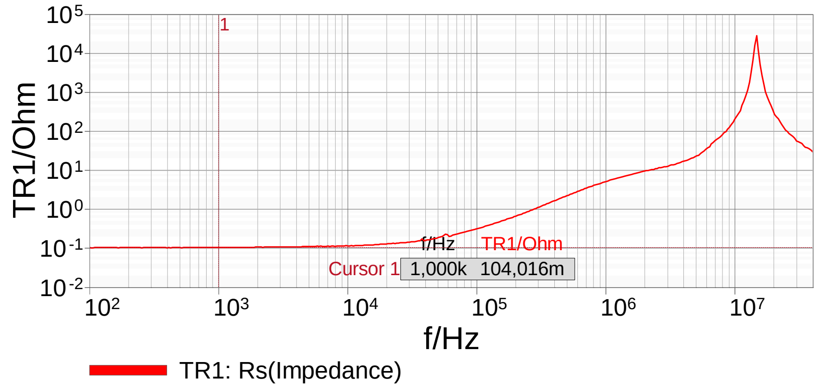
Datasheet:

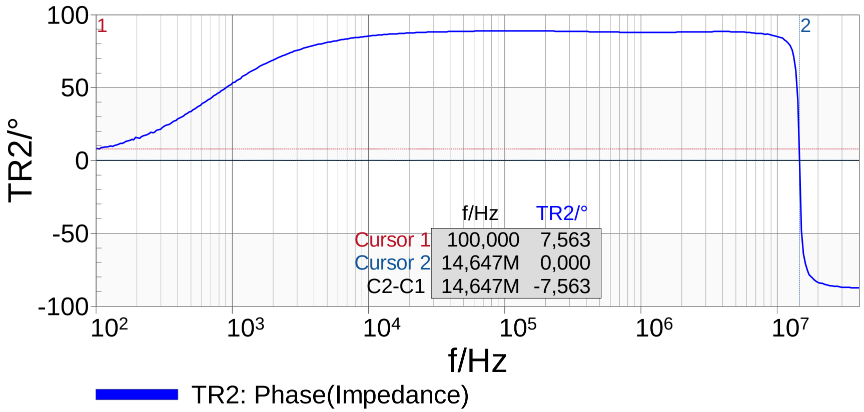
D Electrical Properties:

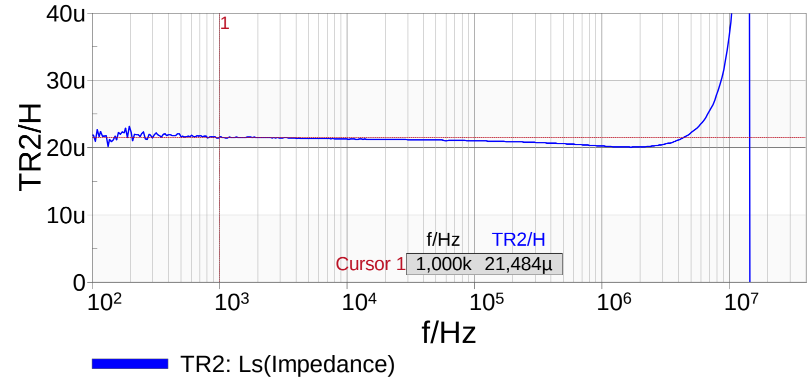
Properties	Test conditions		Value	Unit	Tol.
Inductance	1 kHz/ 250 mV	L	22	µH	±20%
Rated current	$\Delta T = 40$ K	I_R	1.41	A	max.
Saturation current	$\lvert\Delta L/L\rvert < 10\%$	I_{sat}	1.7	A	typ.
DC Resistance	@ 20°C	R_{DC}	0.09	Ω	typ.
DC Resistance	@ 20°C	R_{DC}	0.11	Ω	max.
Self resonant frequency		f_{res}	15	MHz	typ.

One-Port Example







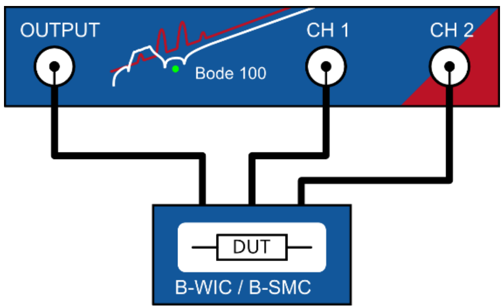


Impedance Adapter Method (Overview)

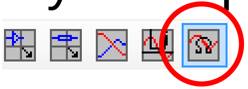
- Special software mode for our B-WIC and B-SMC impedance test fixtures
- Frequency range 1Hz – 40 MHz
- Max. impedance range 0.02 Ω - 600 kΩ
- Full impedance calibration required

Impedance Adapter Method (Setup)

Measurement setup

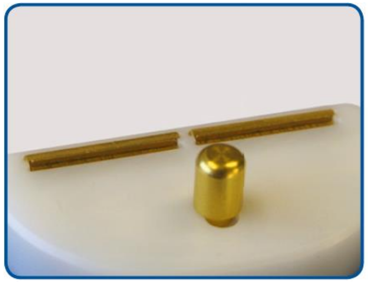


Bode Analyzer Suite

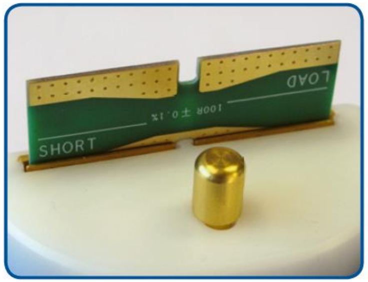
1. Frequency Sweep (Impedance Adapter) Mode 
2. Trace Settings
   - Format: e.g. Mag (Log) & Phase or Rs & Cs
3. Frequency Settings
   - Start Frequency
   - Stop Frequency
   - Sweep Mode, Number of Points
4. Device Configuration
   - pre-set for excellent results

Impedance Adapter Calibration

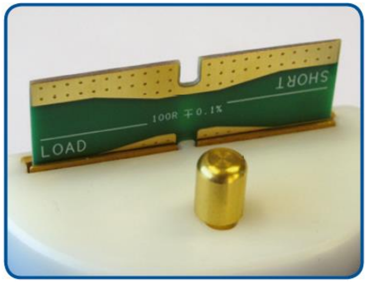
- B-WIC



OPEN

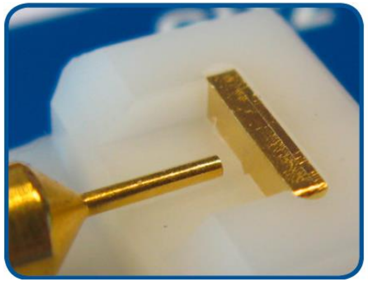


SHORT



LOAD

- B-SMC



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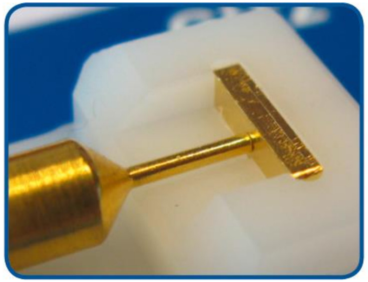
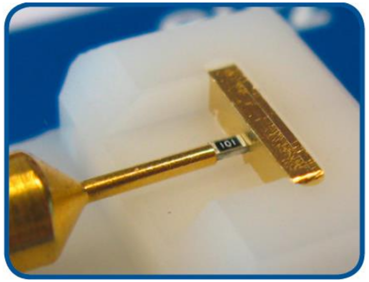


SHORT



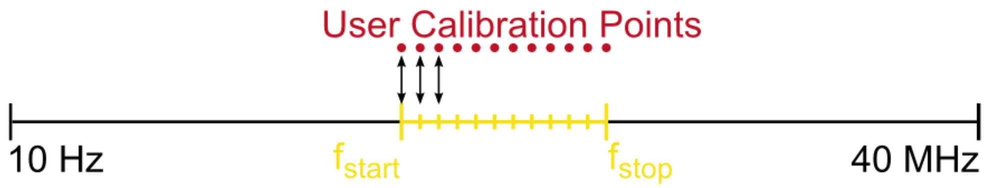
LOAD

User Calibration / Probe Calibration

- User Calibration (User Range Calibration)

  Calibrates at exactly the frequencies that are currently measured

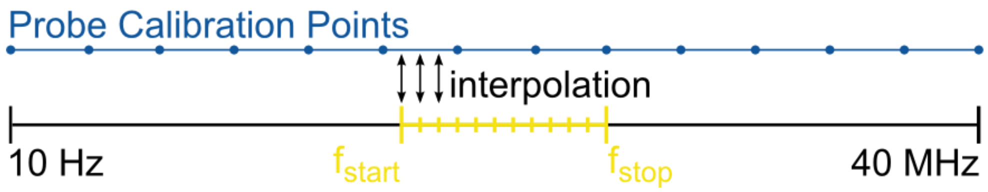
  \+ No interpolation, suitable for narrowband probes



- Probe Calibration (Full Range Calibration)

  calibrates at pre-defined frequencies and interpolates in-between

  \+ Calibration does not get lost when frequency range is changed



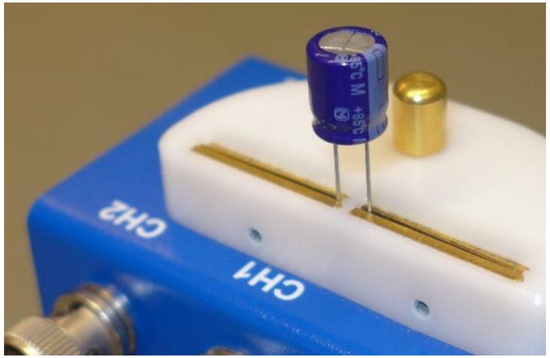
Impedance Adapter Example

Measure capacitance and ESR of a aluminum capacitor

DUT: 220 µF aluminum capacitor (ECA1HM221)

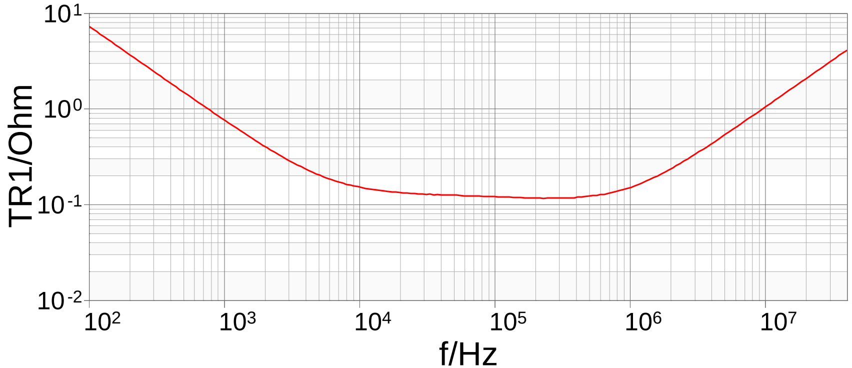
■ Standard Products

W.V.	Cap.	Case size		Specification		Lead Length				Part No.	Min. Packaging Q'ty	
	(±20 %)	Dia.	Length	Ripple Current (120 Hz) (+85 °C)	tan δ (120 Hz) (+20 °C)	Lead Dia.	Lead Space: Straight	Lead Space: Taping *B	Lead Space: Taping *i		Straight Leads	Taping
(V)	(µF)	(mm)	(mm)	(mA r.m.s.)		(mm)	(mm)	(mm)	(mm)		(pcs)	(pcs)
	220	10	12.5	400	0.12	0.6	5.0	5.0		ECA1HM221( )	200	500

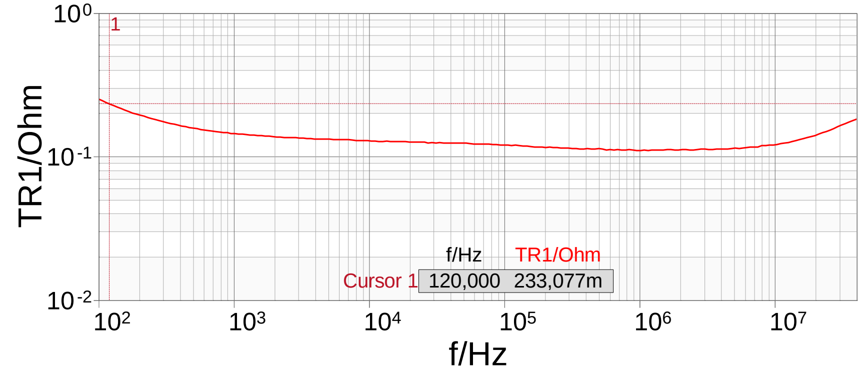


$$ESR = \frac{\tan(\delta)}{\omega C} = \frac{0.12}{2\pi \cdot 120Hz \cdot 220\mu F} = 0.72\ \Omega\ @\ 120\ Hz$$

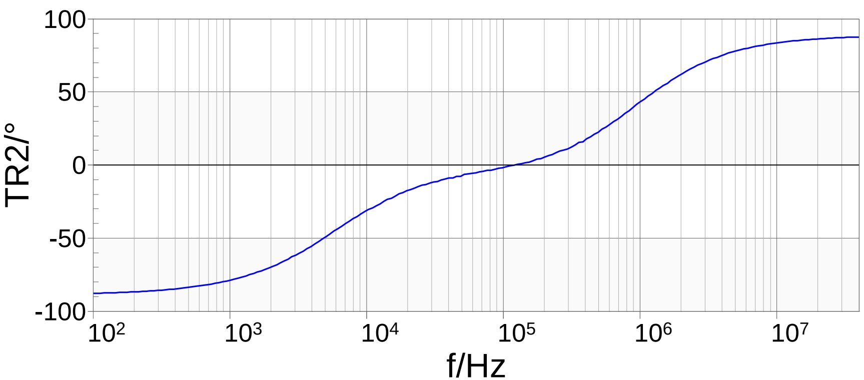
Impedance Adapter Example



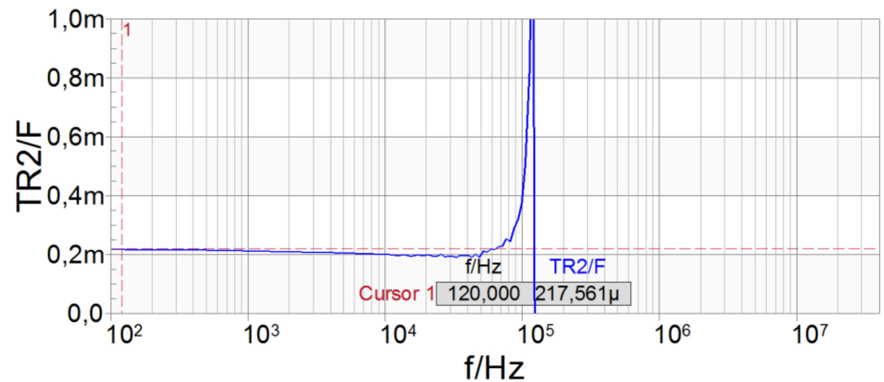
TR1: Mag(Impedance)



TR1: Rs(Impedance)



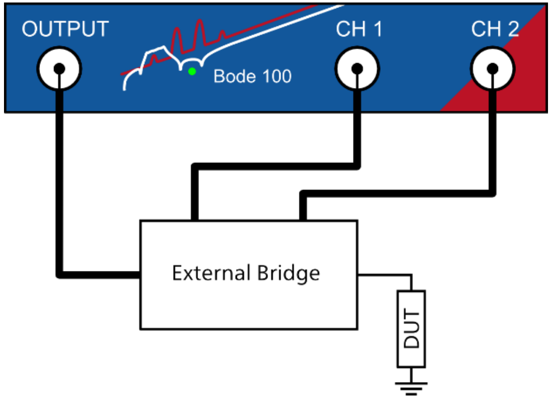
TR2: Phase(Impedance)

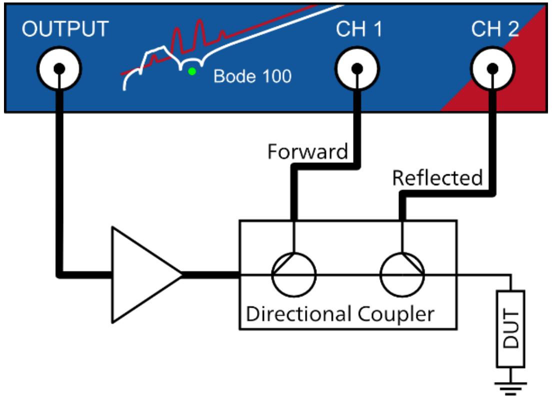


TR2: Cs(Impedance)

External Bridge Method

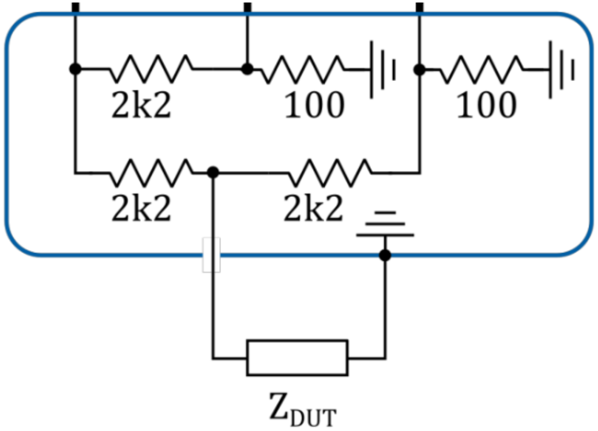
- Use with custom measurement bridges
  (e.g. optimized for very high impedance values)
- Use for measurements that require high power
  (external amplifier + directional coupler)
- Frequency range 1Hz – 40 MHz or depending on bridge
- Full impedance calibration required





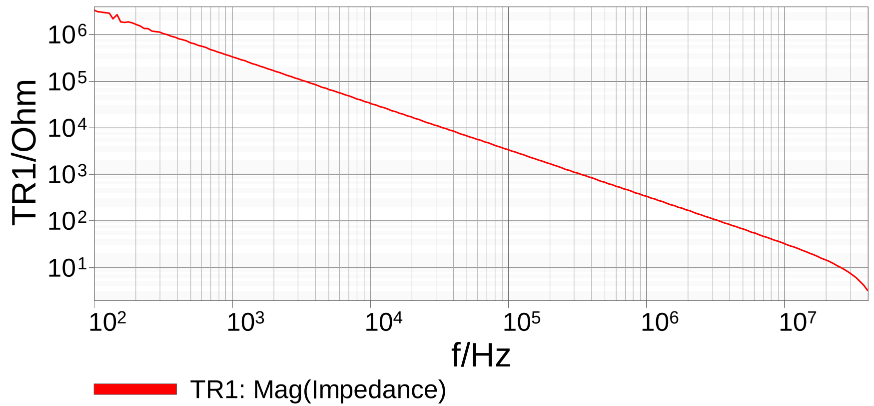
External Bridge Example

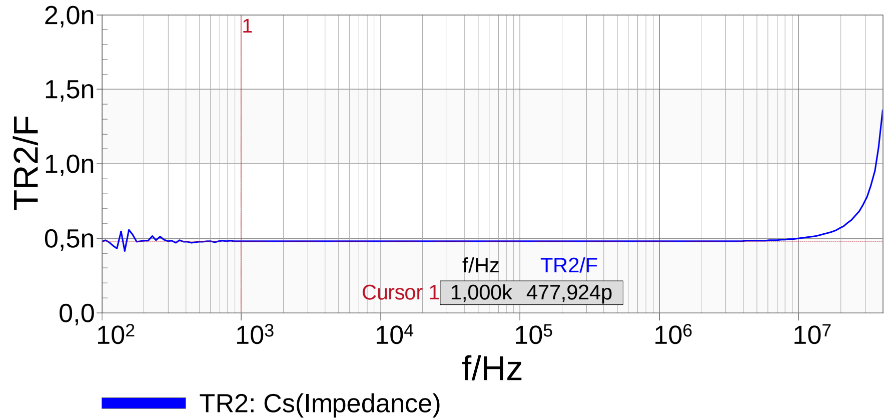
- Measure very high impedance with custom bridge
- Detailed explanation is available for download http://www.omicron-lab.com/bode-100/application-notes-know-how/articles-use-cases.html#3



External Bridge Example

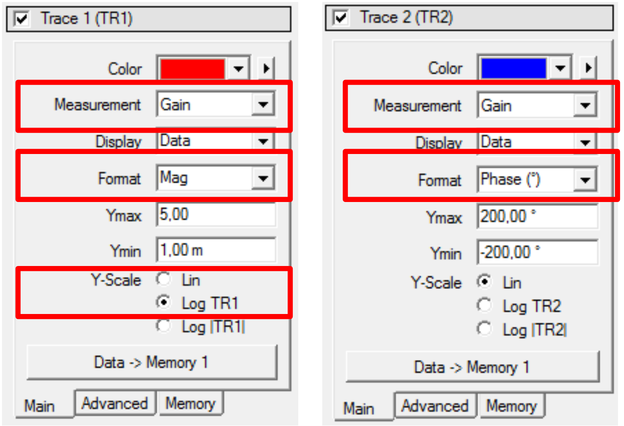
DUT: 470 pF capacitor





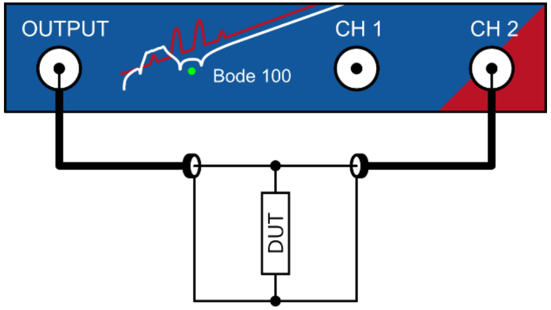
Indirect Measurements (via Gain)

- Bode 100 measures Gain
  - Gain result must be transformed to impedance
  - or already equals impedance
- Thru calibration to remove influence of probes & cables
- Trace settings:

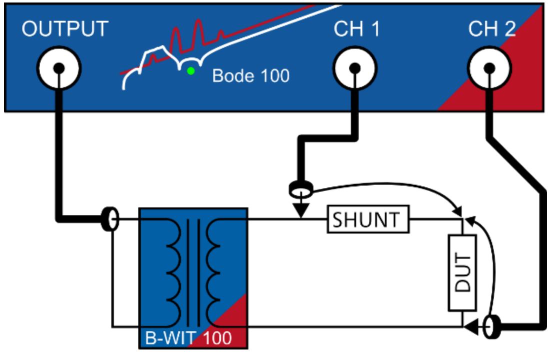


Indirect Measurement Setups

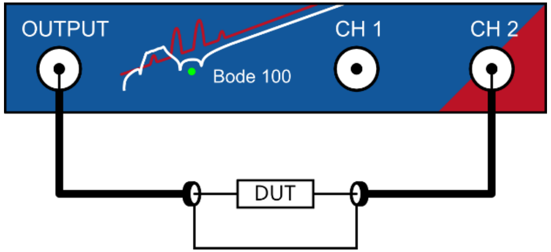
Shunt-Thru



Voltage-Current Gain

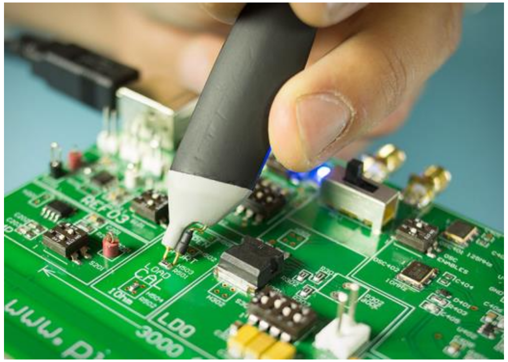


Series-Thru



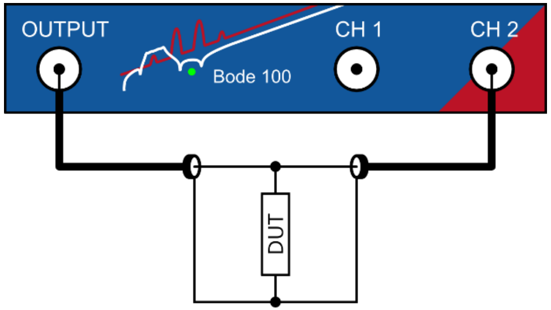
Shunt-Thru Method

- Derives impedance from standard S21 VNA measurement
- Very accurate below 10 Ω
- Best choice for ultra-low impedance measurements (mΩ)
- Full frequency range 1Hz – 40 MHz
- Uncalibrated measurement is possible
- Thru calibration possible to remove influence of cables or probes



Shunt-Thru Method

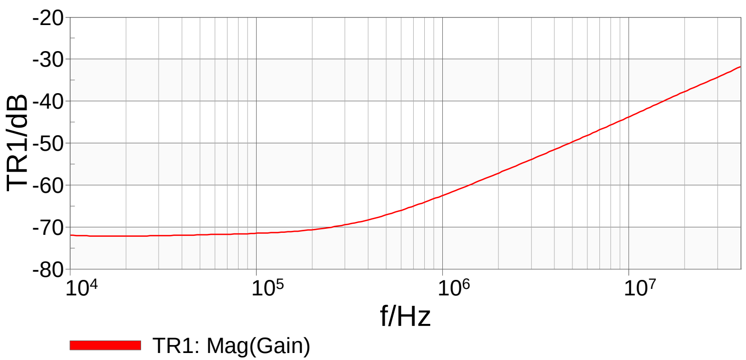
- Measurement Setup



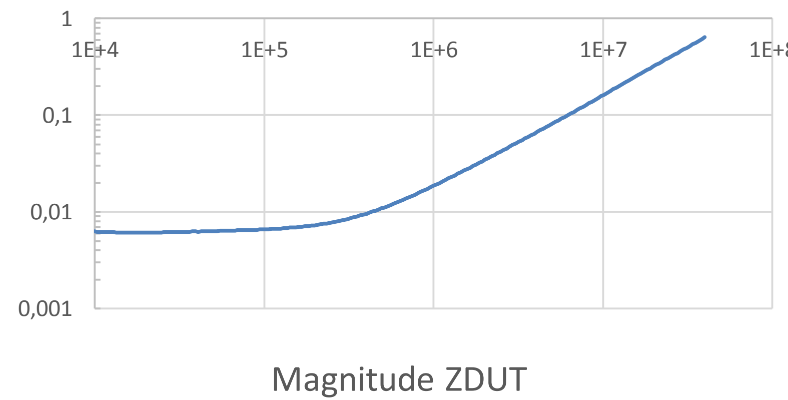
- Convert S21 to Impedance: $Z_{DUT} = 25\Omega \frac{S_{21}}{1-S21}$
- For frequencies <10kHz use a common mode transformer to reduce the cable braid error!
- Configure Bode 100 to measure S21
  (terminate CH2 with 50 Ω and select Gain)

Shunt-Thru Example

5 mΩ shunt resistor (Dale WSR-2)



Calculate Impedance



Inductance at 10 MHz: $L = \frac{X}{\omega} = \frac{0.17\Omega}{10.6MHz \cdot 2\pi} = 2.55\ \mathrm{nH}$

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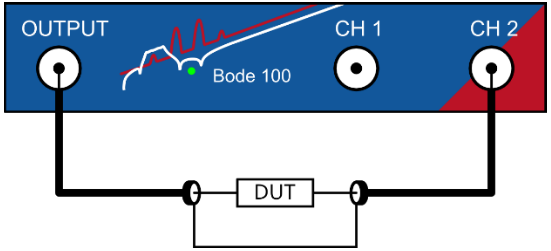
Series-Thru

- Derives impedance from standard S21 VNA measurement
- Very accurate for high impedance values > 100 Ω
- Full frequency range 1 Hz – 40 MHz
- Uncalibrated measurement is possible
- Thru calibration possible to remove influence of cables

Series-Thru

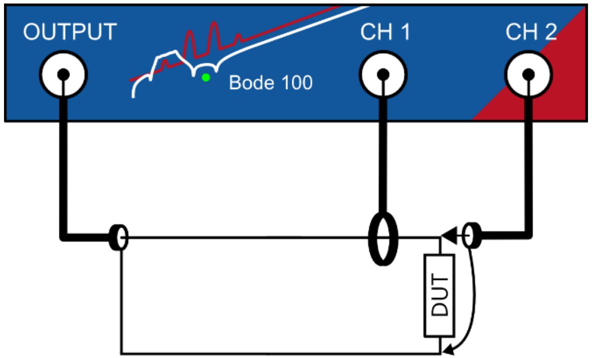
- Measurement setup



- Convert S21 to Impedance: $Z_{DUT} = 100\ \Omega \cdot \frac{1-S_{21}}{S_{21}}$

Voltage-Current Gain

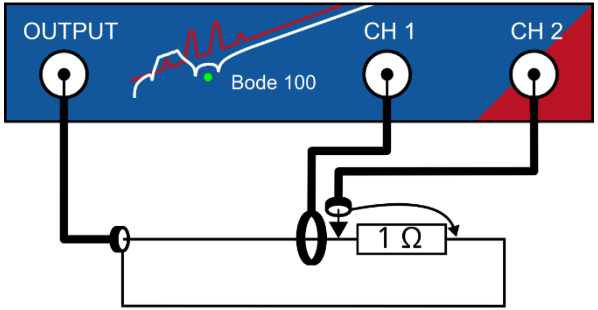
- Suitable for in-circuit measurements
  (input impedance/output impedance)
- Modulate signal with output of Bode 100
- Connect CH1 to current and CH2 to voltage signal →



$$Gain = \frac{V_{CH2}}{V_{CH1}} = \frac{V}{I} = Z$$

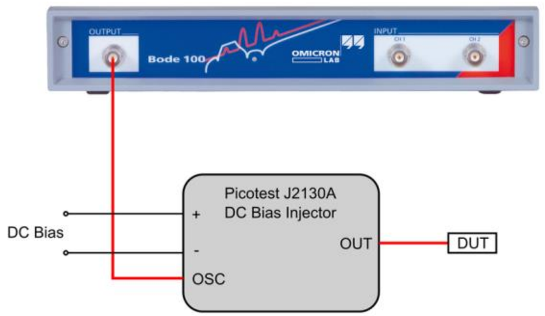
Voltage-Current Gain calibration

- Thru-calibration is possible by using a 1 Ω resistor. This compensates the frequency response of the probes



Application Example – DC Sensitivity

- Measure DC voltage sensitivity of ceramic capacitors
- One-port method and DC-bias injector (J2130A)
- See also application note: http://www.omicron-lab.com/bode-100/application-notes-know-how/application-notes/dc-biased-impedance-measurement.html



Feel free to ask questions via the chat function...

If time runs out, please send us an e-mail and we will follow up.

You can contact us at: info@omicron-lab.com

Thank you for your attention!

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