

IMPEDANCE TESTING		Measurements				Notes	Picotest Equipment Used in the Test (Requires a VNA or FRA, all tests can be performed with the Bode 100)
Circuits	1-Port	2-Port	3-port	Scope			
LDOs, Linear Regulators, POLs, and DC-DC Converters		x	x	x	The P2104A 1-port probe could be useful for very low power LDOs and voltage references, where the signal level needs to be really low. Alternatively, the P2102A two port probe with attenuation (extended range measurement) can be used. That will also attenuate signal levels, with the benefits of the 2-port measurement. Port Saver DC blocks can be used to eliminate DC loading if 50 ohms loads the circuit (limited to 50V). DC blocks at high voltage can potentially damage 500ohm instrument due to inrush. Check with VNA manufacturer.	2-port connections (50 ohm coax, 1-port probe P2104A and/or 2-Port Probe P2102A), Two Port Saver DC Blocks (may be necessary to prevent loading from the 50 ohm probes), J2102B common mode transformer, or J2114A Isolator 2-port can also be performed with Tek Scope with FRA Software + J2161A + J2102B 2-port extended - 2-port equipment plus resistors or attenuating probe 3-port (V/I measurement) - J2111A + Current Probe * Oscilloscopes 2-Port Measurement: J2161A and J2102B + Probes Optional for all measurements: Picotest PDN Cables, DTBK01 Decoupling Test Board Kit) J2160A for the E5061B T/R ports to convert them to 2-port	
References and Opamps		x	x	x	Same Notes as in LDOs above. Again the P2104A 1-port probe and measurement could be useful here	2/3Port - Same as LDOs above	
Voltage Levels							
Low Voltage ≤ 3.3V	x	x	x	x	Can usually use the P2104A probe 1x attenuation if the impedance is above ~0.25 ohms) For the Bode 100 no DC block is required, but can be used to eliminate the DC loading of the 50 Ohm ports by the circuit you are testing	2-port probe P2102A, 1-Port Probe P2104A, (Port Saver DC Block can be purchased separately for direct 50 ohm coax connections) 2/3Port - Same as LDOs above	
Med Voltage 3.3V-50V			x		May require probes with attenuation - See the 2-port extended note below. DC blocks can be applicable to all measurements, with a limitation on minimum measurable impedance magnitude. DC block at high voltage can potentially damage 500ohm instrument due to inrush and especially at the 30V+ level. Check with the VNA manufacturer. The DC blocks will start to get quite noisy above 50% of rating (about 25V) and also the blocking capacitance will dramatically fall, so the low frequency of the measurement increases. This is in part why we try to gravitate to the 2-port range. Modulated e-load or current transformer injection can be used for 3-port measurement. But this might require a power amplifier. Lastly, the 3-port impedance measurement has a ground loop, though it isn't often talked about. For low impedance measurement with the Bode 100, a differential probe is best for measuring the voltage.	P2102A 2-port probe with attenuation and/or Port Savers See 2-port and 3-port above B-AMP 12 - https://www.picotest.com/product/b-amp-12-amplifier/	
High Voltages > 50V			x		See the 2-port extended note below. DC blocks can be applicable to all measurements, with a limitation on minimum measurable impedance magnitude. DC block at high voltage can potentially damage 500ohm instrument due to inrush unless our Port Saver DC block is used. Check with VNA manufacturer. Modulated e-load or current transformer injection can be used for 3-port measurement. But this might require a power amplifier. The P2104A/P2102A probes support the 2-port extended range measurement https://ieeexplore.ieee.org/document/7851286 using embedded resistors and will get up to 14V to a level the VNA can tolerate (with 10x attenuation). This could go down to a few milliohms The 3-port impedance measurement works independently of how it is modulated. It could be modulated using a current transformer, or their top (a) or (b) and measuring with a current probe rather than a resistor. This eliminates one ground loop.	See 2-port and 3-port above B-AMP 12 - https://www.picotest.com/product/b-amp-12-amplifier/	
Impedance Levels							
Ultra low impedance sub-milliohm		x		x	Might require source power amplifier. Applicable to less than 3.3V unless an attenuating probe is used	See 2-port above B-AMP 12 - https://www.picotest.com/product/b-amp-12-amplifier/ J2114A 100dB Isolator allows lower impedances to be measured as compared to the J2102B/J2113A	
Impedance 500mOhm-5kOhm	x			x	A DC block needs to be included if the voltage is greater than 3.3V. DC block at high voltage can potentially damage 500ohm instrument due to inrush. Check with VNA manufacturer.	See 1-port above	

*** Notes: 3-Port Test Limitations**

The measurement is limited by the probes (varies with attenuation) and/or the J211xA injector (to 50V).

The 3-port measurement is hard to calibrate given the nature of the setup and usage of the J2111A for current monitoring/sinking. The J2111A adds 25mA to load current which may be too large for some references.

It is generally a harder test to setup (often a current probe, which can be noisy is needed) and unlike the 1 or 2-port measurements you can't measure with power off (a VERY useful data set in PDN design).

The J2111A Output Voltage limits are -40V to -1V and 1V to 50V. The J2112A Output Voltage limits are 0.7V - 50V (the range of the power supply output voltage that the injectors may be connected to).

50-72V is a challenging voltage range. For 50-72V+ you will need to use a J2111B with a series resistor (1k or so to drop the voltage) and a differential probe to then measure the voltage.

J2102B vs. J2113A vs. J2114A

The J2102B paired with the Picotest PDN Cable is the best general solution. The J2113A is a better choice if you need to measure below 3kHz and below a maximum frequency of 500kHz.

Due to the limited CMRR, the J2113A is not recommended below 1mOhm. If you are interested in measuring below 1mOhm, the J2114A would likely be needed.

If other cables are used with either solution, there may be significant degradation in measurement accuracy below 1MHz due to poor cable shield resistance and isolation.

Measurement	Instrument								Picotest Website Solution Page	Picotest Equipment Used in the Test
	Bode 100 Bode 500	R&S ZNL/ZNLE	Keysight E5061B	CM S5048	Tek Scope Series 5/6	R&S RTA/B/M	Siglent SDS1000X-E-FG series scopes	Keysight InfiniiVision X-Series		
Stability via Bode Plot	x		x		x	x	x	x		FRA Bundle (include J2100A, J2120A) Optional: J2101A, J2110A, B-AMP12 Requires Scope's FRA Software add-on (see below) and in some cases an AWG Keysight: J2160A T/R Probe Adapter for the E5061B
Stability via NISM	x	x	x						x	NISM Software is available for all of these products at no charge Bode 100 VNA (Included in the Bode software) Copper Mountain requires Picotest NISM software E5061B requires Picotest NISM software R&S ZNL requires Picotest NISM software Simulators: Keysight ADS and Cadence PSpice simulators Standalone EXE/DLL
Impedance	x	x	x	x	x	x	x		x	See Measuring Impedance Table
PSRR (Low Power)	x	x	x	x	x	x	x	x	x	J2120A, J2123A (Negative voltage), J2124A (Medium Power)
PSRR (High Power)	x	x	x	x	x	x	x	x	x	J2121A, J2124A, P2124A
TDR: Cable, PCB, Dielectric					x	x	x	x	x	J2154A, P2105A probe, P2103A Differential Probe
DC-Biased Component Test	x		x							DC Bias Board or J2130A (Optional DTBK01 Decoupling Test Board Kit, or higher frequency Black Boards)
Inductors Biased (low current up to xx amps)	x	x	x	x	x	x	x	x	x	J2121A
Inductors Biased (high current up to 125A)	x	x	x	x	x	x	x	x		J2131A
DC-DC Converter Input Impedance	x	x	x	x	x	x	x	x	x	J2121A
EMI					x	x	x	x		EMI Probes
Load Step					x	x	x	x		P2105A/S10, S50, Custom Transient Load Stepper (In-Socket Load Board)
Load Step (Small Signal)					x	x	x	x		J2111B, J2112A
Noise Measurements					x	x		x		J2180A, J2181A, P2106A High Voltage

Scope Software: e.g. R&S®RTx-K36 FRA option, Tek 4/5/6-PWR software