ANALYTICAL **HEAVY** LIFTING

Comparisons of Non-Invasive Stability Measurements vs. Bode Plots

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More Information: https://www.picotest.com/non-invasive-stability-measurement.html

What's Included Here

- Hardware circuitry including Linear Regulators, POLs, and Switchers were constructed and bench tested
  - Non-Invasive Stability Measurement ('NISM') of Stability Margins and Bode Plots were both recorded
  - In some cases, the circuit were also simulated
  - The Stability Margin vs. Phase Margin results are compared and documented

Note: The testing was performed by AEi Systems.

What is NISM and Why It's a Critical Technology

- Non-Invasive Stability Measurement is a method of determining control loop stability margins without requiring 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 ICs that do not allow loop access
  - 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
- NISM is computed by converting output impedance to group delay. Then the 'Q' is derived from the group delay and the stability margin from the Q
- The NISM technology is licensed and promoted by Picotest.com
- The measurement capability can be found on various VNAs
  - OMICRON Lab, Keysight, Copper Mountain, Rhode-Schwarz

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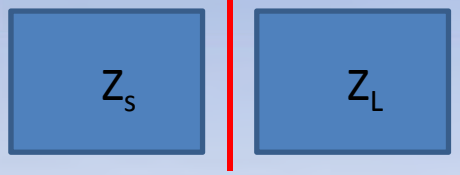
NISM is Based on Fundamentals

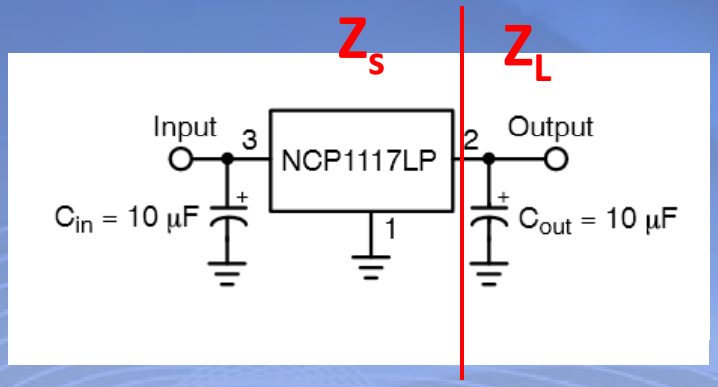
- Dr. R.D. Middlebrook popularized the topic of *Minor Loop Gain*, T_m with his introduction of the extra element theorem which allowed us to assess the stability of power supplies and input filters
- Minor loop gain, based on Nyquist criteria is now one of the most researched electronics topics
- Many 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, ZS and ZL



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

- Phase margin is determined by setting |Tm| = 1 and solving for phase

NISM is Based on Fundamentals



A complication exists in that we cannot separate the voltage regulator into two parts, Z_S and Z_L without cutting a trace or removing the capacitor

- NISM software extracts data from impedance and group delay and allows the Z_S and Z_L to be mathematically separated so they can be converted to Stability Margin
- Practically speaking, impedance is measured with a suitable probe in a 1 or 2 port configuration
- The instrument converts the impedance to group delay and Q
- The user positions waveform cursors on the impedance and Q waveforms and the conversion to phase margin is read out on the instrument's screen
- A video of the process can be viewed here, **https://www.picotest.com/products_NISM_software.html**

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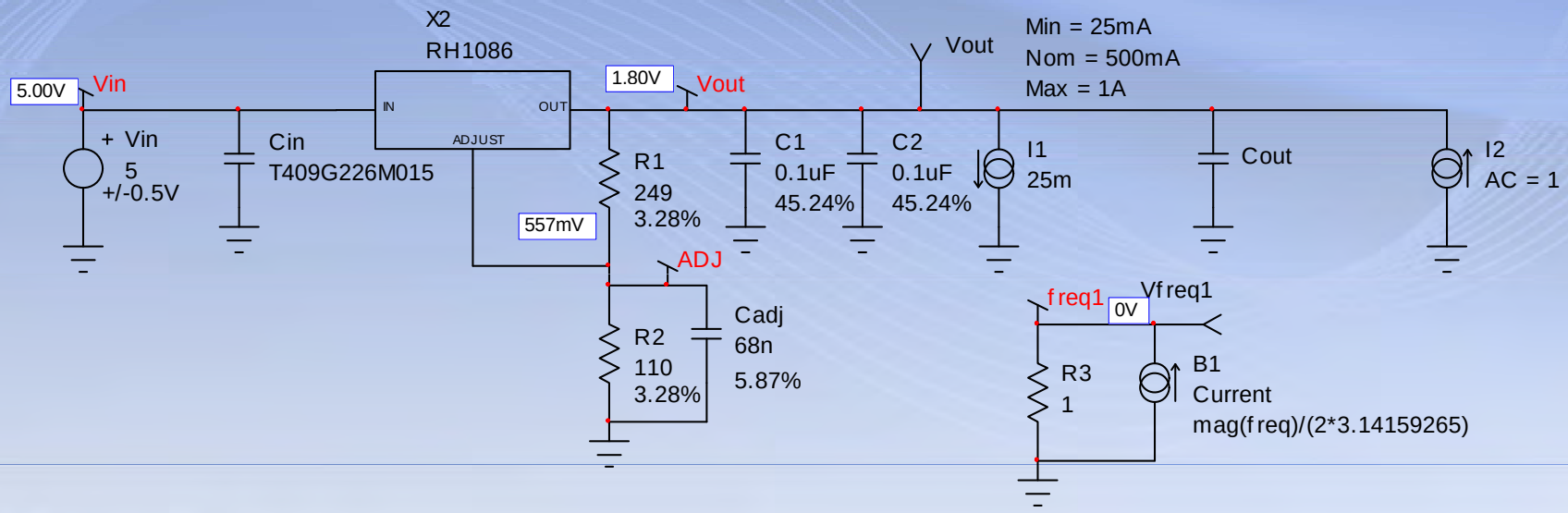
Non-Invasive Stability Measurement vs. Bode Plot Measurement

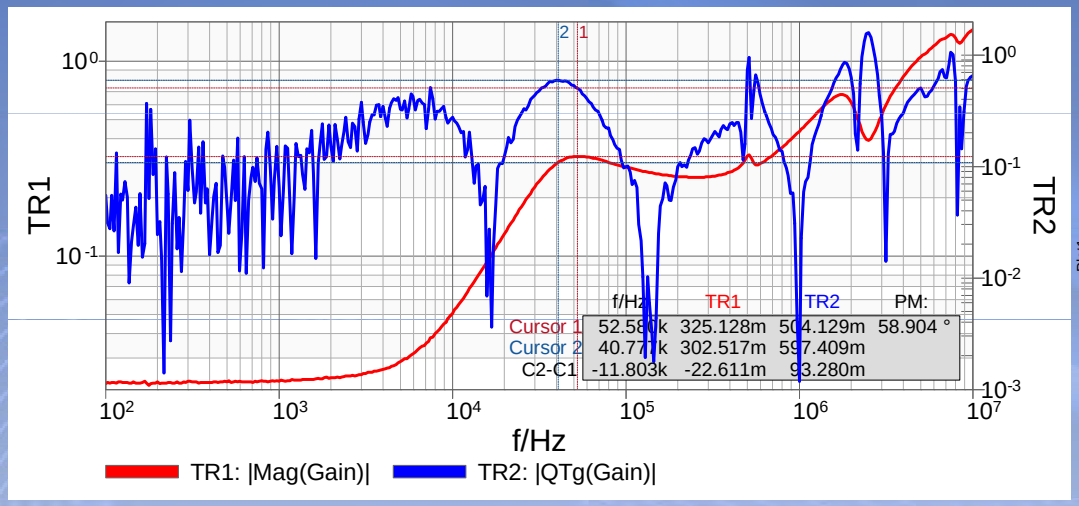
- RH1086 Linear Regulator
- RH1085 Linear Regulator
- LM317 Linear Regulator– Various Configurations
- TPS4022 Buck Regulator
- TPS7A4501 Linear Regulator
- LMR10515 Simple Switcher
- TL431 Adjustable Shunt Regulator
- VRG8666 (RH3080) Linear Regulator
- CLC1007 245MHz Opamp

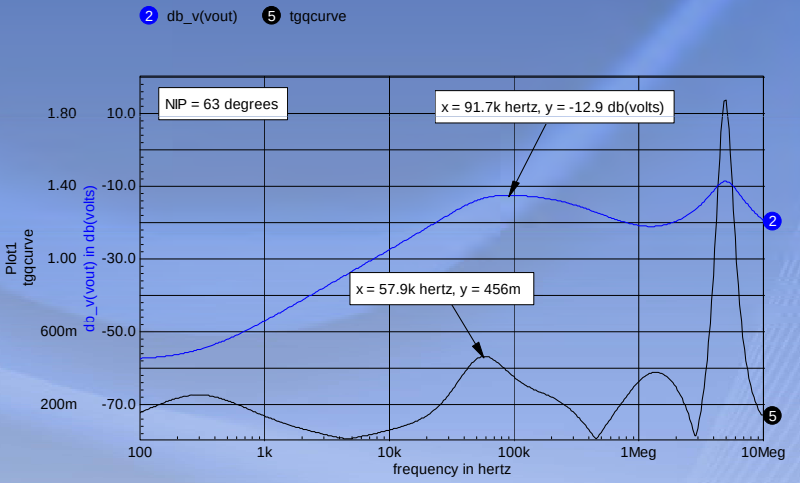
RH1086 Linear Regulator

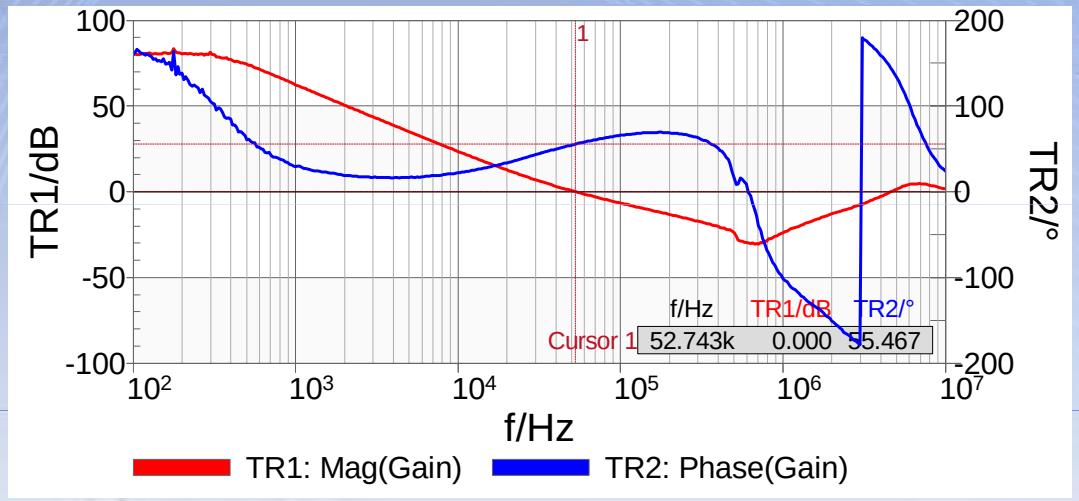
	NISM	Bode Plot PM
Measured	59 deg	56 deg
Simulated	63 deg	56 deg

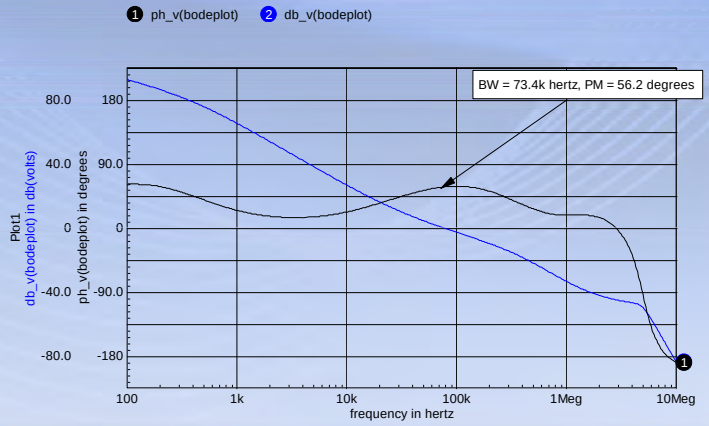


RH1086 Linear Regulator



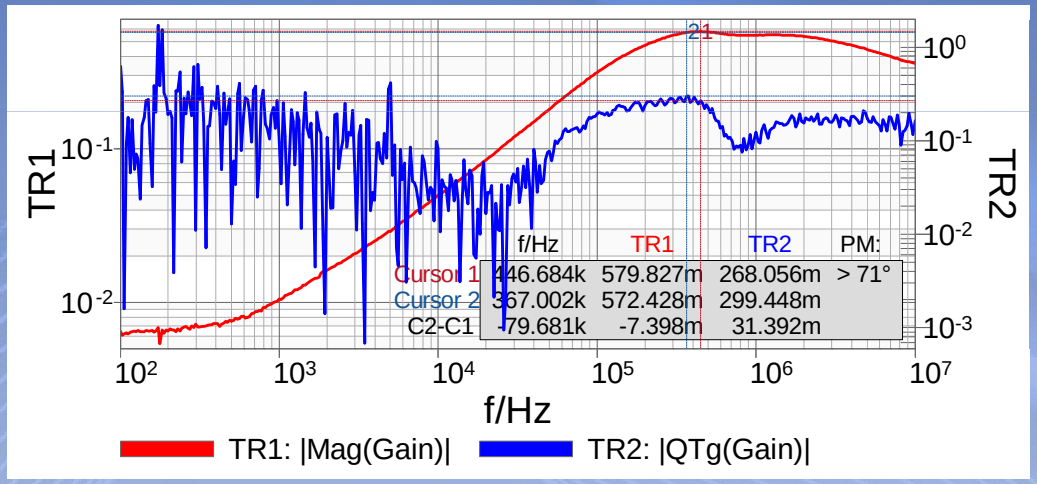




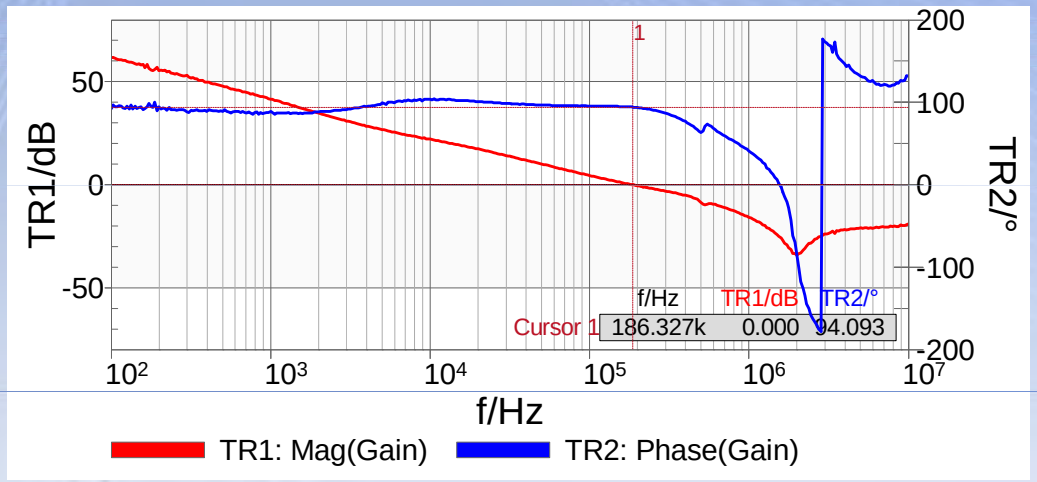


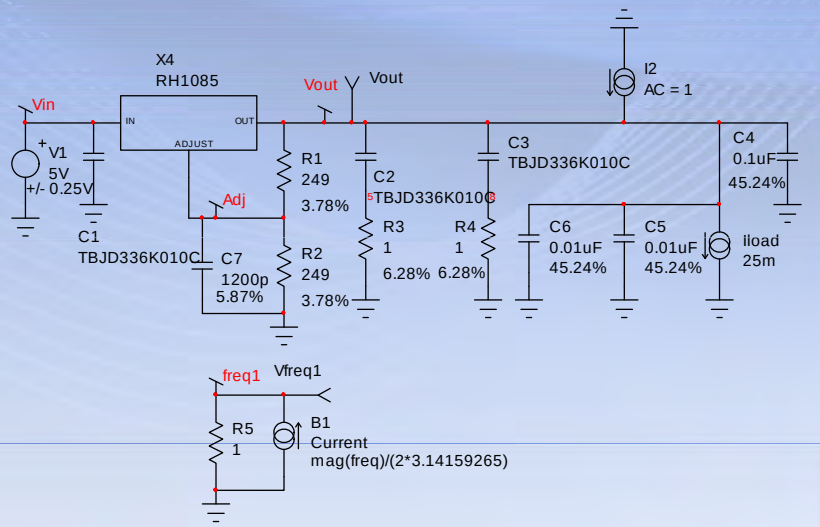
	NISM	Bode Plot PM
Measured	59 deg	56 deg
Simulated	63 deg	56 deg

RH1085 Linear Regulator

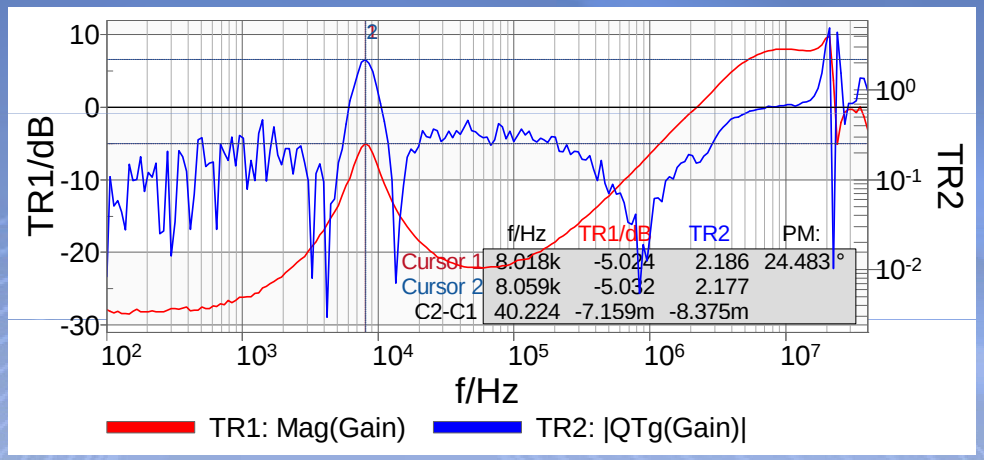


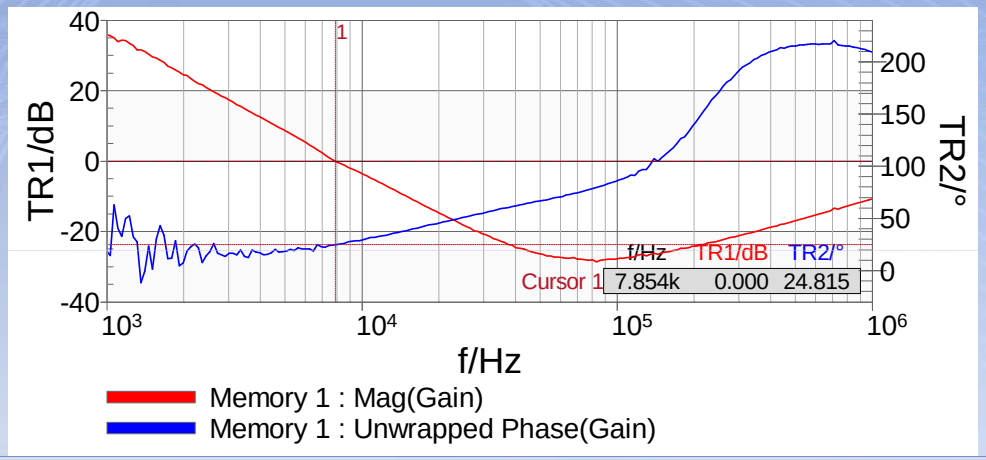
	NISM	Bode Plot PM
Measured	> 71 deg	94 deg



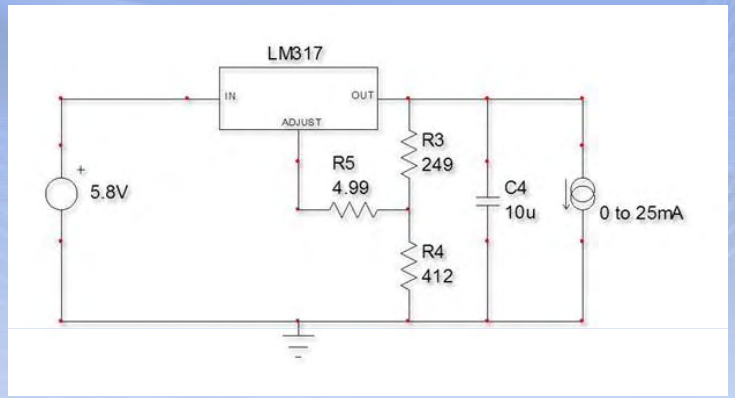


LM317 Linear Regulator, Cap 1





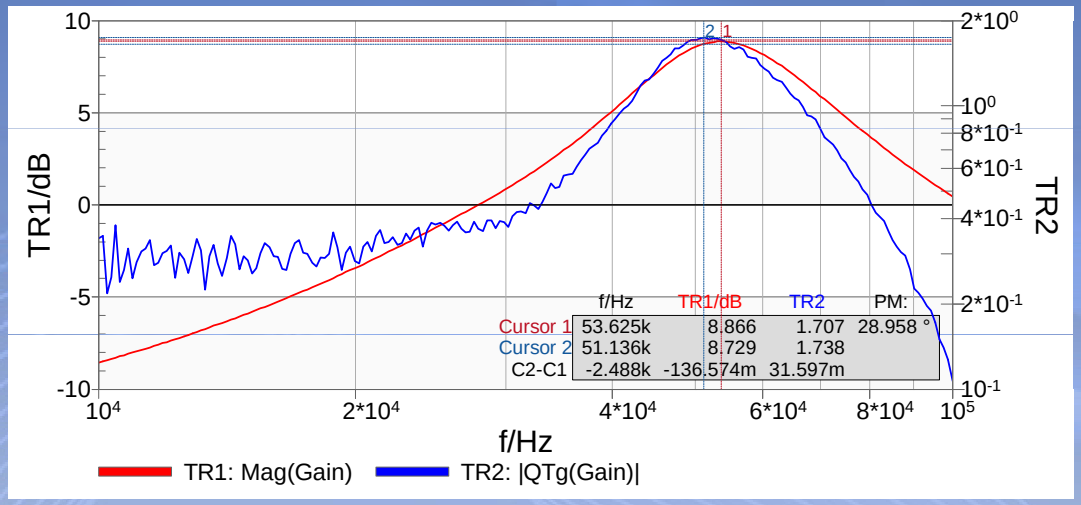
	NISM	Bode Plot
Measured	24 deg	25 deg

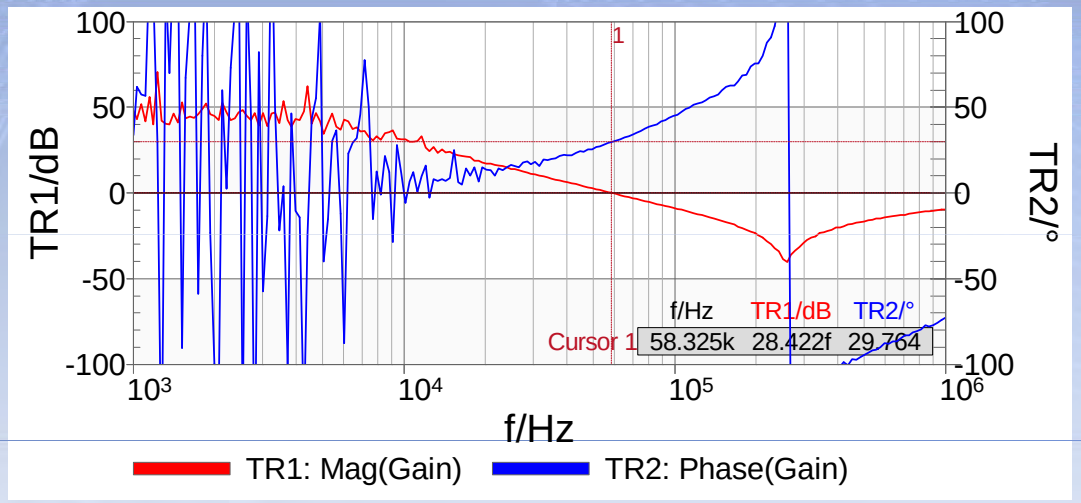


General LM317 configuration used, Cap 1 is a 100uF Tantalum

Note: The circuit is from the Picotest VRTS 1 board, https://www.picotest.com/products_VRTS01.html.
It was measured using several capacitors in the kit.

LM317 Linear Regulator Cap 4

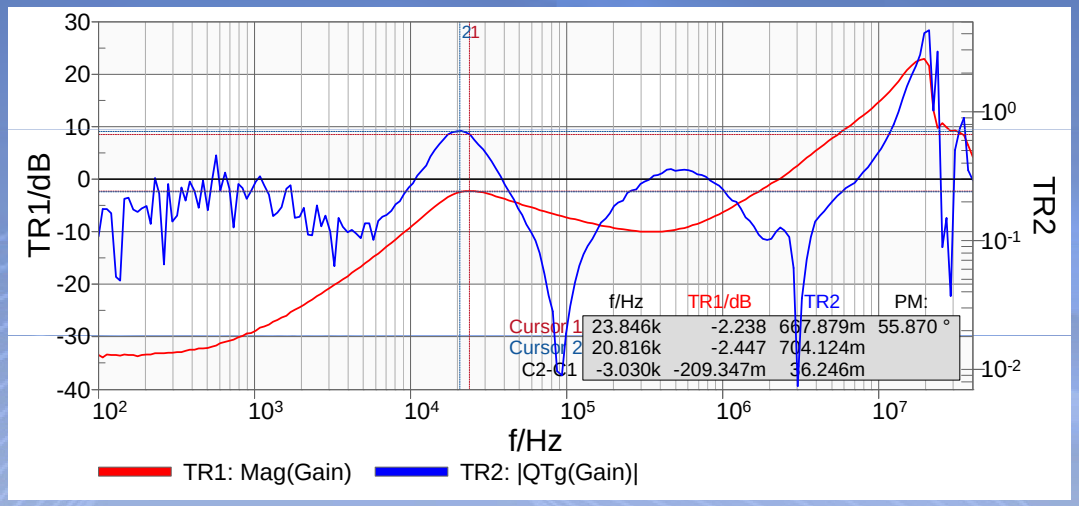


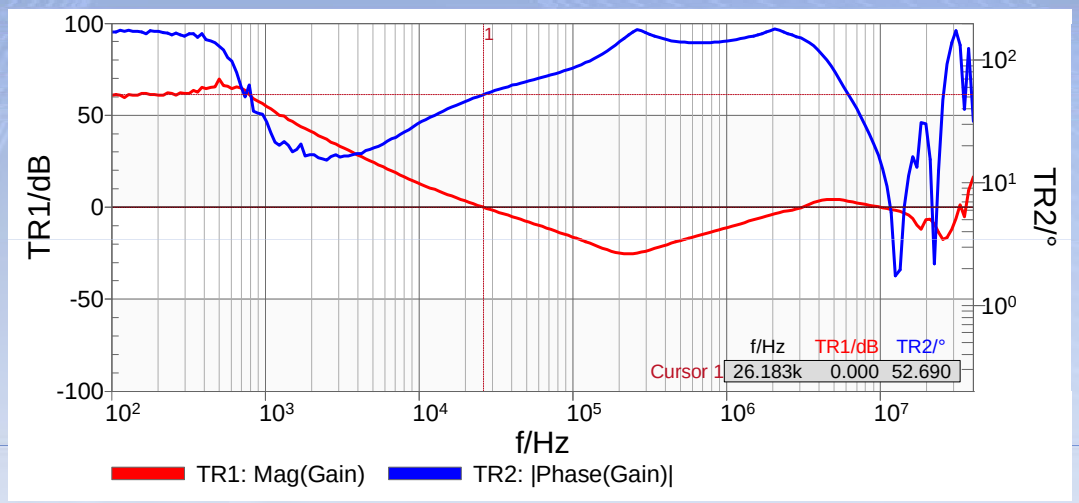


	NISM	Bode Plot
Measured	29 deg	30 deg

Measured on the VTRS 1 board,
Cap 4 is a 2.2uF Tantalum

LM317 Linear Regulator Cap 5

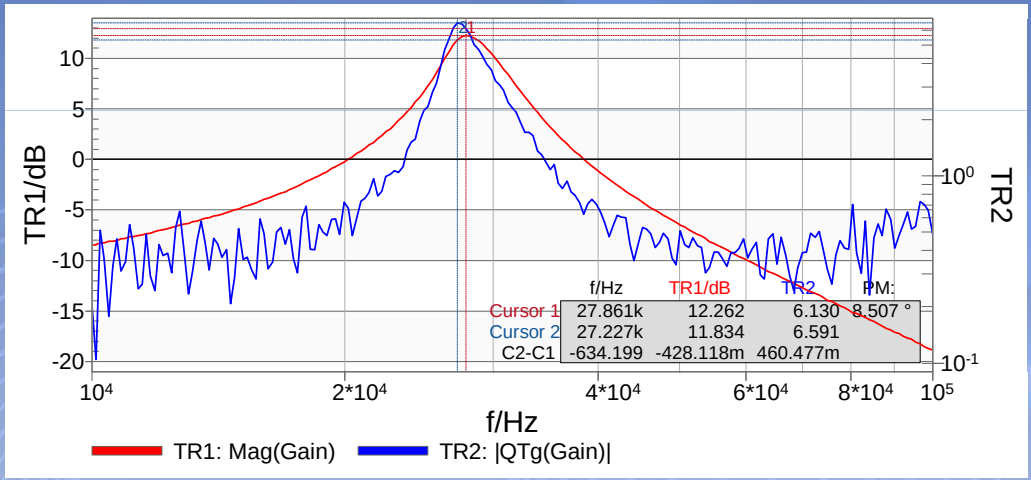


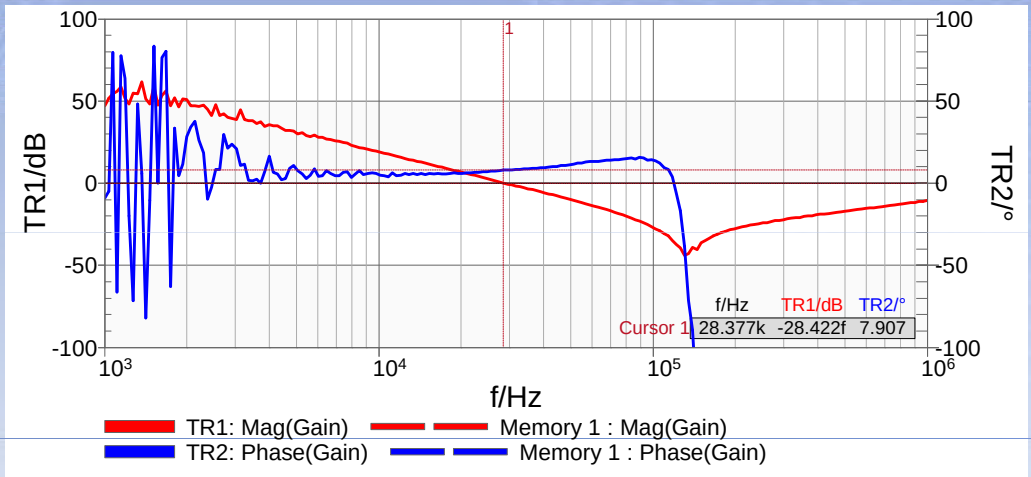


	NISM	Bode Plot
Measured	56 deg	53 deg

Measured on the VTRS 1 board,
Cap 5 is a 15uF Tantalum

LM317 Linear Regulator Cap 6

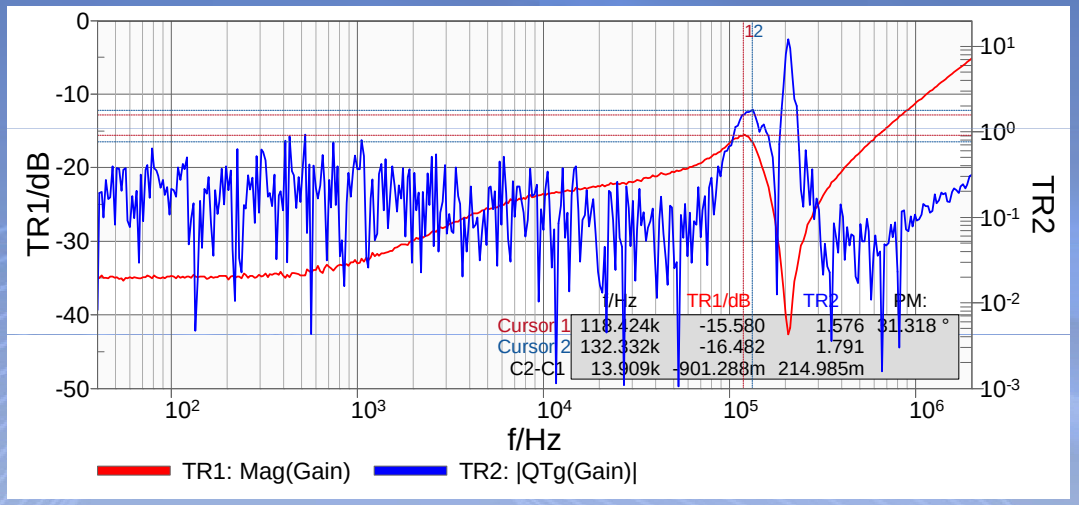


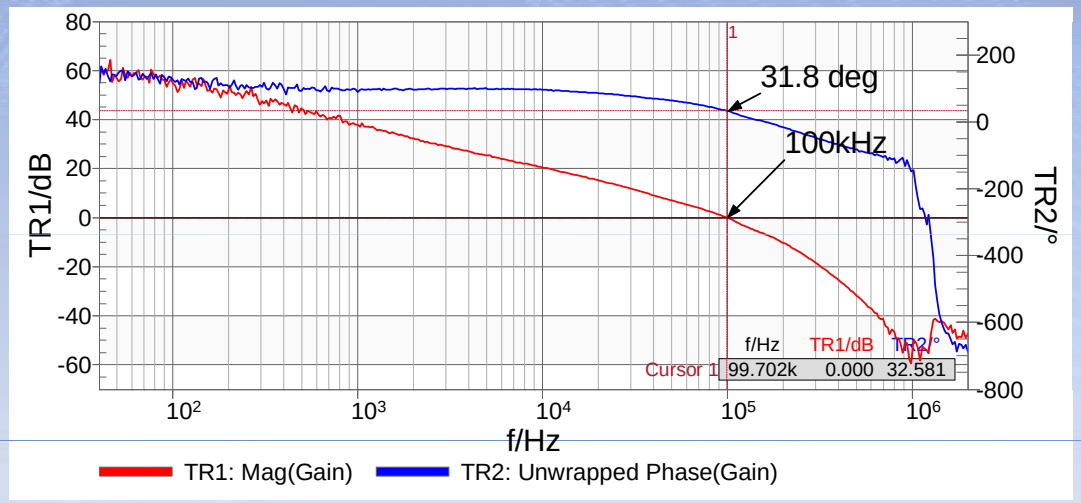


	NISM	Bode Plot
Measured	9 deg	8 deg

Measured on the VTRS 1 board,
Cap 4 is a 22uF Ceramic

TPS40222 Buck Regulator



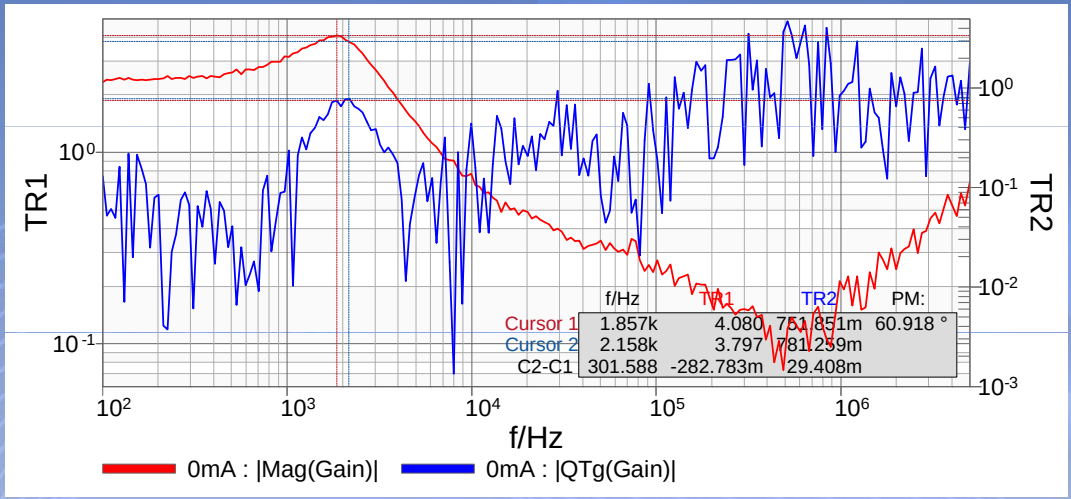


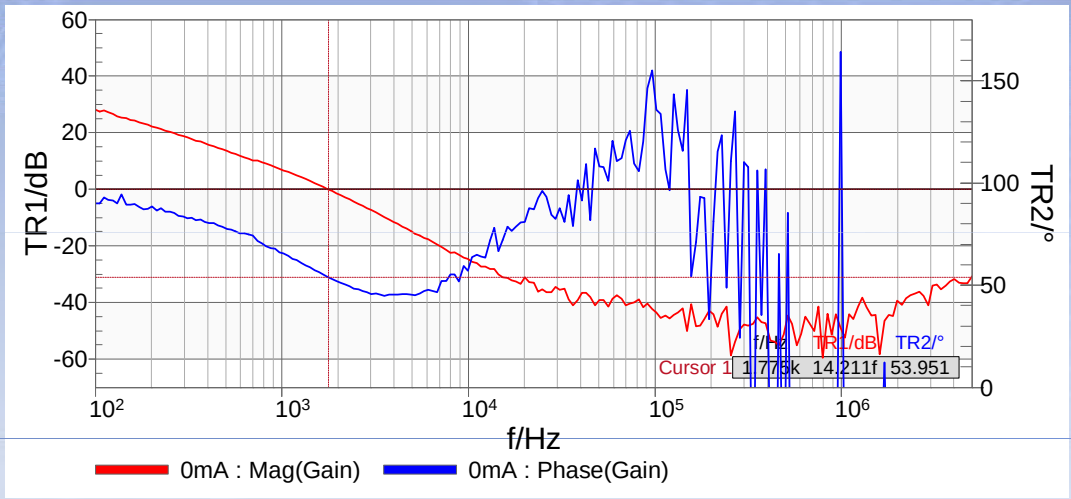
	NISM	Bode Plot
Measured	31 deg	32 deg

A 5-V Input, 1.6-A Output, Non-Synchronous Buck Converter

http://www.ti.com/lit/ug/slvu153/slvu153.pdf

TPS7A4501 Linear Regulator 0mA



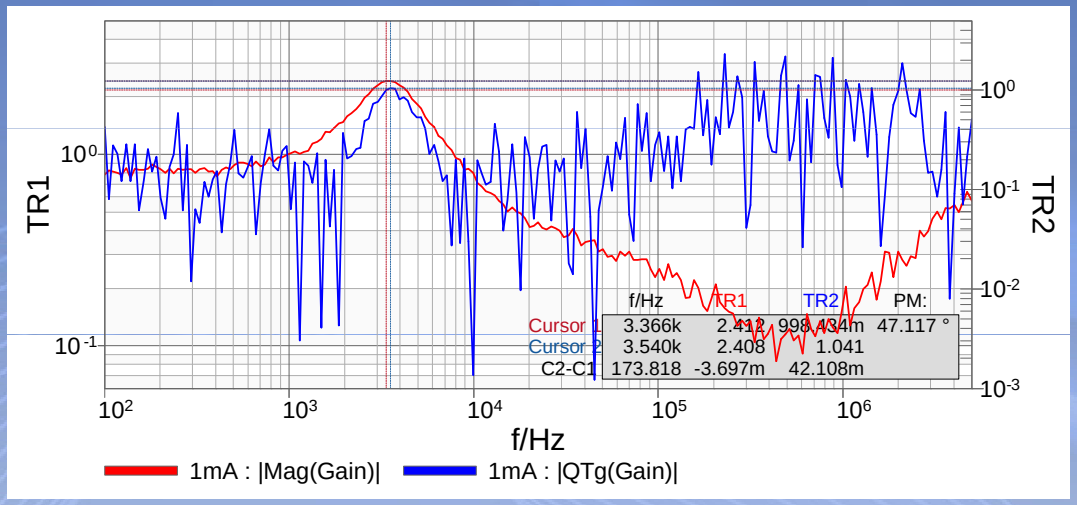


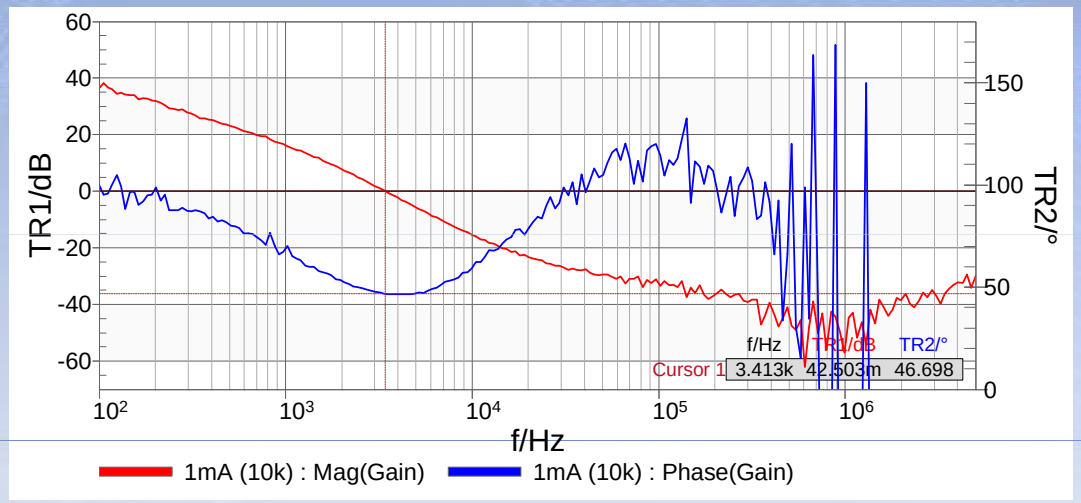
	NISM	Bode Plot
Measured	61 deg	54 deg

A low-noise, fast-transient-response 1.5-A low-dropout (LDO) voltage regulator

http://www.ti.com/lit/ug/slvu259a/slvu259a.pdf

TPS7A4501 Linear Regulator 1mA



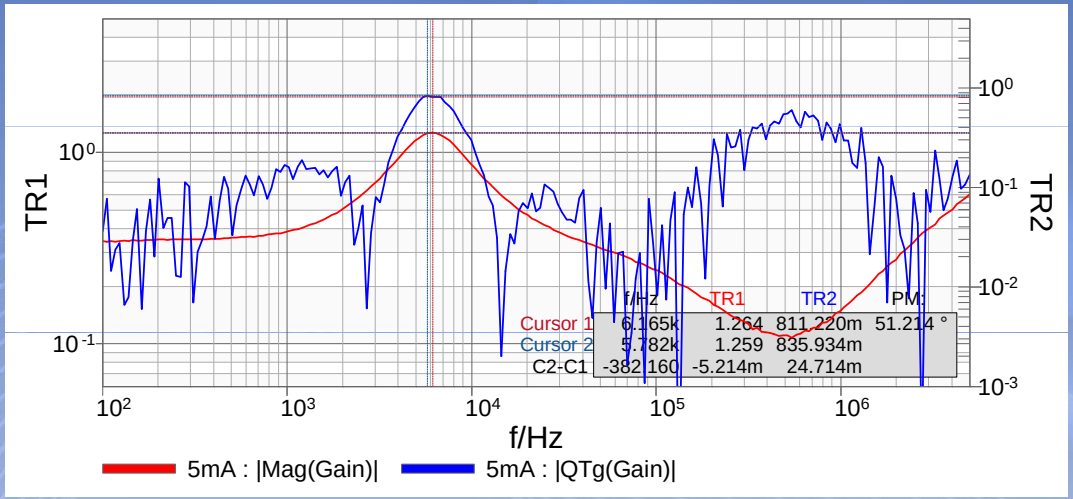


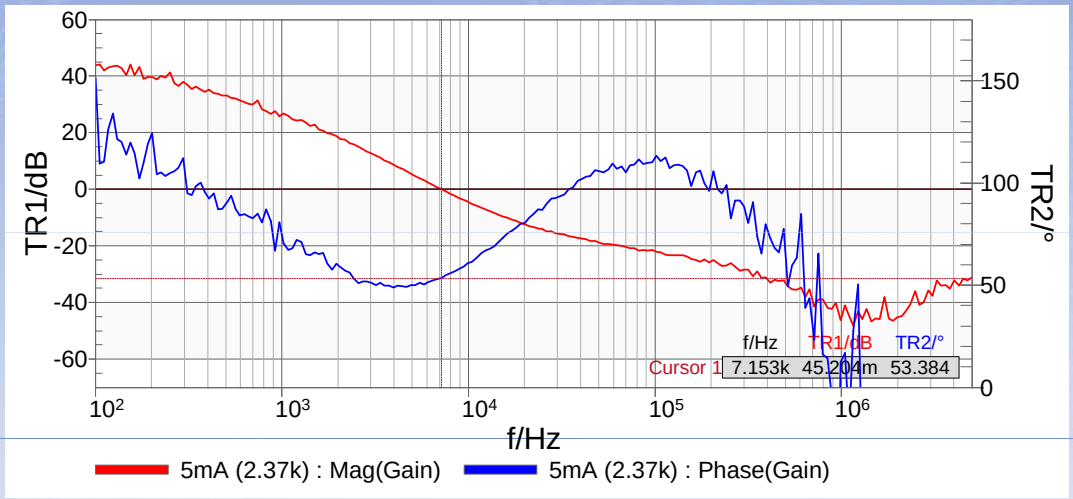
	NISM	Bode Plot
Measured	47 deg	47 deg

A low-noise, fast-transient-response 1.5-A low-dropout (LDO) voltage regulator

http://www.ti.com/lit/ug/slvu259a/slvu259a.pdf

TPS7A4501 Linear Regulator 5mA



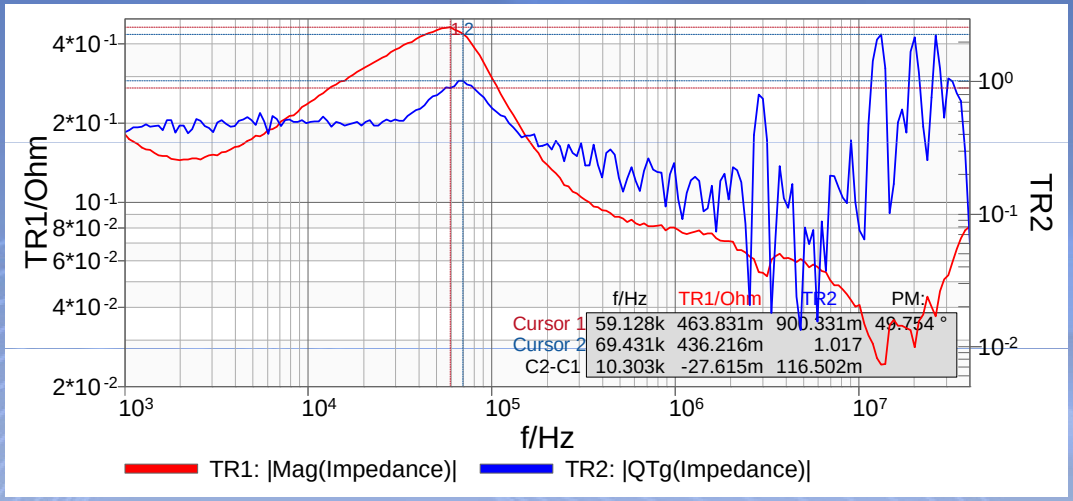


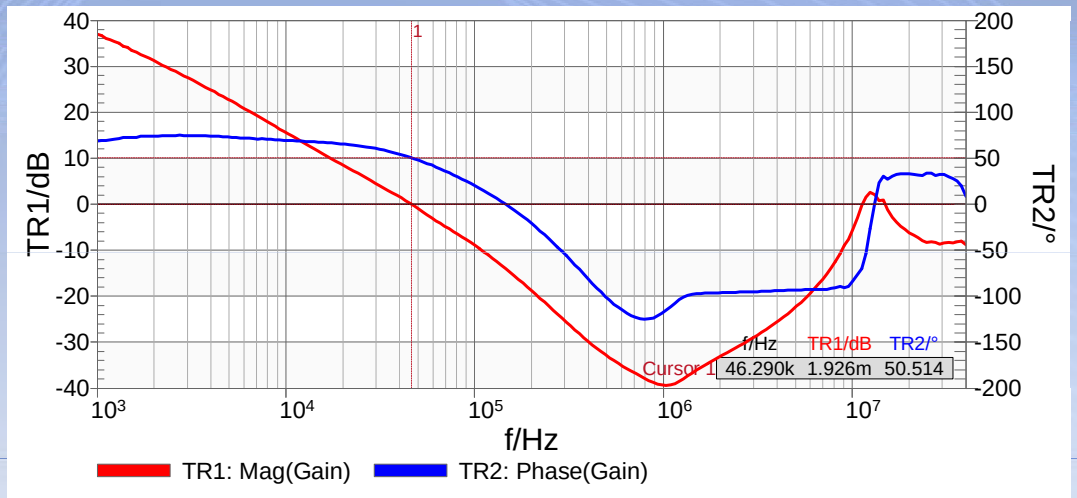
	NISM	Bode Plot
Measured	51 deg	53 deg

A low-noise, fast-transient-response 1.5-A low-dropout (LDO) voltage regulator

http://www.ti.com/lit/ug/slvu259a/slvu259a.pdf

LMR10515 'Simple Switcher' POL



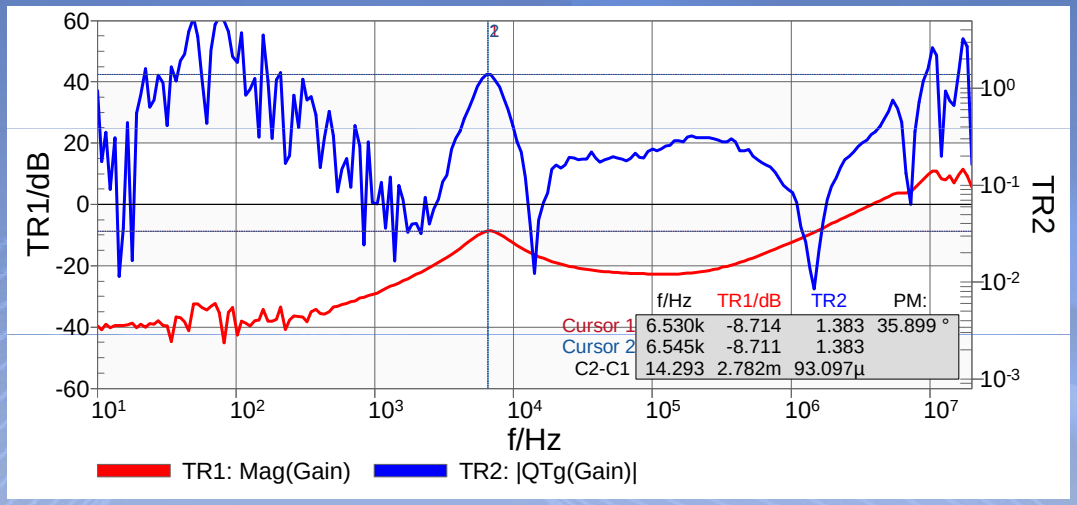


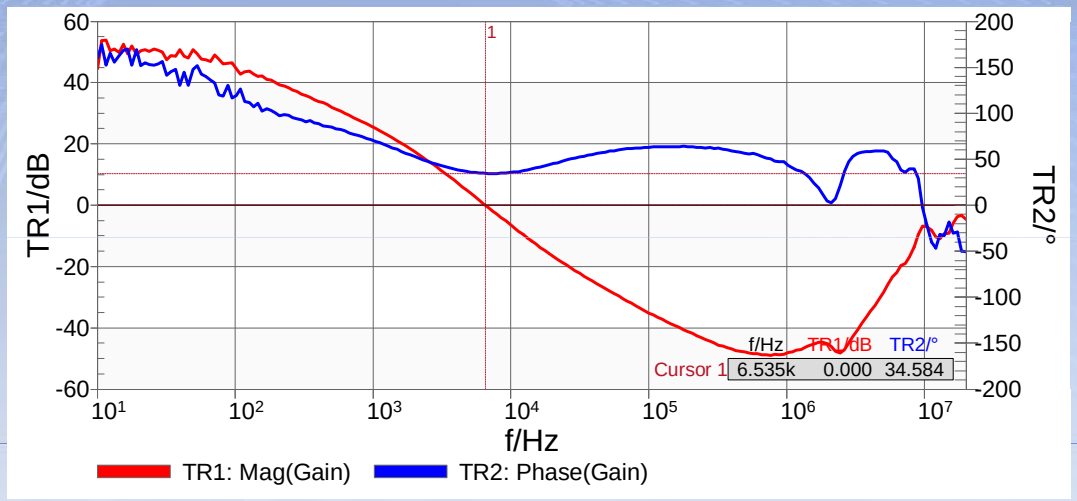
	NISM	Bode Plot
Measured	50 deg	51 deg

A 5V to 3.3P POL
(Simple Switcher Step-Down Buck Regulator)

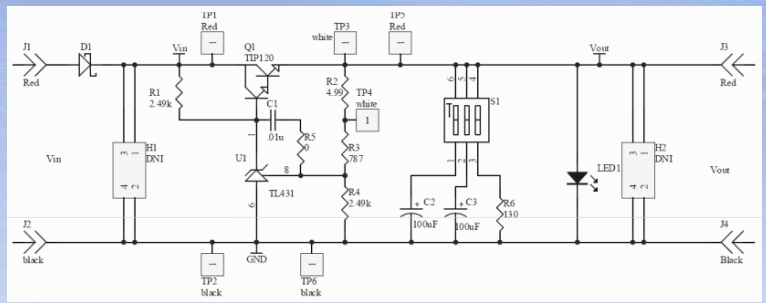
https://www.picotest.com/products_VRTS03.html
http://www.ti.com/product/lmr10515

VRTS1P5 - TL431 Adj. Shunt Regulator





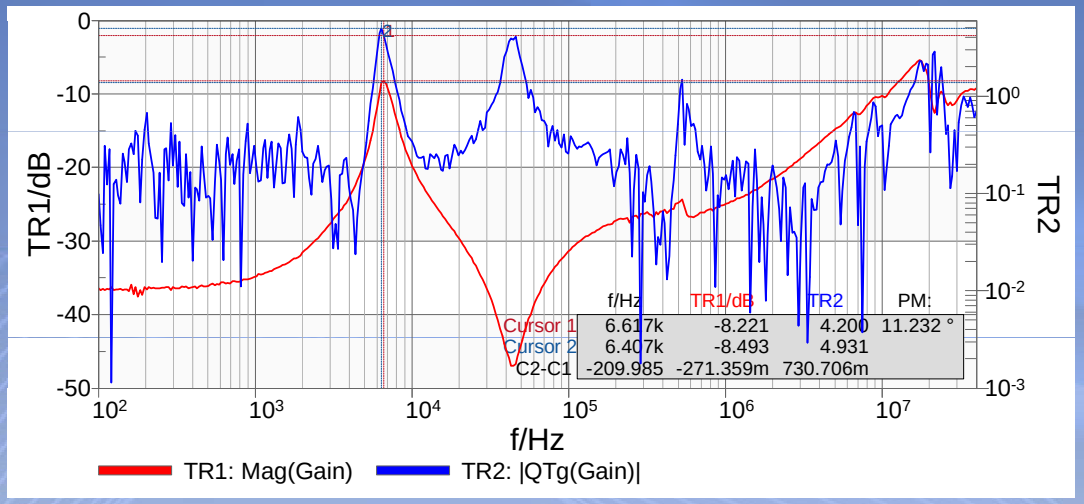
	NISM	Bode Plot
Measured	36 deg	35 deg

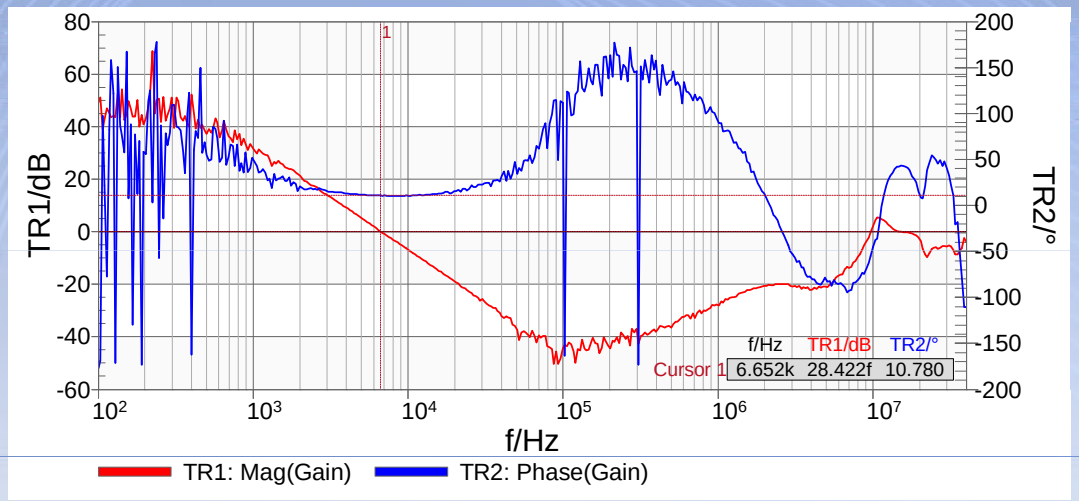


An Adjustable Shunt Regulator with 2.5V Reference

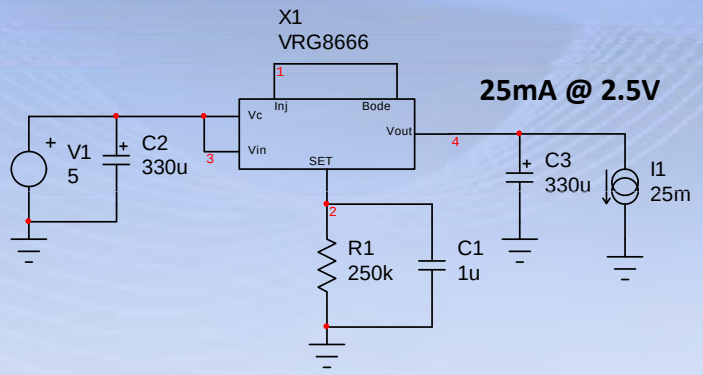
https://www.picotest.com/products_VRTS03.html
http://www.ti.com/product/lmr10515

VRG8666 (RH3080) Linear Regulator

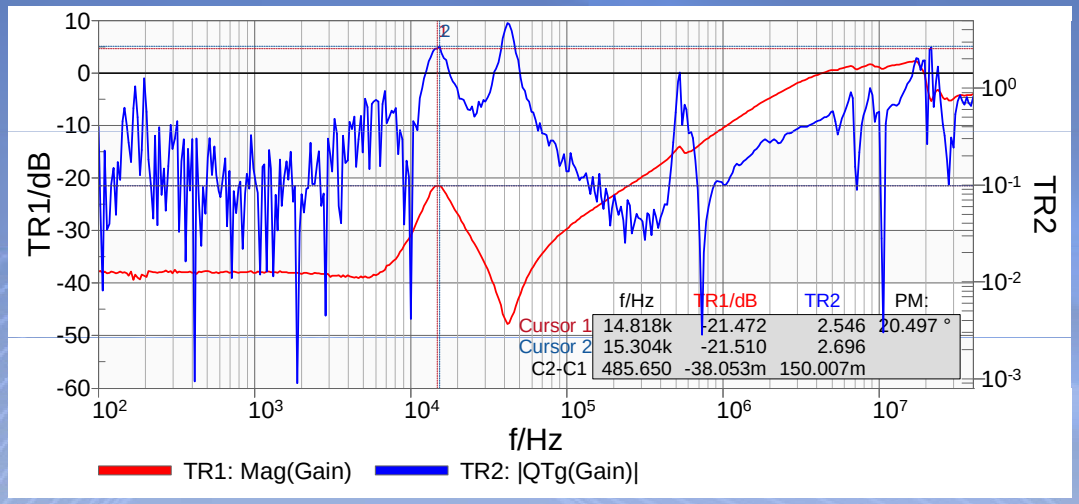


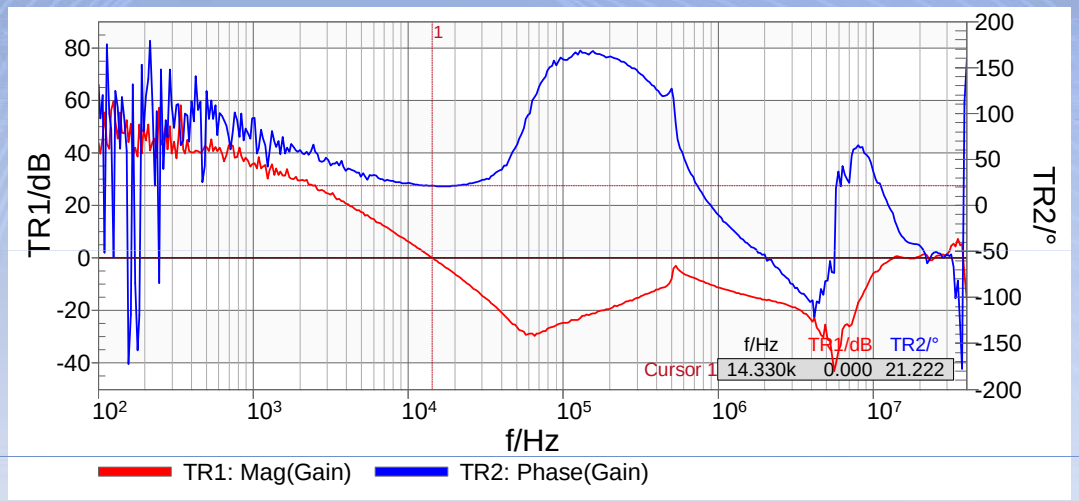


	NISM	Bode Plot
Measured	11 deg	11 deg

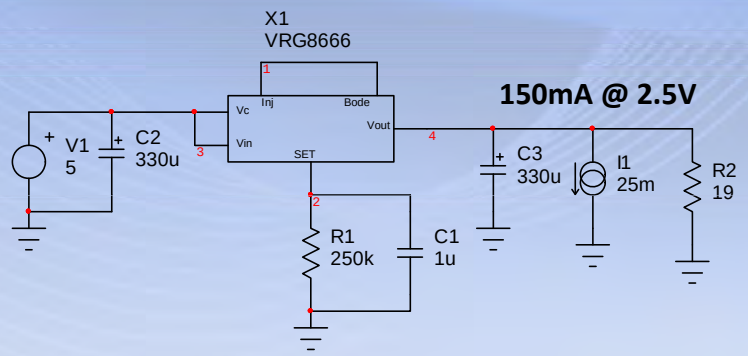


VRG8666 (RH3080) Linear Regulator



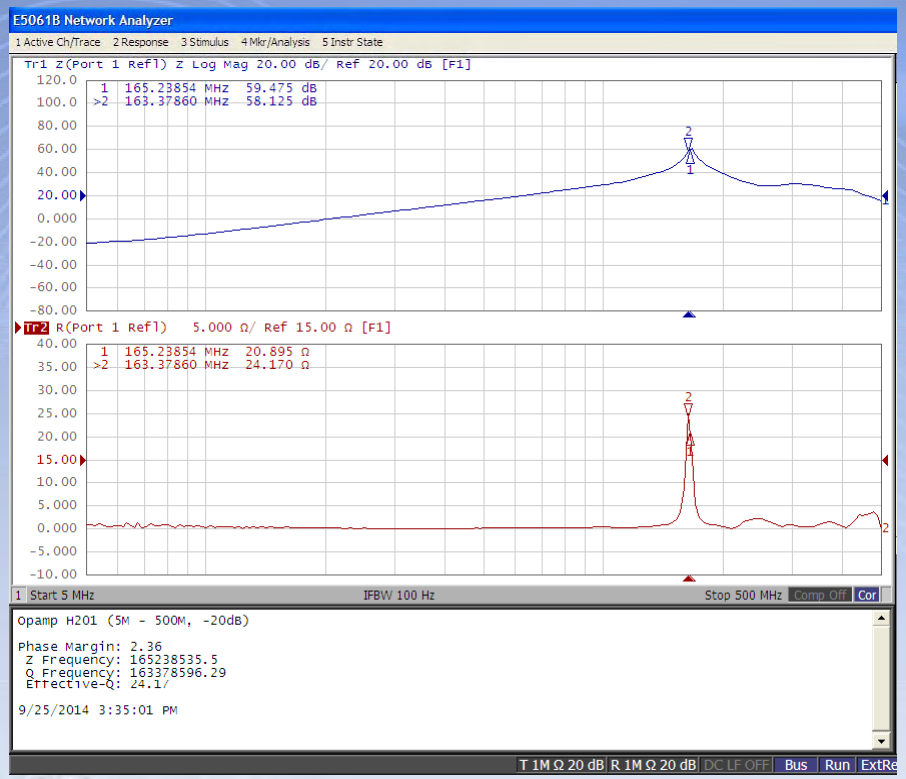


	NISM	Bode Plot
Measured	20 deg	21 deg



CLC1007 245MHz Opamp

Using the Keysight E5061B VNA, with the NISM software, we were able to test the stability of this 245 MHz opamp. The big WOW is that we obtained the (very poor) phase margin from the impedance measurement using NISM (just about 2 degrees). This is a great capability; to be able to accurately assess stability at 100's of MHz or higher without lifting any wires (which would interfere with the measurement). While there is no loop “correlation” for this NISM test, The measured phase margin of 2.36° is not acceptable because signals near the 163MHz bandwidth would become very distorted and fast transitions would see oscillations at this high frequency.



	NISM	Bode Plot
Measured	2 deg	N/A

245 MHz opamp