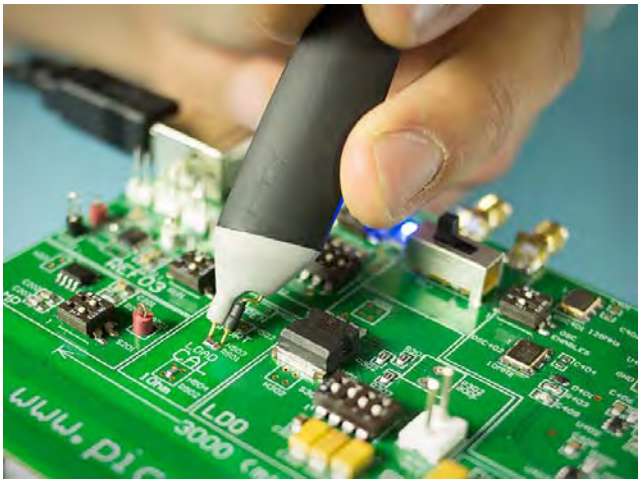
PICOTEST

Transmission Line PDN Probes



Documentation

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Chapter 1 - Overview

Welcome

Thank you for purchasing Picotest's PDN probes.

The Picotest PDN probes are 50 ohm passive transmission line probes. These precision 1x probes support a variety of measurements including impedance (1-Port Reflection and 2-Port Series and Shunt-thru), 3-Port Voltage/Current, step-load, ripple, noise, TDT/TDR, PCB resonances, clock jitter, and the non-invasive stability measurement ('NISM')[1] [2]. The probes have some significant advantages over active probes and other types of passive probes.

The 1-port probe, being a unity gain wide bandwidth probe, allows the measurement of ripple and noise with optimum signal to noise ratio (SNR). Both probes can be used to record a signal or inject a signal into your circuit. For example, by connecting either the 1 or 2-port probe to the J2150A Harmonic Comb Injector[3]. The 2-port probe, for instance, can be used to transmit a load current step pulse through one port, while measuring the response from the other port, simultaneously. The probes can both be used to inject noise for the assessment of sensitivity to the power supply for sensitive circuits such as clocks and LNAs. The probes are supported by a wide range of signal injectors and accessories, such as DC blockers, preamplifiers, and high speed current injectors.

[1] https://www.picotest.com/non-invasive-stability-measurement.html
[2] https://www.picotest.com/Power-Integrity-Book.html
[3] https://www.picotest.com/products_J2150A.html

The high-bandwidth (DC-1.3GHz), variable-pitch probe tip design enables accurate measurements for a wide variety of component and connector sizes. It eliminates the need for soldering SMA or coax cables to your board and the risk of damaging fine copper pads or pulling up small components. You can get connectivity to circuit boards and devices without connectors.

The probes can be used for 'browser' style measurement. For instance, if you have multiple power rails across your board, the small form factor and easy probe tip placement enables you to quickly browse the regulator outputs, allowing you to decide which rails need further investigation. When coupled with NISM, you have a powerful tool for assessing the stability of multiple power sources not matter the physical configuration.

The probes are compatible with all equipment including VNAs, oscilloscopes, and spectrum analyzers and come with an accessory kit that includes a variety of probe tips and lead extenders, as well as, a DC blocking device.

The probes are also designed to work with the Picotest J2180A low noise pre-amplifier to improve signal-to-noise performance and the J2102A common mode transformer which eliminates instrument DC ground loops. [4] [5]

Probe Feature and Benefit Summary

- Variable pitch ground lead with multiple replaceable tips
- 1x for optimum in sensitivity and SNR
- Bi-Directional for signal measurement and signal injection
- Virtually no capacitive loading (< 0.2pf)
- 50 ohm impedance
- Wide Bandwidth – Exceed 1GHz+
- Supports the following measurements
    - Impedance, Step-Load, Ripple, Noise TDT/TDR, PCB resonances, Power Distribution Network ('PDN'), Clock Jitter, Noise, EMI, and Non-invasive Stability
- Single (1 Port) or Dual (2 Ports)
- Supports Non-Invasive Stability Measurement
- Supports the J2150A Harmonic Comb Injector
- Full complement of accessories including the P2130A DC Blocker
- Reduces the risk of damaging the fine copper pads of circuit boards
- Rugged, ergonomic design, Small Form Factor gets into tight places
- Slim body with extended tips provides good visibility of the target

[4] https://www.picotest.com/products_J2180A.html
[5] https://www.picotest.com/products_J2102A.html

What's a Transmission Line Probe

Transmission line probes are a special type of passive probe that replaces the high impedance probe cable found in a traditional passive probe with a precision transmission line, that has a characteristic impedance that matches the oscilloscope's input (50Ω). This greatly reduces the input capacitance to a fraction of a picofarad, minimizing the loading of high frequency signals. The probes are referred to as 'PDN' probes, because of their effective use in measuring the low and ultra-low impedances found in power distribution networks.

The input impedance of the Picotest probes remains nearly constant over their entire frequency range. A traditional ÷10 passive probe has a high input impedance at DC, however, this impedance drops rapidly with frequency, passing below the input impedance of a transmission line probe at <100MHz. The probes are useful in applications that produce fast rising, narrow pulses with amplitudes which exceed the dynamic range of active probes. They also tend to have less parasitic effects on frequency response and so they are ideal for measuring impedance. By providing a simple yet elegant and flexible solution to probing high-frequency signals, Picotest's 1 and 2-port transmission line probes preserve signal fidelity and allow high-bandwidth test equipment to properly measure circuit characteristics.

Impedance Measurement Demands New Probe Capabilities

High speed applications put pressure on the measurement of power supply busses to unprecedented frequencies. As an example, the measurement of PDN impedance for FPGAs, ASICs, and high-speed digital devices generally requires the measurement of impedance levels in the milliohm scale at frequencies exceeding 1GHz. Measuring the high speed step load response in power systems using 2-port impedance is difficult because of the need to connect two 50Ω transmission lines to the output capacitor. Compounding this difficult task is that these measurements often need to be made in very small circuits such as cell phones, solid state disk drives, and computer tablets; to name just a few examples.

These revolutionary probes alleviate many of these challenges while maintaining the precision 50Ω characteristics required for these types of measurements.

What's Included

Your Picotest Probe kit (P2100A, P2101A, or P21B01) includes one or more of the following:

- 1-Port Probe, 2-Port Probe or both
- Probe Tip Accessories Kit (plastic box)
- Probe Case
- P2130A DC Blocker
  - One (1) blocker for the 1-Port probe, two (2) blockers for the 2-Port probe, and two (2) blockers when both probes are purchased in a bundle (P21B01)

2-Port Probe, DC Blockers, Accessories, and Case

Documentation and Support

This documentation details the use of various probes. Specifications for the individual probes are also included.

The support section of Picotest's web site, https://www.picotest.com/support.html, contains additional documentation and various publications on testing power supplies, regulators, and other equipment using the Picotest probes.

Warranty

Every Picotest product you buy from Picotest.com is backed by a 1-year manufacturer's warranty.

For warranty service or repair this product must be returned to a service facility designated by PICOTEST. Please contact your local service representative for further assistance.

Calibration

The probes do not require calibration though the test setup where they are used normally requires calibration. See the instrument guide you are using the probes with for calibration instructions (usually measurement and setup dependent).

Chapter 2 –PDN Probes Usage

Introduction

The PDN probes have a wide dynamic range and can measure levels up to 5 V (RMS) without distortion. The low inherent noise enables the measurement of small input signals. The comprehensive accessory set allows this probe to be connected to a wide variety of devices under test (DUT) without impairing the very high bandwidth, though the length of the ground lead should be kept as short as possible.

The Picotest Probes may be used with any 50ohm instrument. They are bi-directional and can be used like a traditional probe to record signals as well as to inject stimulus (load step currents or EMI).

The key characteristics of the probe are as follows:

Characteristic	Rating
Bandwidth	DC-1GHz
Input Capacitance:	<1pF
Probe impedance	50 Ohms
Maximum voltage	5 Vrms
Maximum thru current any port	1Amp
Probe connections	SMA
Probe tip size range	0603-1206
Rise time	350 ps
Attenuation	1x

Connecting the Probe to the Instrument

The probe consists of the probe head for connection to the DUT, the probe cable, and the attached SMA connector(s).

The small and lightweight probe head is designed for easy handling and high-performance measurements. The probe head is used for connecting the probe and the DUT. Different accessories for the signal and ground sockets allow the probe head to be connected to a wide range of DUTs.

The probes have a standard SMA connector on each port for connection to the instrument. The 2 Port probe has two SMA connectors, one for each port with a common ground. For BNC input terminals a BNC to SMA adapter such as the one in the PCK01 High Performance Cable and Connector Kit is required.

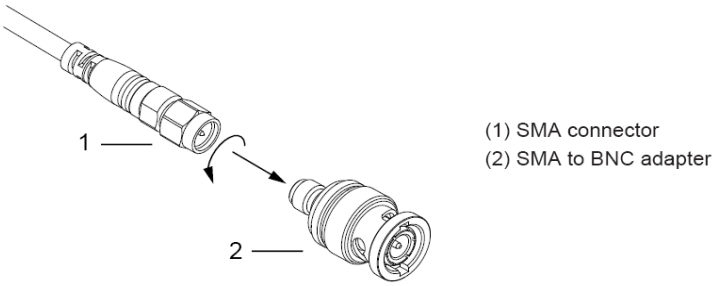


Figure 1: To connect the probe to a BNC connection use an SMA to BNC adapter (available in the Picotest Cable Kit (PCK01).

Figure 2: The 1-Port probe shown here connected to the J2150A Harmonic Comb via its SMA connector.

The transmission line probes have been designed to withstand a moderate amount of physical and electrical stress. You should treat the probe with care. It can be damaged if excessive force is applied to the probe tip.

Connecting the Probe Tips and Ground

The 2-Port probe generally has both ports connected together using the as shown in Figure 3. This allows 2 Port impedance measurements, as well as step load measurements where one port injects a load step signal and the other port simultaneously reads the voltage at the injection point.

The pin is usually used for the 1-Port probe. A variety of ground pins are available with each probe.

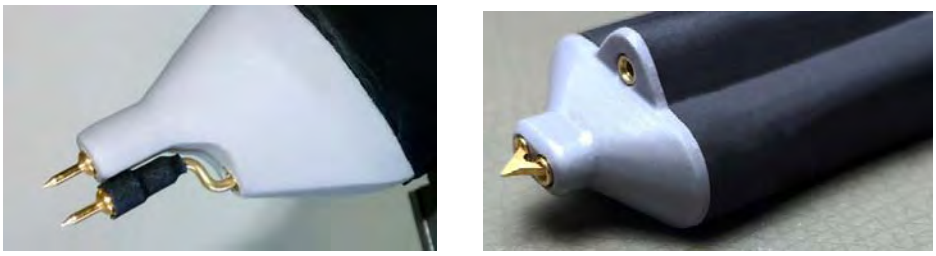


Figure 3: Probe head. The 1-Port probe on the left shows the stationary tip and swiveling/replaceable ground lead. The 2-Port probe on the right shows the 2 ports connected forked 2 prong probe tip and hole for the ground lead (no ground lead connected).

Important Note: The bandwidth of the probe is directly related to the length of the interconnects including both the ground and signal leads. Please keep the signal and ground pins/leads as short as possible in order to achieve the highest bandwidth measurements.

To change the probe tip, use pliers and apply a light grip or preferably your fingertips to remove and insert various probe pins.

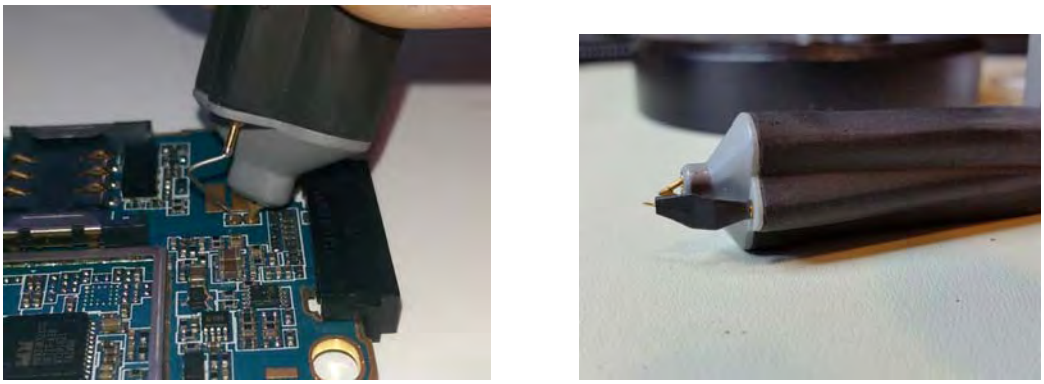


Figure 4: The 2-Port probe is shown above with two different ground lead attachments (angled pin, left, and pogo, right). It is important to keep the ground pin as short as possible.

Important Note: Pressing too hard on the ground pin while making a measurement can cause the ground pin to break.

Special accessories for signal and ground sockets
The signal and ground sockets of the probes have a special design to ensure optimal performance. The signal socket is not compatible with standard accessories. Use only the special accessories provided with the probes. Use of other pins and probe tips may damage the socket connections.

Making a Measurement

Connect the SMA connector of the probe to the SMA connector on the instrument. If the instrument has a BNC connector, then an SMA to BNC adapter is required.

For measurements on most instruments configure the settings as follows:

- Input impedance of the channel = 50 Ω
- Unit = V
- Attenuation = 1 : 1

You can now place the signal and ground pins on the target measurement points in your circuit

Figure 5: Making a measurement with the 1-Port probe. It is often necessary to set the ground pin placement first using the variable pitch pin and then apply the signal pin connection, rotating the probe into place.

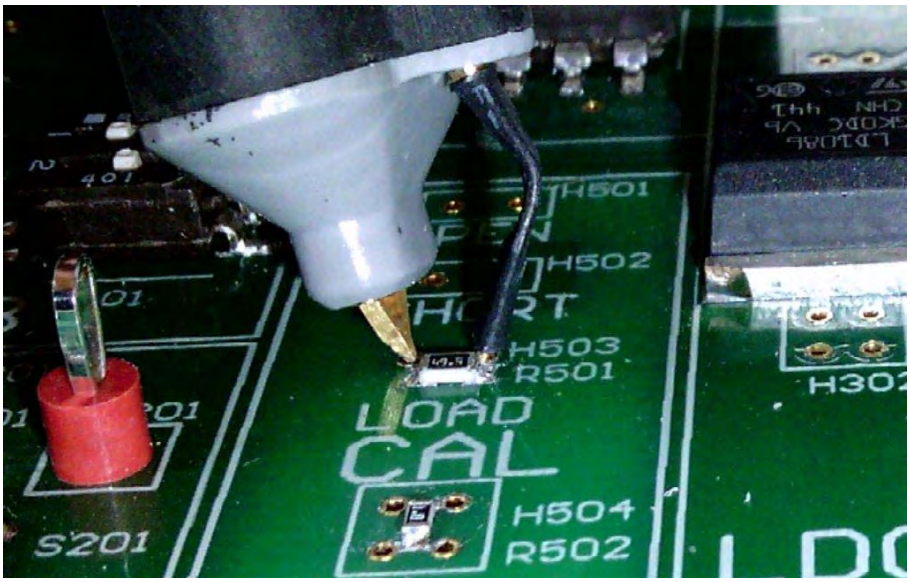


Figure 6: A 2-Port measurement using the 2-Port probe. Excessive pressure on the ground pin tip can break the pin.

DC Blockers: When and Why to Use Them

A coaxial DC Block (or Blocker) is used when DC isolation is required to protect sensitive test equipment or RF circuitry. Since the probe impedance of 50 ohms would load low impedance sources, it is often necessary to block any DC current. Either the J2130A DC bias Injector or the P2130A DC Blocker can be used for this purpose. The P2130A has male and female SMA connectors that allow it to be easily connected to the 1-Port and 2-Port probes.

As SMA to SMA cable (included in the Picotest Cable Kit (PCK01) or similar), or an SMA to BNC cable can then be used to connect the probe to the instrument.

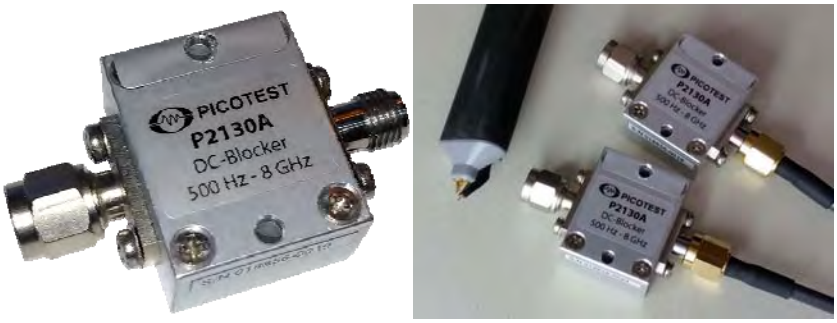


Figure 7: The P2130A DC blocker. 1 DC block is included with the 1-Port probe, 2 if the 2-Port probe is purchased or the P21B01 probe bundle.

The P2130A DC Blocker lets through frequencies between 500 Hz and 8 GHz while simultaneously providing low insertion loss and excellent VSWR. Its maximum differential (input – output) voltage is 50V.

1-Port Probe Applications

Shown below are some sample applications using the Picotest 1-Port probe. The 1-Port probe is bidirectional and can be used both record a signal and inject a signal. You can use the probe to make ripple, noise, impedance (1-Port reflection), and stability (via the NISM software) measurements. Using the J2150A harmonic comb injector you can also make EMI measurements and interrogate your PDN for impedance resonances.

Ripple and Noise (LM20143 Flat Impedance VRM)

The LM20143 Flat Impedance Demonstration Board, available from Picotest, is the shown in the figure below. This board is used to illustrate and teach good VRM design practices.

The next three figures show three different ways of measuring the PDN impedance. The measurement is made at the output of the VRM either on the board via the output SMA connector. The results are shown in figure 11.

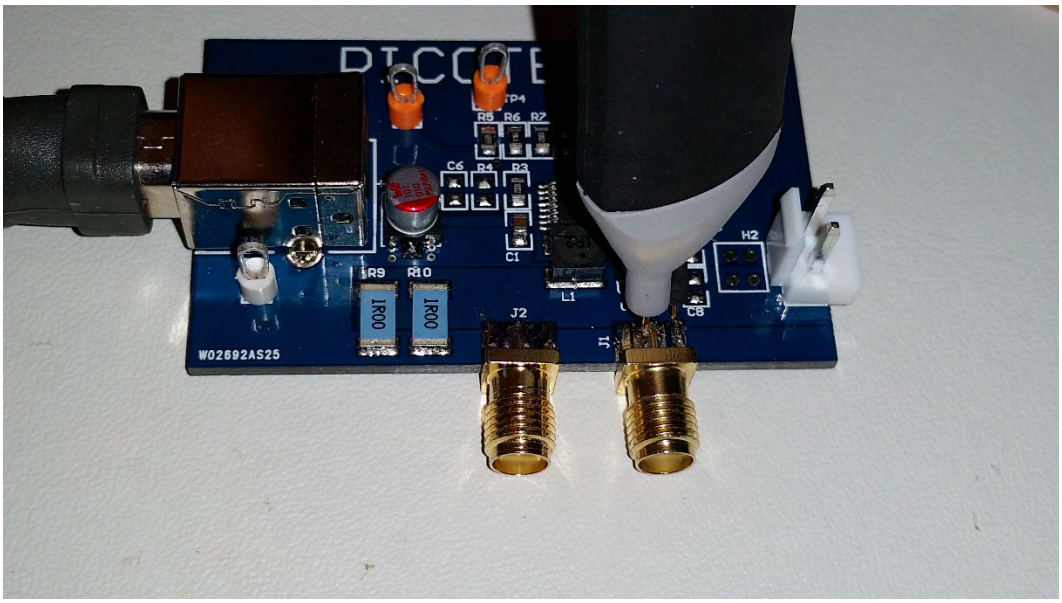


Figure 8: The 1-port probe is terminated into a P2130A DC Blocker and a 50Ohm scope input.

Figure 9: Direct connection of the VRM output to a 50Ohm scope input using P2130A DC Blocker.

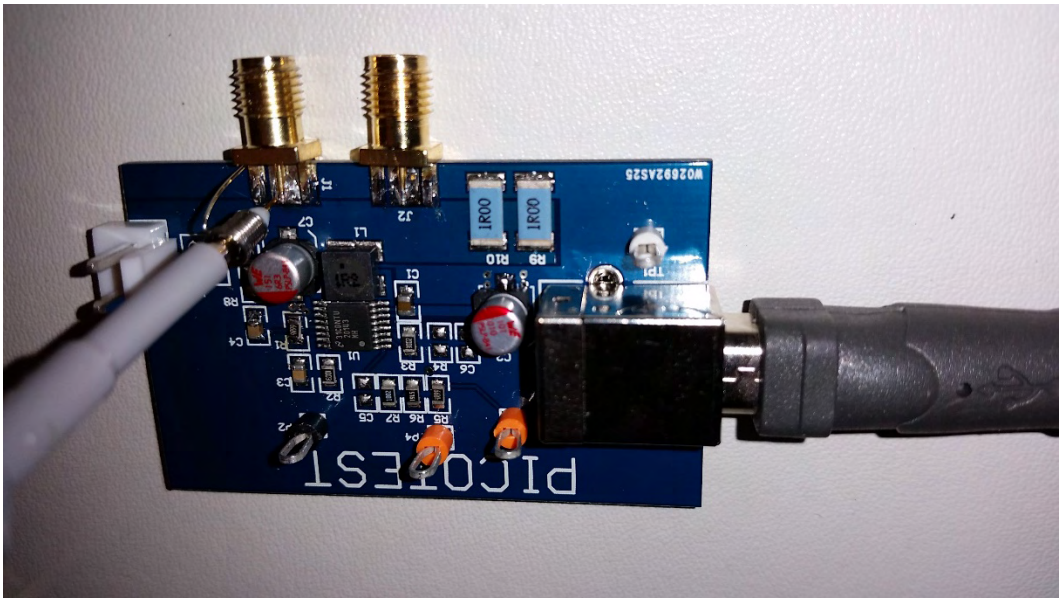


Figure 10: A 10X 500MHz scope probe with short spring clip.

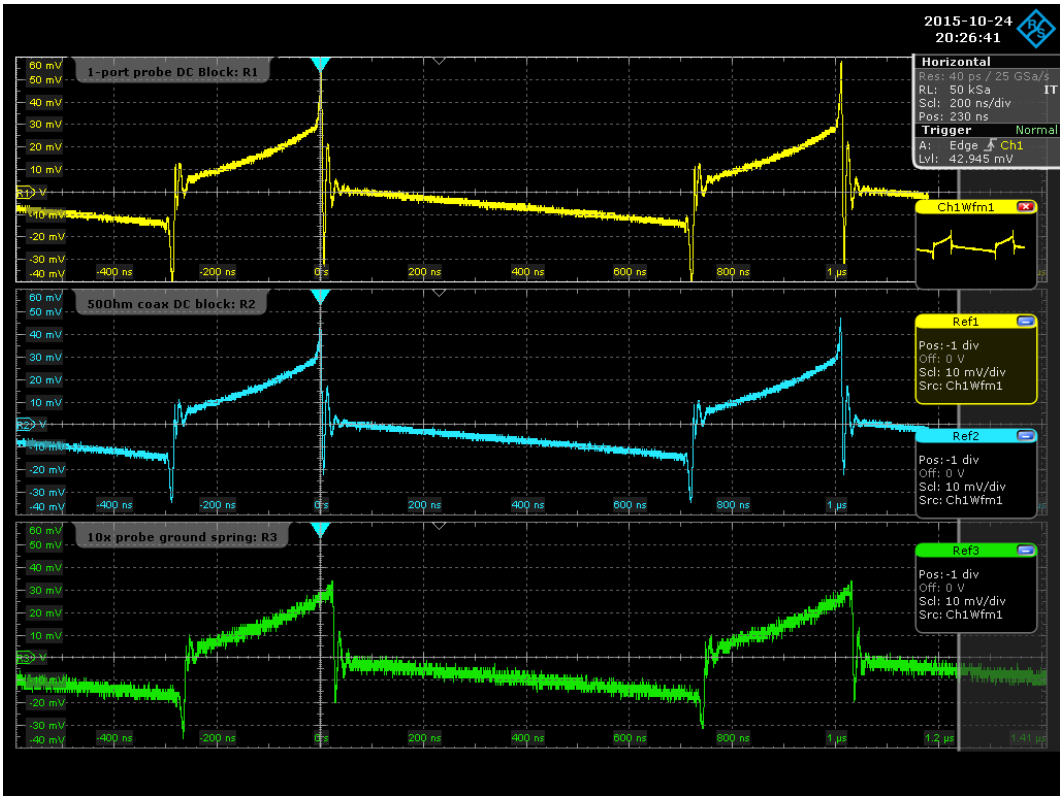


Figure 11 Comparison of the ripple measurement using the three different methods shown in the previous figures. Note that the 1-port probe has about the same fidelity as the direct connection while the scope probe is noisier.

S-Parameter Measurements

As a simple test, the 1-port probe was measured using the Keysight E5061B VNA.

Figure 12: The S-parameters of 1 port probe, S11, S22 and S21, are tested using the E5061B VNA. The CH2 terminator is used as the MATCH load.

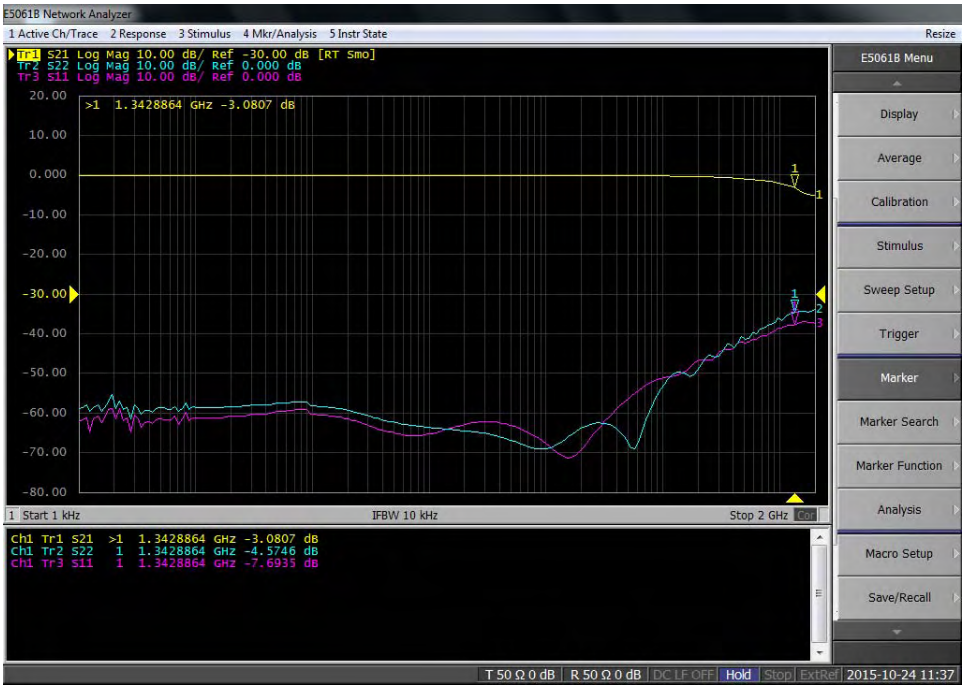


Figure 13: The 1-port probe S-parameter measurements show a -3dB frequency of 1.3GHz, which is mostly due to the 5.5nH ground lead.

Harmonic Comb Injection (VRTS3 Board)

The 1-Port probe can be used to inject a signal into a circuit. This is a very useful feature for many applications including PDN interrogation, EMI testing, and clock jitter measurement.

Shown below is the Picotest VRTS3 training board, which has a variety of sample circuits that supports many types of measurements. On the board is a power supply that powers a clock. In this example, the Picotest J2150A Harmonic Comb injector (generator) is connected to the 1-Port probe. The probe is connected to the power supplies' output capacitor and injects a broadband signal. The resulting spectrum can then be viewed on a Signal Source Analyzer or Spectrum Analyzer and the impact of the power supply's stability and distribution impedance on clock jitter can be assessed.

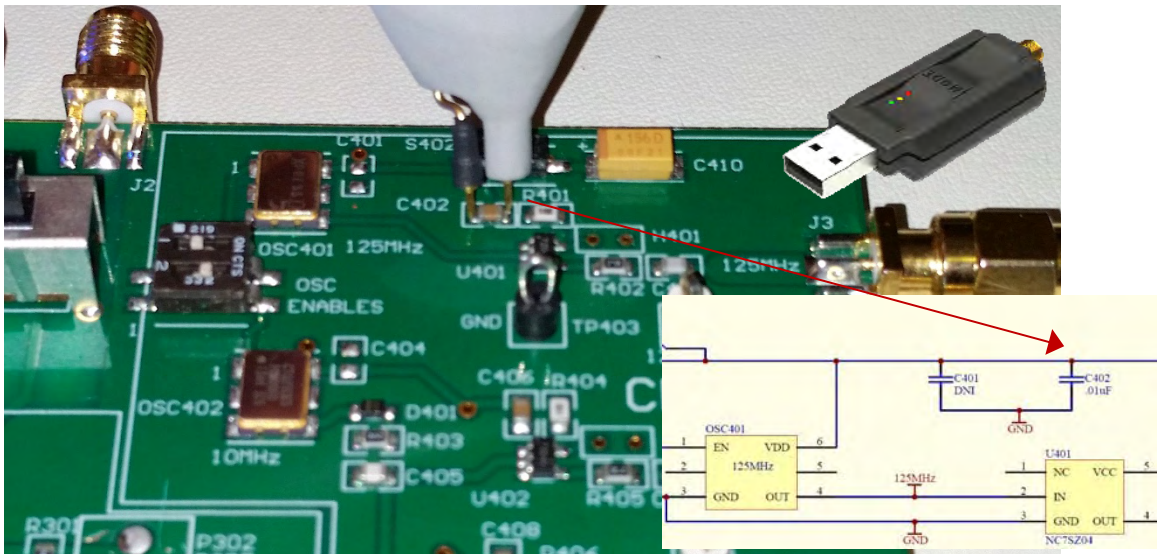


Figure 14: The J2150A harmonic comb (inset and in Figure 2) is connected to the 1-Port probe via a P2130A DC Blocker and connected to C402 (VDD of a 125MHz clock oscillator). The broadband signal extends from 1kHz to over 1GHz.

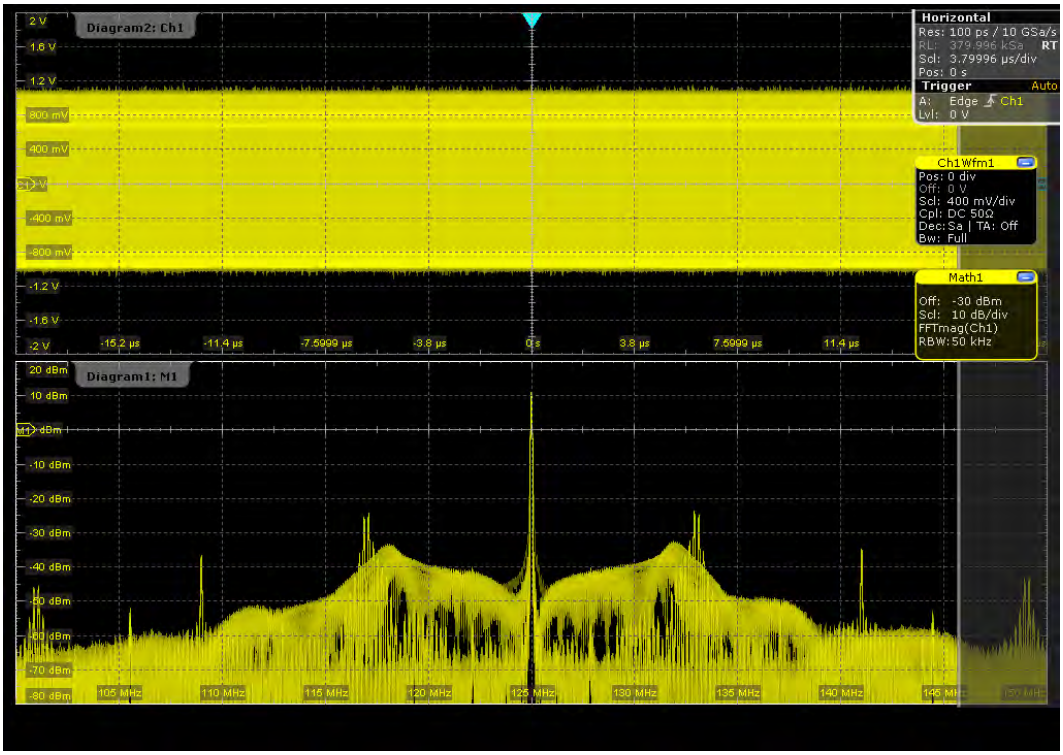


Figure 15: The spectrum measurement shows the clock sensitivity due to a PCB impedance resonance at capacitor C402.

NISM Stability Measurement (VRTS3 Board)

Non-Invasive Stability Measurement, or NISM, is a powerful technique for measuring the stability of control loops. The NISM software, embedded in commonly used VNAs, converts output impedance to phase margin. This is extremely useful considering that many of today's power ICs do not have their control loops exposed, and in fact, in those cases, NISM is the only way to make an accurate stability measurement.

In this case, the output impedance of a Voltage Reference is measured. The VNA, in this case the Bode 100, is used to measure the impedance at the output of the reference. The impedance is then converted to Phase margin using a simple cursor measurement as shown below.

Figure 16: 1-port probe connected to H101 to measure the impedance of a voltage reference. This same test can be performed on any power supply control loop including those of POLs, switchers and linear regulators.

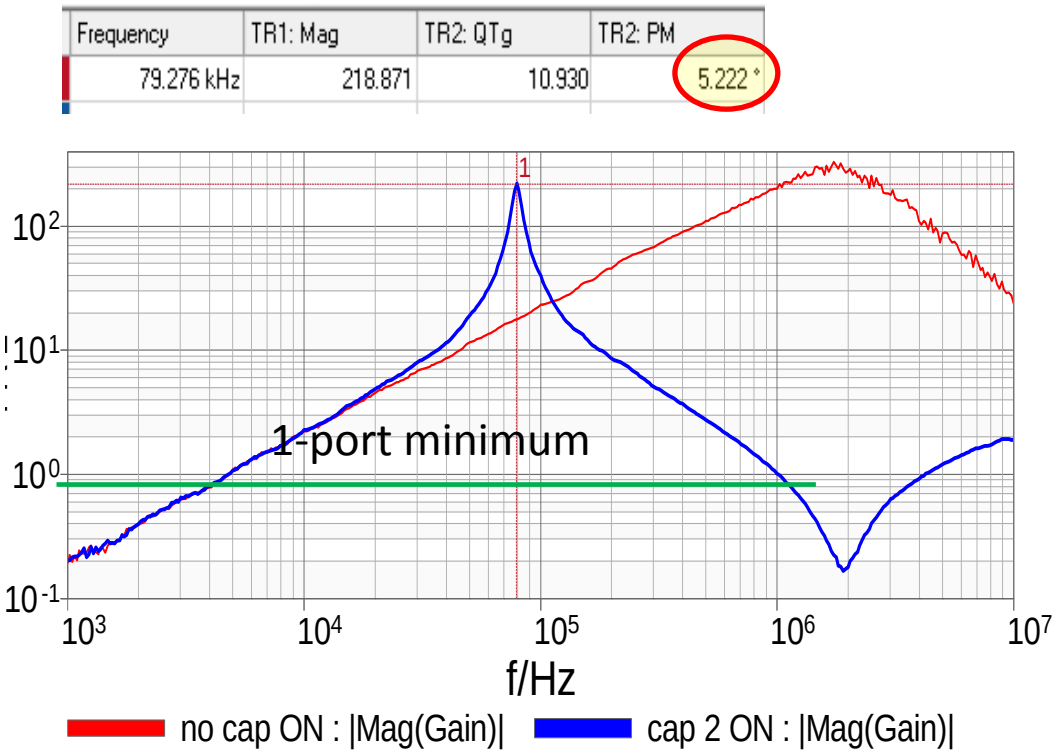


Figure 17: The NISM measurement reveals the phase margin of the voltage reference to be 5.22 degrees.

TDR Measurement (VRTS3 Board)

The VRTS3 training test board includes two 50Ω microstrip traces. One with a solid ground plane and the other with a hole in the ground plane, resulting in excess inductance. Each trace has two aberrations exactly 3 inches apart allowing PCB dielectric measurements as well as excess inductance and capacitance measurements.

Here, the 1-Port probe is used to measure the impedance on a TDR instrument. The measurement below shows the impact of the hole in the ground plane, as well as the direct measurement of the excess inductance.

Figure 18: The 1-Port probe is used for TDR measurement on the VRTS3 test board.

Figure 19: The excess inductance resulting from the hole in the ground plane.

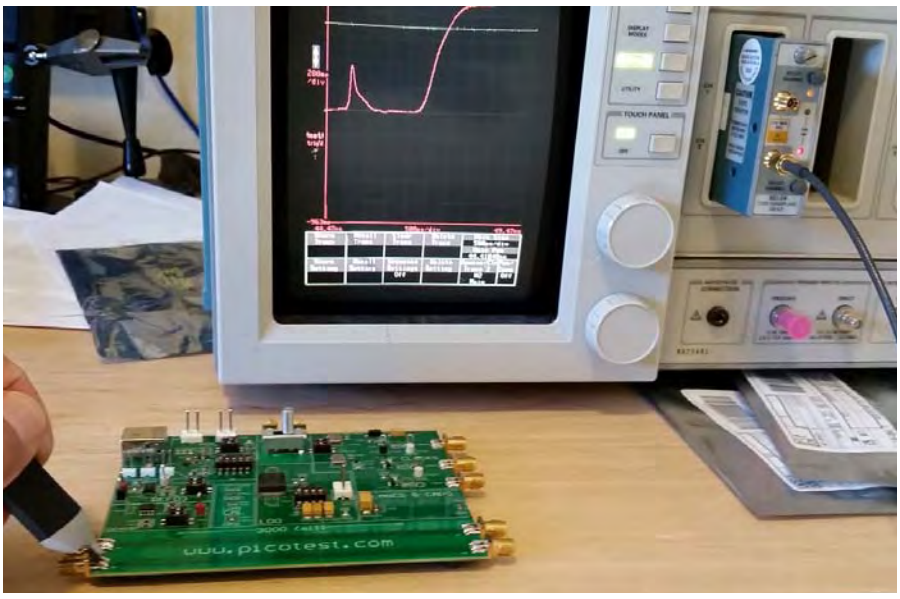


Figure 20: TDR connection to 1-port probe used to measure trace and plane impedance. The positive "spike" is a reflection of the ground lead inductance. Beyond the spike the 50Ohm trace is shown as a 0 reflection.

2-Port Probe Applications

The 2-Port probe can be used to transmit a load current step through one port, while measuring the response from the other port, simultaneously. This is a great advantage when browsing your board's power rails, looking for problems and poor stability. All you have to do is setup the load step range and then simply move the probe to the capacitor at the output of each regulator IC in order to view the transient response.

The probe is also essential for performing 2-Port impedance measurements. When the impedance you need to measure is low (less than an ohm), the 1-Port reflection measurement will not be adequate as it can't measure impedance in that range. In low impedance cases, the 2-Port probe, with its near zero capacitance and 50 ohm compatibility, is the perfect option.

Regulator Load Step Testing (VRTS3 Board)

In this example of a linear regulator load step test, the J2150A Harmonic comb is used as a simple and portable square wave generator (one of its modes of operation). It drive the Picotest J2111A current injector. This modulates the load current at the output of the regulator when the probe is applied. The P2130A DC blocker is inserted so that the scope does not load the output of the regulator.

Load step testing doesn't get any easier.

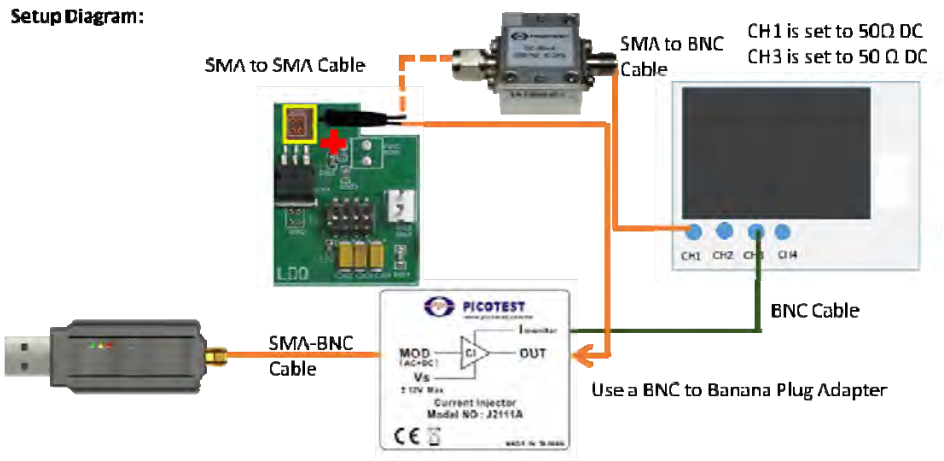


Figure 21: Test setup for the load step test using the 2-port probe.

Figure 22: The step load response is shown on CH1 and the applied load step is shown on CH3. The amount of ringing is related to the stability of the system.

Low Impedance PDN Power Integrity Testing (VRTS3 Board)

This sample test measures the output impedance and stability of an LDO using a 2 port probe and a common mode transformer. The 2-port probe has two leads at the tip (joined with a special pointed clip) and a common ground port. While the connection of the tip and ground wire to the board may take some getting used to, this "browser" class probe is very useful in making multiple measurements in tight places without the need to recalibrate.

The J2102A common mode transformer is essentially here as there is an instrument ground loop which would otherwise distort the low frequency data. Therefore, it is generally required for VNA 2 port measurements.

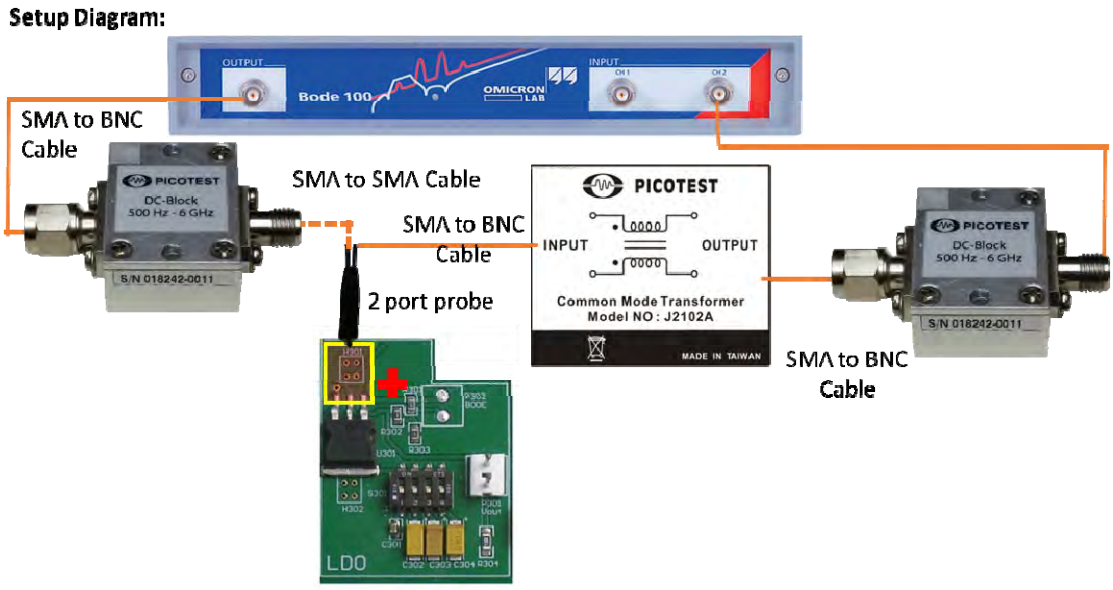


Figure 23: The 2-Port probe setup for a 2-port impedance/stability measurement of an LDO. In this case, NISM software is also used to convert the impedance measurement to phase margin (stability). The J2102A common mode transformer is used to break the instrument ground loop that impacts low frequency data.

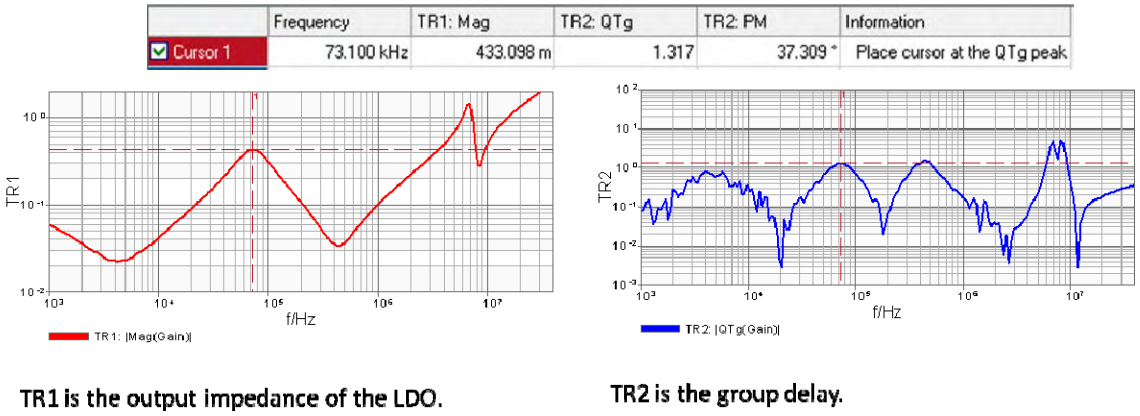


Figure 24: The impedance data is shown to the left. The group delay is shown on the right and it converted to phase margin (stability) via a simple cursor measurement and the built-in NISM software.

Chapter 3 – Accessories and Specifications

Accessories

The probes come with the following accessories.

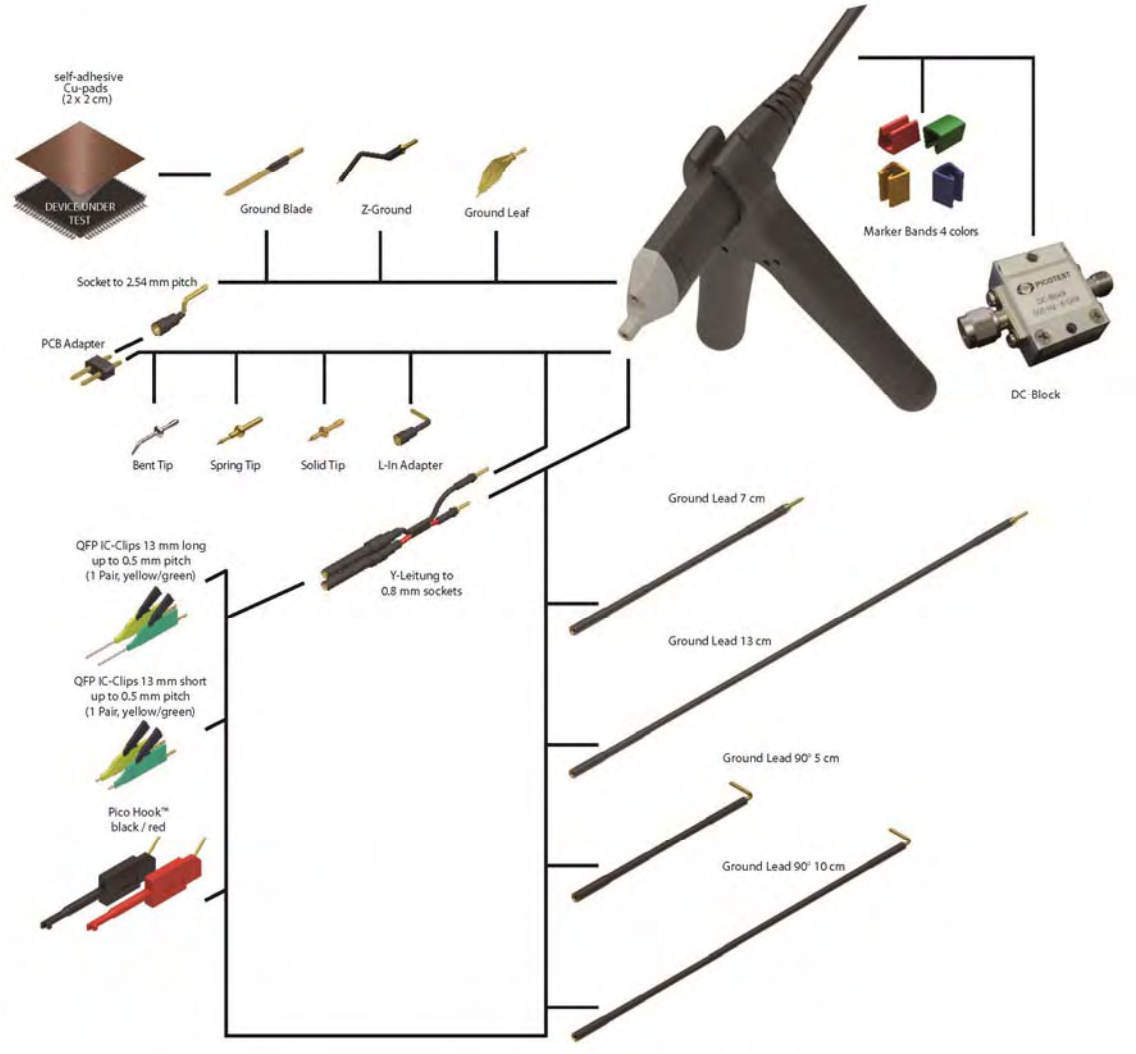


Figure 25, P2100A 1-Port Probe Accessories.

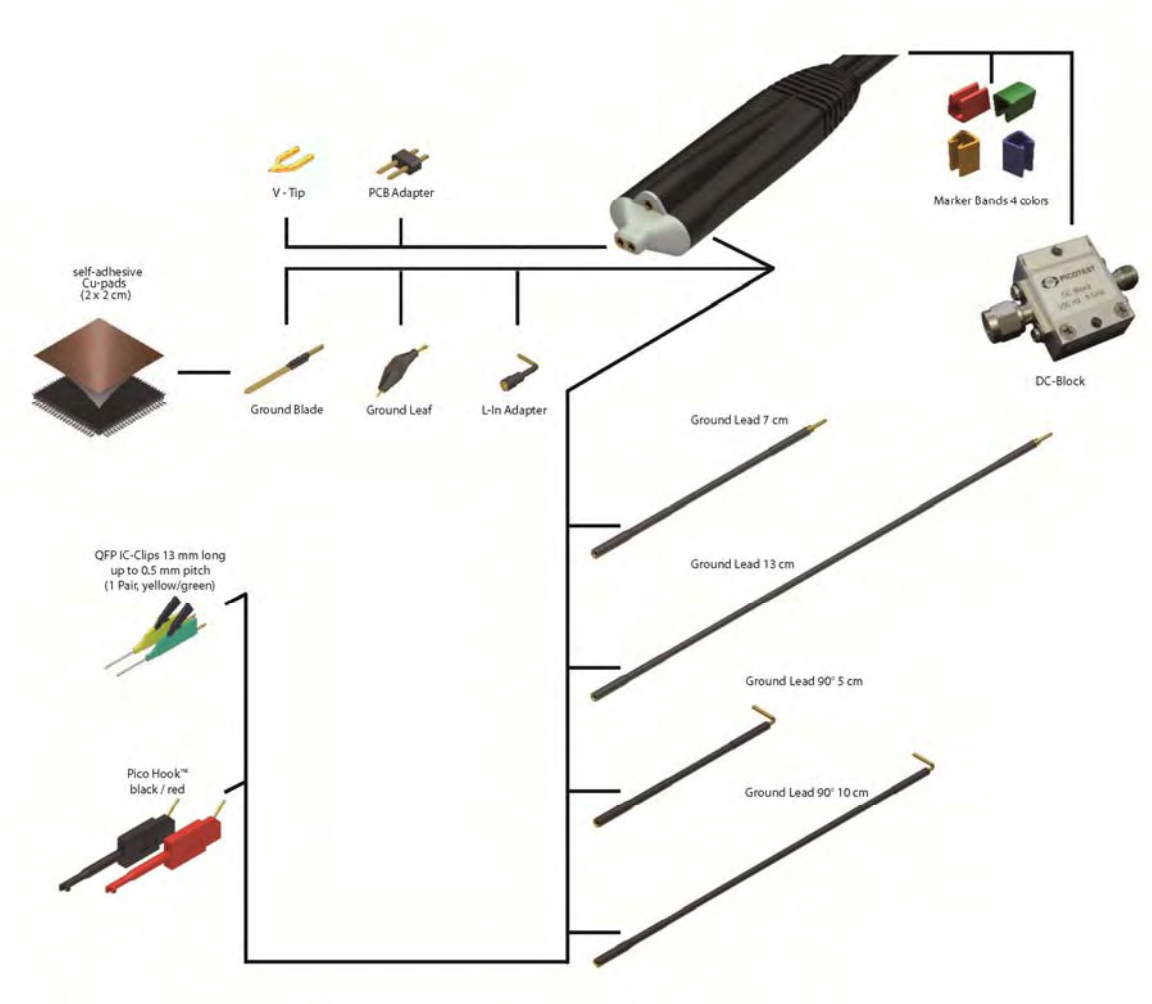


Figure 26, P2101A 2-Port Probe Accessories.

The following items are included in the scope of delivery. Please check the delivery for completeness. If any item is missing, send a message to our service department and we will send you this item immediately.

Item	**Qty**
2 Footer Positioner	1
Coding Rings (set) 3x4 Colors	1
Ground Blade 2.5	1
Ground Lead 15 cm	1
Ground Spring 2.5	1
IC-Cap 2.5 0.5 mm pitch; green	1
IC-Cap 2.5 0.65 mm pitch; blue	1
IC-Cap 2.5 0.8 mm pitch; grey	1
IC-Cap 2.5 1.0 mm pitch; brown	1
IC-Cap 2.5 1.27 mm pitch; black	1
Instruction Manual	1
Insulating Cap 2.5	1
PCB Adapter Kit 2.5	1
Probe	1
Protection Cap 2.5	1
Self adhesive Cu Pad (2 x 2 cm)	2
Solid Tip CuBe 0.5 mm	1
Spring Tip gold plated 0.5 mm	1
Sprung Hook 2.5	1

Safety Information

To avoid personal injury and to prevent fire or damage to this product or products connected to it, review and comply with the following safety precautions. Be aware that if you use this probe assembly in a manner not specified, the protection this product provides may be impaired. Only qualified personnel should use this probe assembly. Do not connect the probe to any voltage that exceeds the maximum permissible input voltage specified in the data sheet. Non-compliance with this instruction carries the risk of an electric shock. Make sure not to cause any short circuits when performing measurements on sources with high output currents. Short circuits may cause injuries or burns.

Risk of injury caused by pointed object
The pins of the probe are extremely pointed and can easily penetrate clothes and skin. Therefore, handle the probe pins with great care. When transporting the probe, e.g. when carrying it in a pocket or tool bag, always use the supplied case. To exchange a probe pin, use tweezers or pliers to avoid injuries.

Use only grounded instruments.
Do not connect the probe ground lead to a potential other than earth ground. Always make sure the probe and the measurement instrument are grounded properly.

Observe probe ratings.
Do not apply any electrical potential to the probe input which exceeds the maximum ratings of the probe or the accessories connected to it. In a combination always the lower rating / measurement category applies to both probe and accessories connected to it.

Do not operate with suspected failures.
Refer to qualified service personnel.

Indoor use only.
Do not operate in wet/damp environment. Keep product surfaces dry and clean. Do not operate the product in an explosive atmosphere.

Handling Information

Handle with care especially when fitted with the extra thin and sharp spring contact tip to avoid any injury. Note that the probe cable is a sensitive part of the probe. Do not damage through excessive bending or pulling. Avoid mechanical shock to this product in general to guarantee accurate performance and protection.

Caution: To avoid equipment damage and/or severe injuries or death ensure that the absolute maximum ratings defined in this manual are observed at all times and never exceeded.

Cleaning

To clean the exterior of the probe, use a soft cloth moistened with either distillated water or isopropyl alcohol. Before use allow the probe to dry completely.

Electrical Specifications

Specifications that are not defined to be guaranteed are typical and are published as general information to the user. In order to achieve these results, the instrument should have warmed-up for at least 20 minutes and the environmental conditions should not exceed the probe's specified limits.

1-Port Probe	
Characteristic	**Rating**
Bandwidth	DC-1GHz
Input C:	<1pF, 420fF Typical
Ground Inductance	3.7nH Typical
Input R: Maximum voltage	50 Ohms 5 Vrms
Maximum thru current any port	1Amp
Probe connections	SMA
Probe tip size	0603-1206
Probe impedance	50 Ohm
Port to port isolation	N/A
Probe-only Propagation Delay	TBD
Rise time	350 ps
Operating temperature	0 to 45° C (32° F to 104° F) at 80% relative humidity
Nominal length with cable	1 meter
Attenuation	1x
Probe-only bandwidth	1Ghz
Probe pitch	TBD
Probe connection	SMA male
Size	TBD
Maximum relative humidity	80% at 31° C max
Usage	Indoor
Altitude	3000 m (9850 feet)
Absolute Maximum Voltage	< 50VAC and 75VDC

2-Port Probe	
Characteristic	**Rating**
Bandwidth	DC-1GHz
Input C:	<1pF
Input R: Maximum voltage	50 Ohms 5 Vrms
Maximum thru current any port	1Amp
Probe connections	SMA
Probe tip size	0603-1206
Probe impedance	50 Ohm
Port to port isolation	TBD
Probe-only Propagation Delay	TBD
Rise time	350 ps
Operating temperature	0 to 45° C (32° F to 104° F) at 80% relative humidity
Nominal length with cable	1 meter
Attenuation	1x
Probe-only bandwidth	1Ghz
Probe pitch	TBD
Probe connection	SMA male
Size	TBD
Maximum relative humidity	80% at 31° C max
Usage	Indoor
Altitude	3000 m (9850 feet)
Absolute Maximum Voltage	< 50VAC and 75VDC

DC Blockers Electrical Specifications

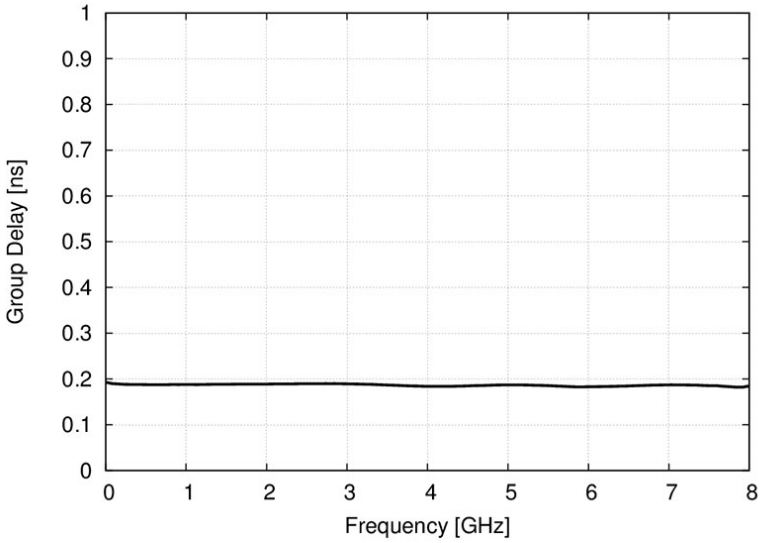
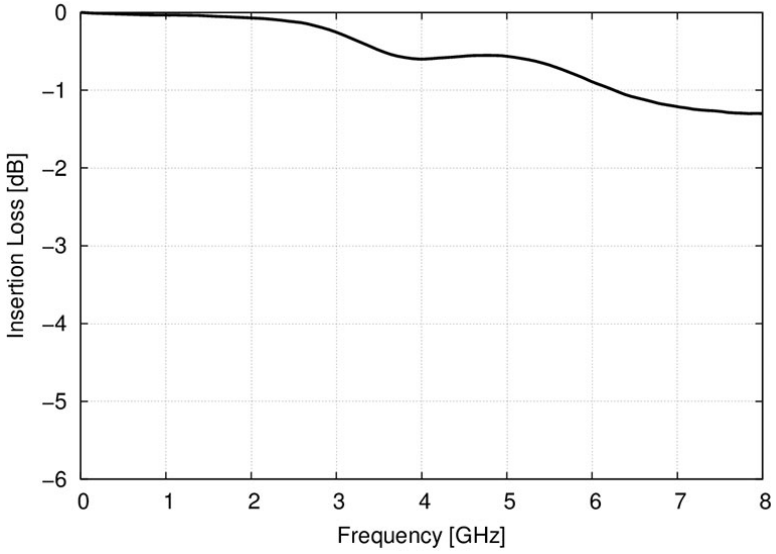
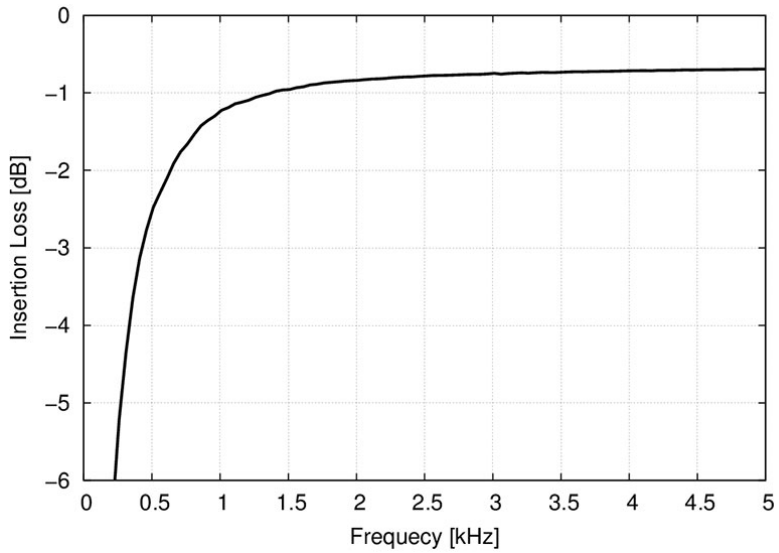


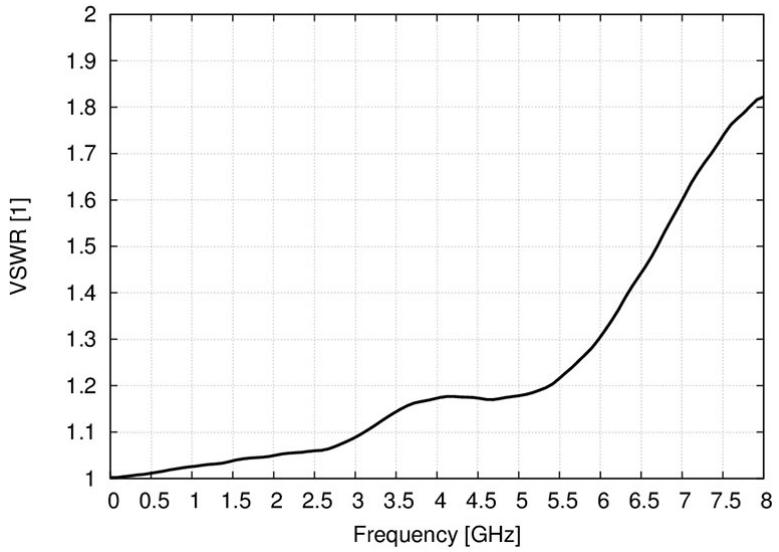
Figure 27, DC Blocker characteristics, DC Block 8GHz Group Delay.



DC Block 8GHz Insertion Loss.



DC Block 8GHz Near DC Insertion Loss.



DC Block 8GHz VSWRs.

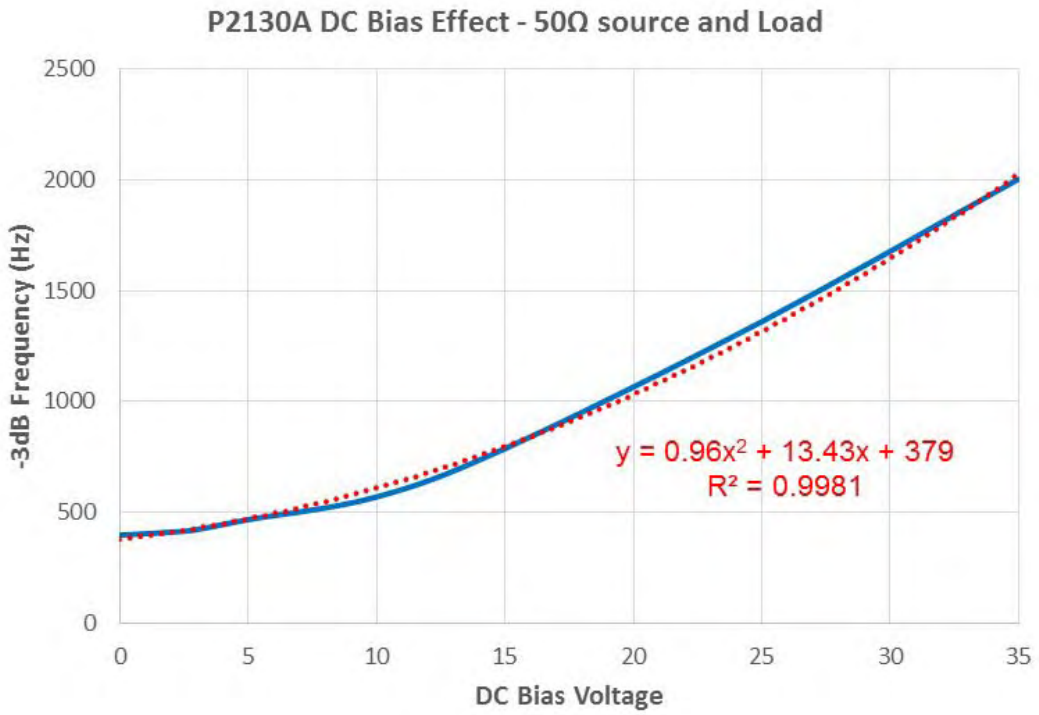


Figure 28: The effect of DC bias on the P2130A DC blocker frequency performance which shifts the - 3dB frequency.