Non-Invasive Stability Measurement of Power Supplies with the Bode 100

OMICRON Lab Webinar Nov. 2014

PICOTEST

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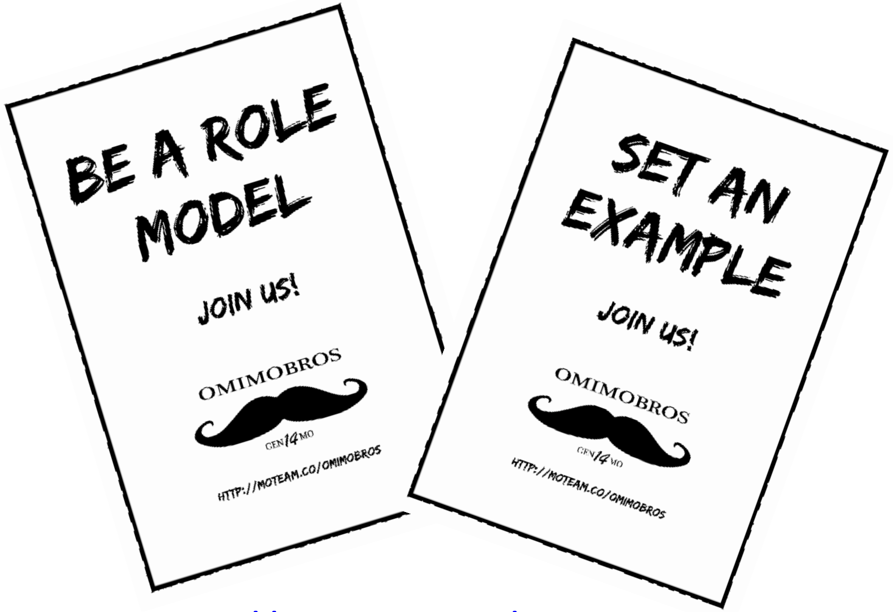
Let‘s start with a question

- Why do the presenters wear moustaches?



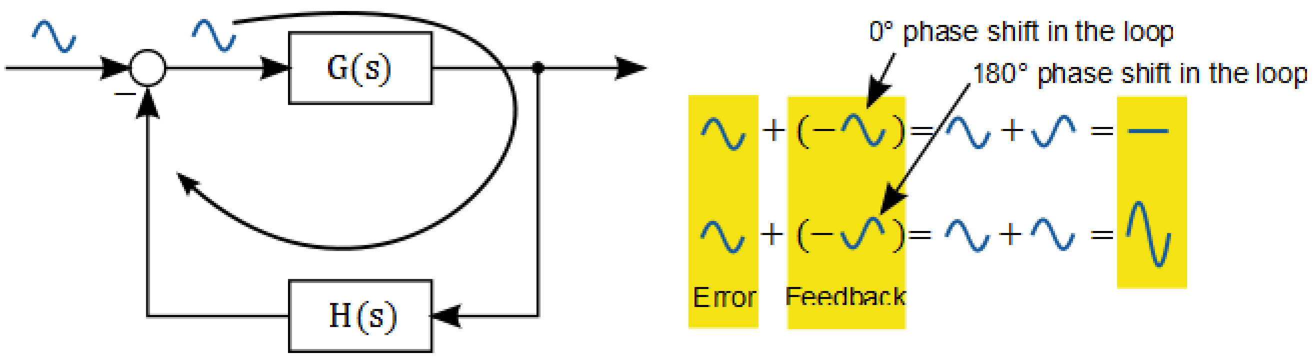
http://moteam.co/omimobros

Agenda

- What is stability?
- Stability Measurement Methods
- Short introduction to NISM by Steve Sandler
- How to measure the output impedance
- Basic and advanced PM calculation method
- Live measurement of a linear regulator
- Live measurement of a SMPS
- Q&A

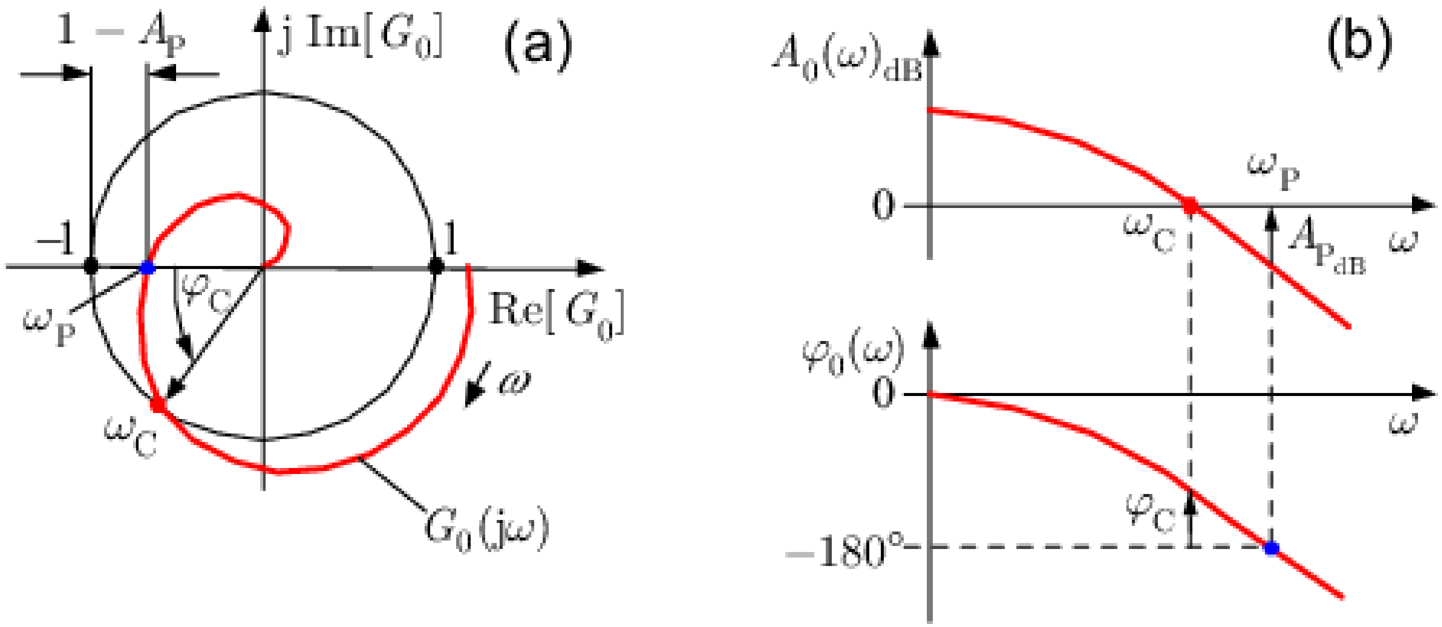
Stability

Negative feedback system



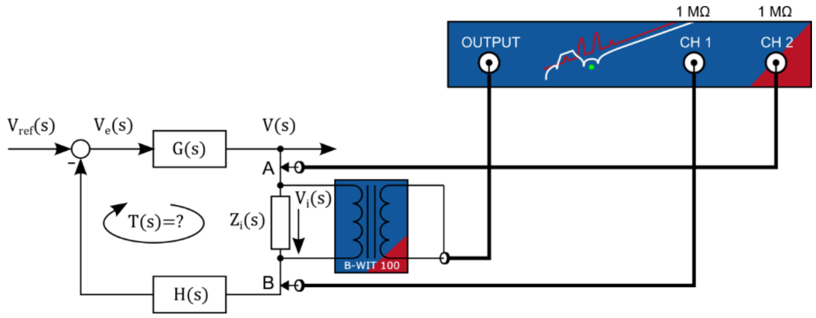
- Negative feedback → stable
- Positive feedback → oscillating (instability)

Stability Margins

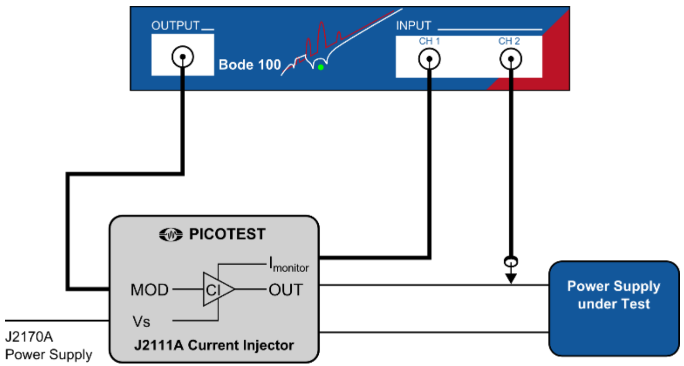


How can we measure stability

- Option A:
  Signal injection into the feedback loop



- Option B:
  Non-invasively by deriving the stability from the output impedance



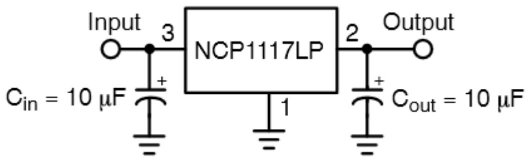
What is Non-Invasive Stability Measurement?

- Non-Invasive Stability Measurement (NISM) is a method of determining control loop stability margins without access to the feedback loop

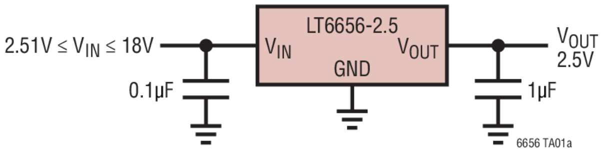
- In many situations it is not possible to access the control loop
  - Examples – POLs, Fixed Voltage Regulators, Voltage References, High BW Opamps
  - Integrated Switching regulators

- In other cases it might be impractical to break the control loop because cutting a printed circuit board trace or lifting components might be required to insert the injection signal

Voltage Regulator



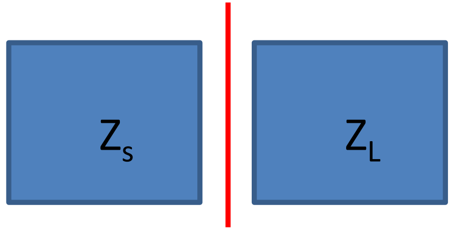
Voltage Reference



NISM is Based on Nyquist and Minor Loop Gain

- Dr. R.D. Middlebrook popularized the topic of Minor Loop Gain, T_M with his introduction of the extra element theorem which allowed us to assess the stability of switching power supplies and input filters.

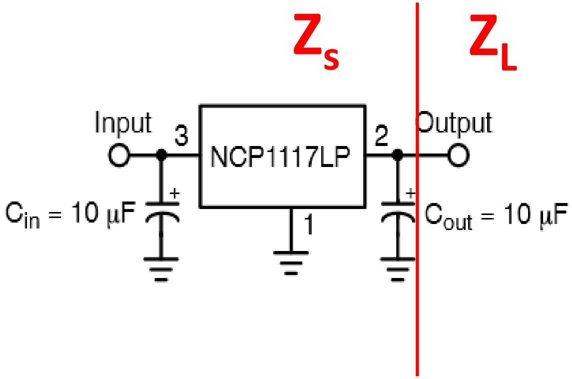
- Minor loop gain, based on Nyquist criteria is now one of the most researched power electronics topics. Many papers and articles can be found with an internet search of "forbidden region stability criteria". The concept is simple. Break a system into two parts, generally termed a System and a Load and determine the impedance of each part, Z_S and Z_L



$$T_m = \frac{Z_S}{Z_L}$$

Phase margin is determined by setting $|T_M| = 1$ and solving for phase

Separating Regulator into Z_S and Z_L

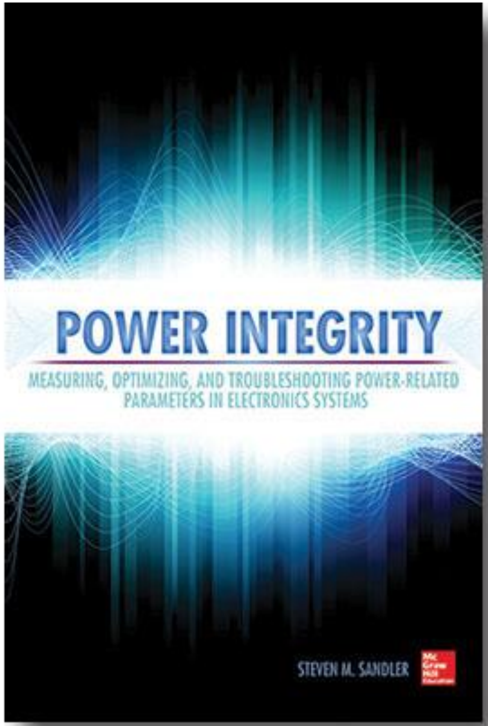


The NISM extracts data from the impedance and group delay that allow the Z_S and Z_L to be mathematically separated for the computations.

At higher phase margins, three data points are required to mathematically separate Z_S and Z_L while at low phase margins only two data points are required.

The two cursor method provides all three data points while the one cursor method only provides two. So the two cursor method is always precise while the one cursor method provides good results up to approximately 35 degrees

Learn More About Power Related Measurements



"**Power Integrity**: Measuring, Optimizing, and Troubleshooting Power-Related Parameters in Electronics Systems"

by Steve Sandler

From McGraw-Hill
November 2014

EDN Book Review by Steve Taranovich

http://www.edn.com/design/power-management/4436745/Book-Review--Power-Integrity

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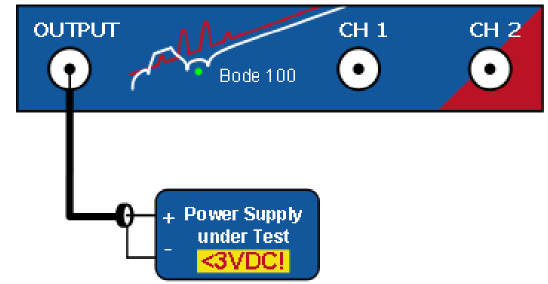
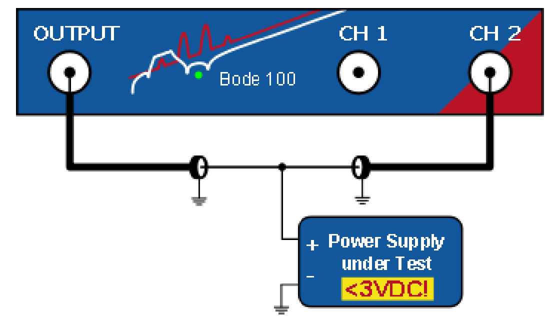
How to measure the output impedance Z_s

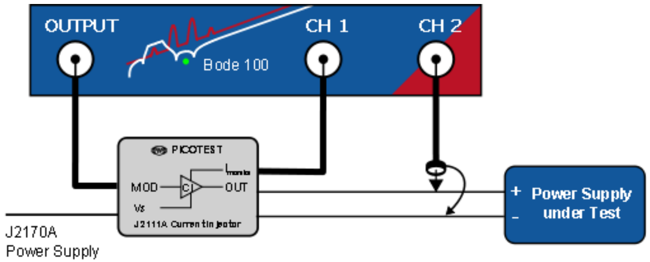
- Modulation of the output current
  - Using the Picotest J2111A Current Injector
  - Directly with the Bode 100 for low voltages <3 V (!)
  - Alternative setups using AC loads and probes

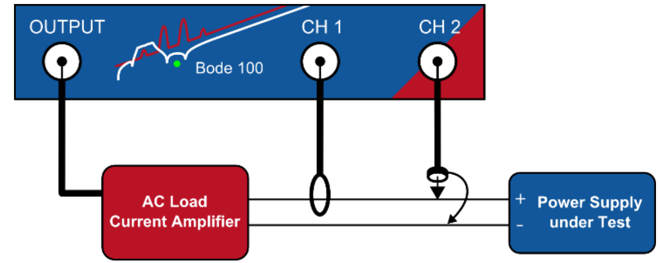


- Methology:
  - measure current at Ch1
  - measure voltage at Ch2
  - the resulting gain is the output impedance

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



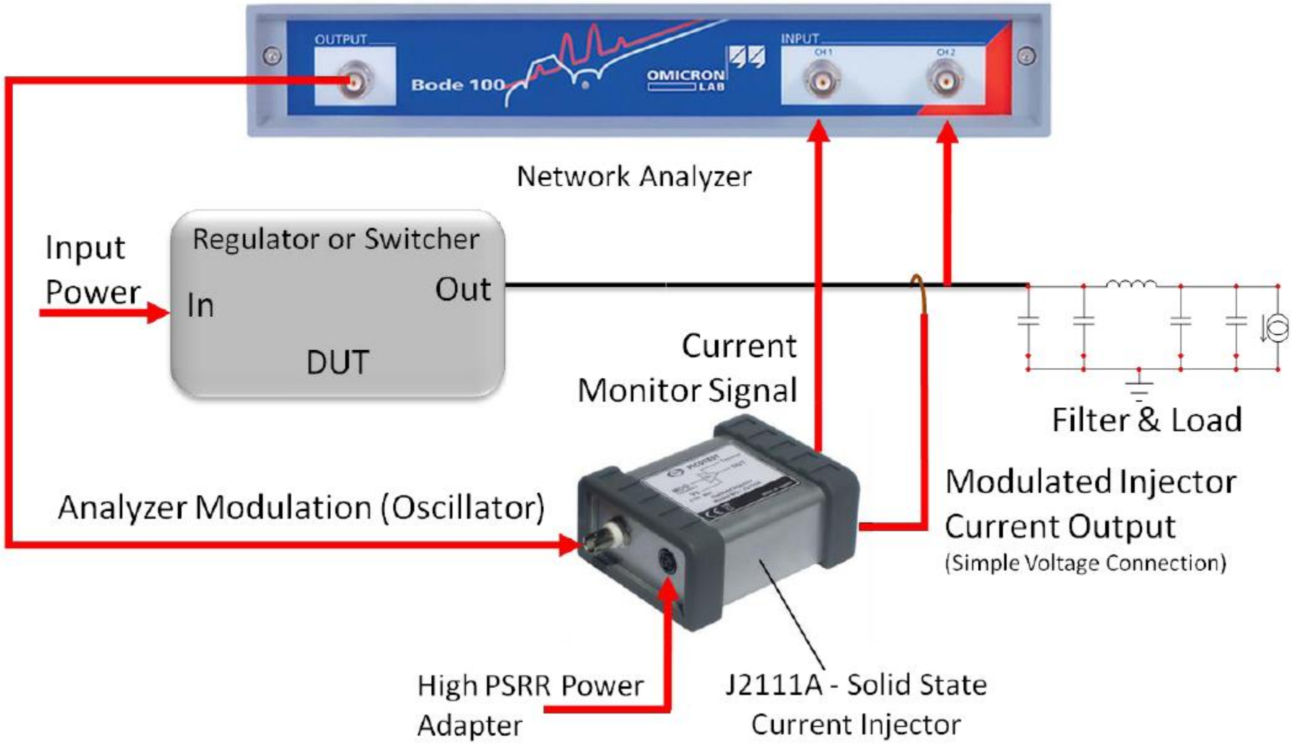




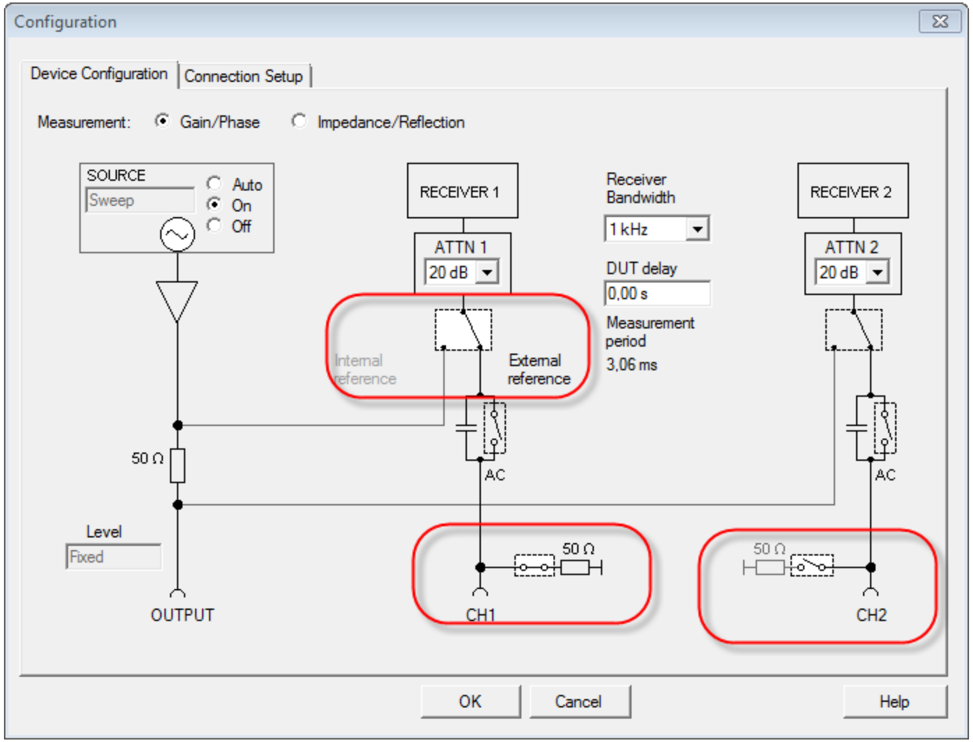
Picotest J2111A Current Injector

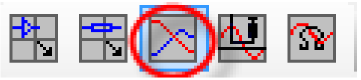
- high speed current injector
- f range: DC – 40 MHz
- usable for power supplies with up to 40 V output
- includes precision current monitor output
- DC bias 24mA
- max AC current 48 mA_{pp}

Measurement Setup



Configure the Bode 100 for J2111A

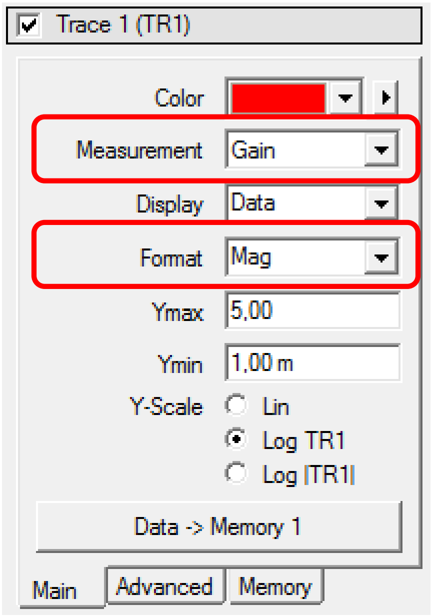


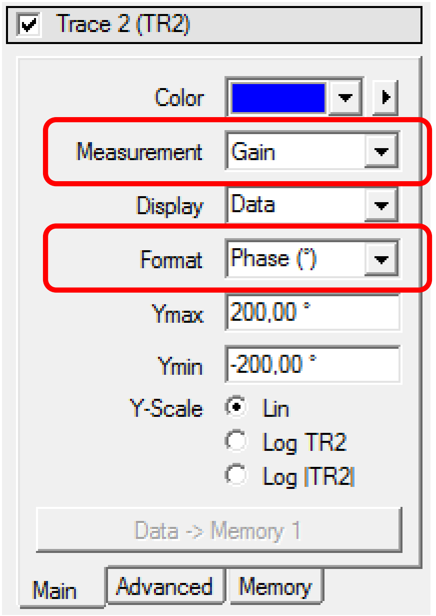


- Device configuration
  - Frequency Sweep Mode
  - external reference
  - CH1: 50 Ohms
  - CH2: high impedance

Trace Settings for the output impedance measurement

- TR1: Output Impedance
- TR2: Q of group delay



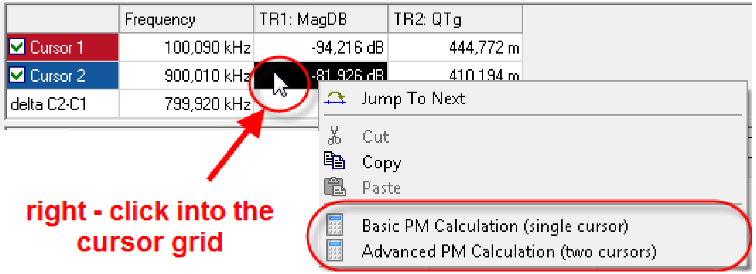


Two Calculation Methods

- Basic (single cursor) PM calculation
  - is implemented in Bode Analyzer Suite since >3 years
  - used to get a quick stability impression
  - reccomended for low PM values < 35°
  - derives the phase margin from Q(Tg)

- Advanced (two cursor) PM Calculation
  - new in BAS V2.43 SR1
  - more accurate for PM values > 35°
  - derives the phase margin from Q(Tg) and Z_s

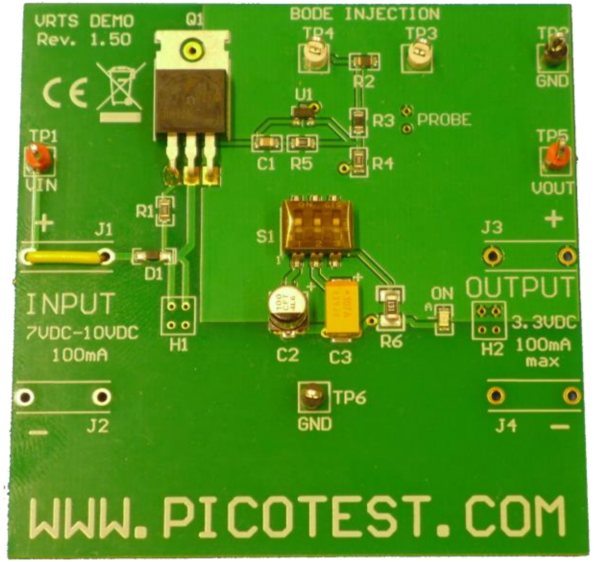
Both PM calculations are available by right clicking on the cursor Grid.



Our DUT

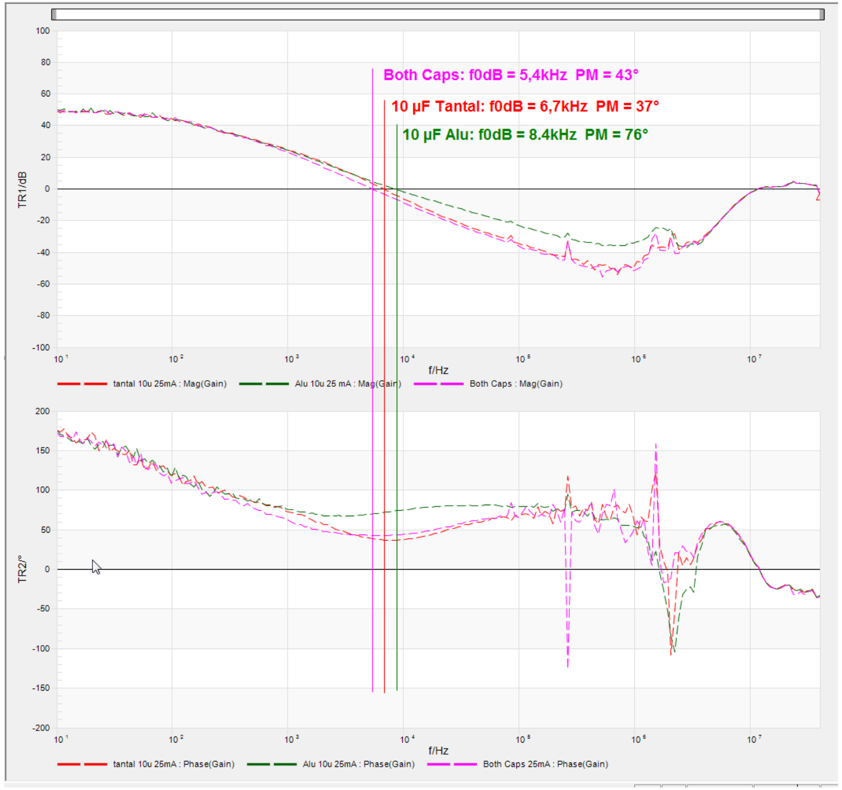
- VRTS 1.5 Demo board
  - Linear regulator
  - Switchable Caps & load
    - 2 oputput caps
      (10µF Tantal, 10 µF Aluminium)
    - 1 resistive load
    - 1 LED
  - On-board 5 Ω injection resistor

- Every attendee can request one just send us an E-Mail.

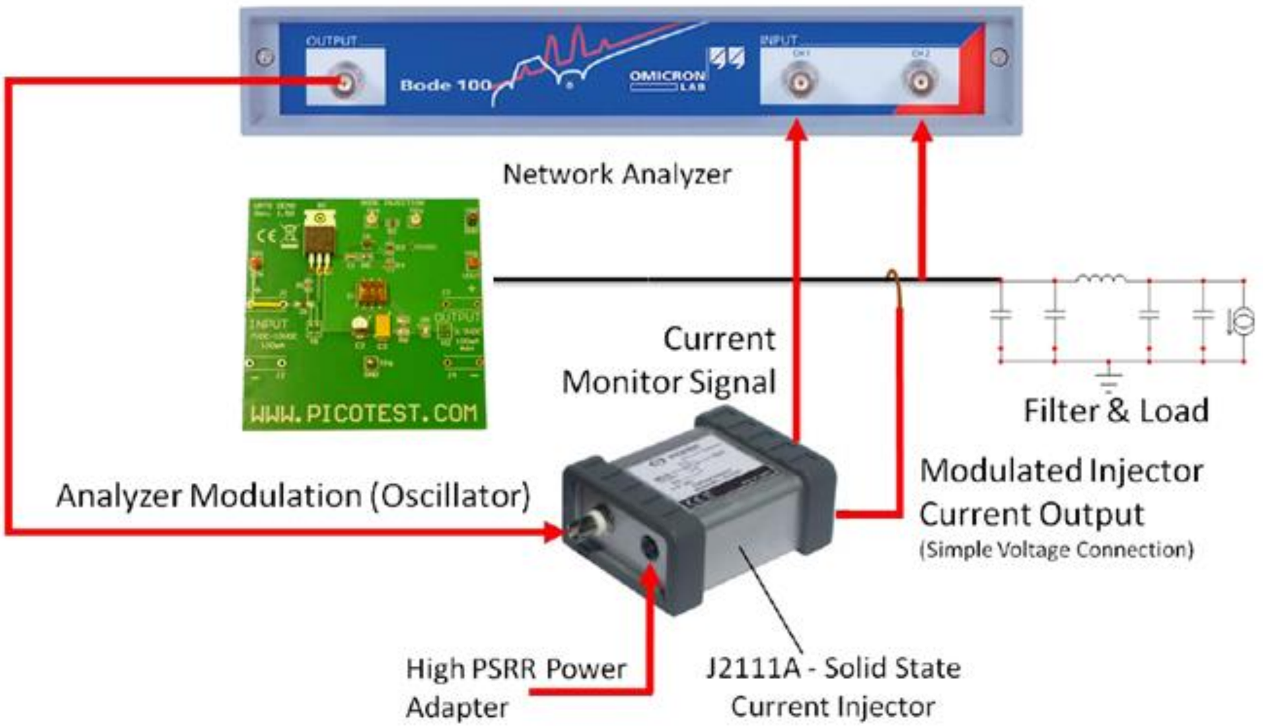


Results from voltage injection method

- Stability results with voltage injection method:
  - Alu 10 µF:
    f_{0dB} = 8.4 kHz PM= 76°
  - Tantal 10 µF:
    f_{0dB} = 6.7 kHz PM= 37°
  - Both used:
    f_{0dB} = 5.4 kHz PM= 43°

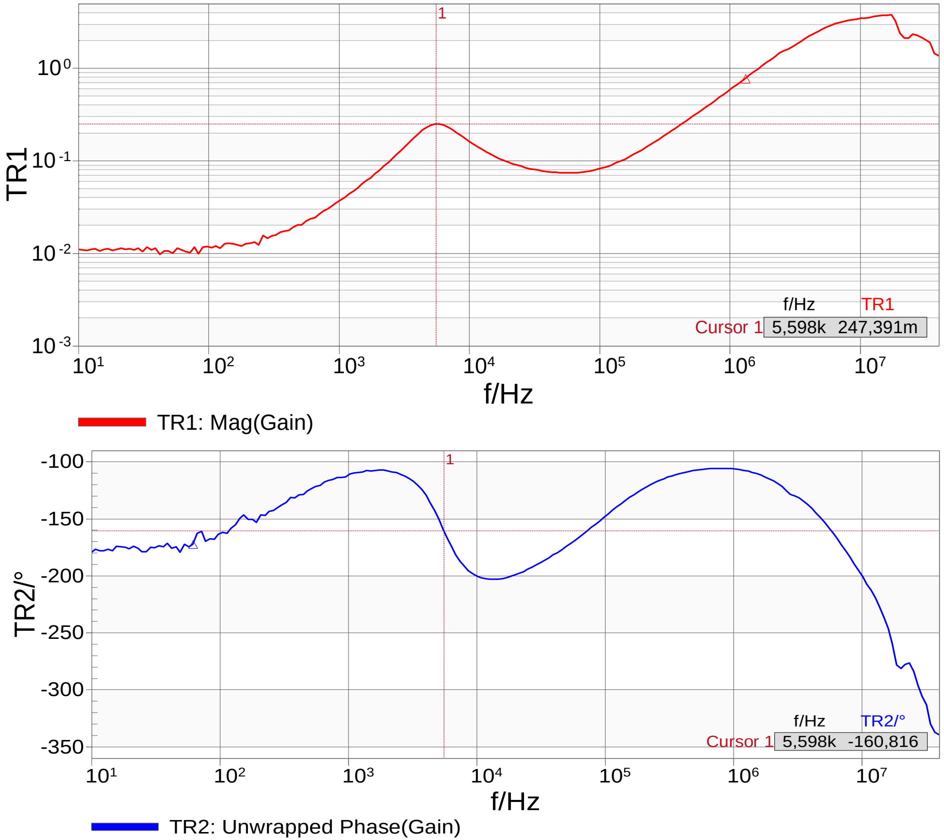


Measurement Setup for Z_s



Output Impedance Measurement

- Measurement with both Capacitors
  - output impedance peak at 5.6 kHz (247 mOhms)
  - Phase starts resistive (φ = -180°)
    180° phase shift caused by direction of load current



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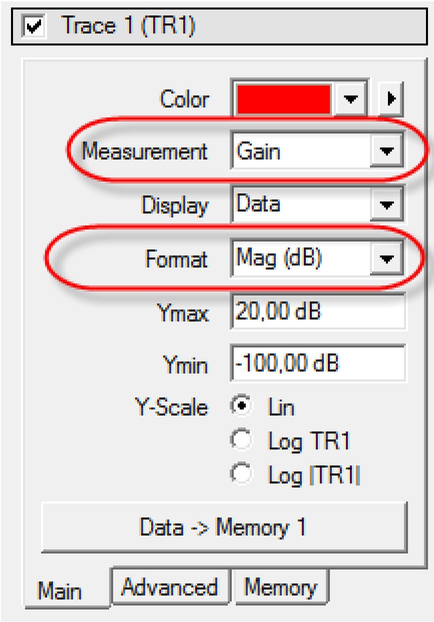
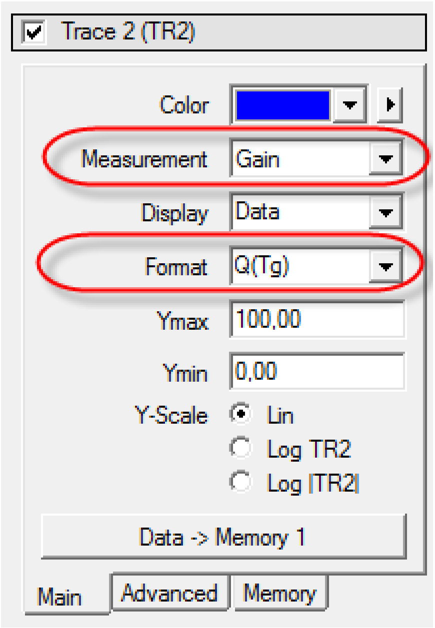
Trace Settings for the NISM measurement

- TR1: Output Impedance
- TR2: Q of group delay





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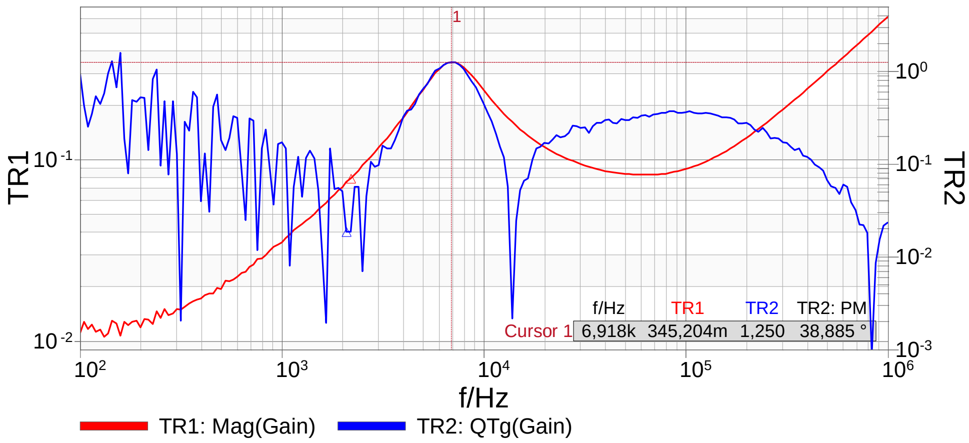
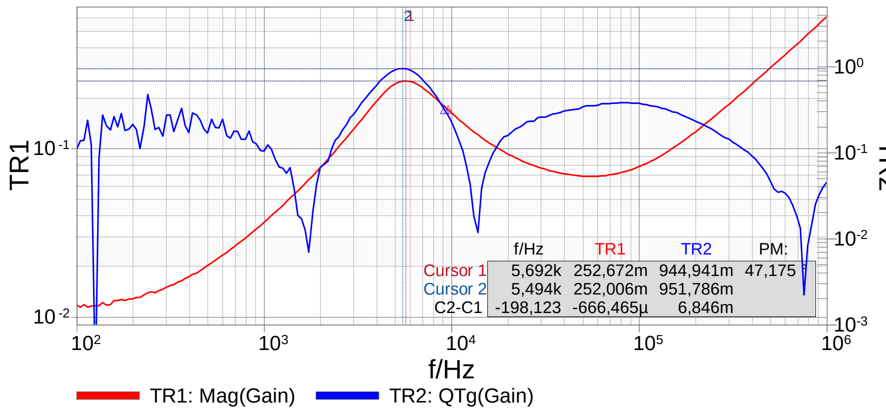
Non invasive stability measurement

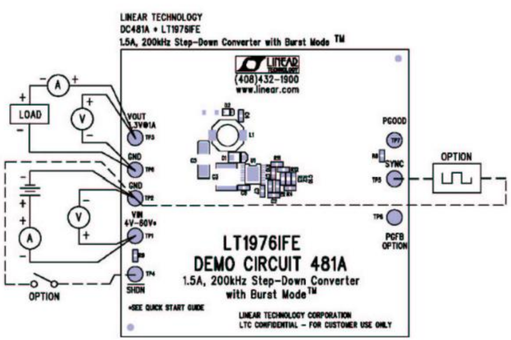
- Measurement result:
  - 10µF Tantal: PM 38° (single cursor)
  - 10 µF Aluminium: PM > 71°
  - Both Caps: PM 47° (double cursor)

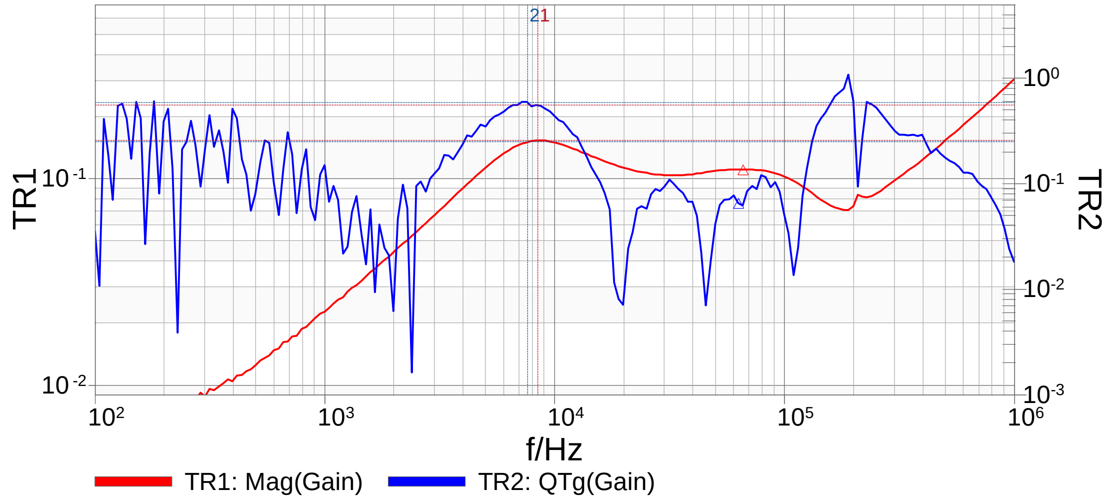




SMPS Example

- Linear LT1976 IFE Demo board
  - input voltage 12V
  - output current: 100mA + 25 mA (J2111A)





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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