Keysight N7020A Power Rail Probe

User's Guide

KEYSIGHT TECHNOLOGIES

Notices

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WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Contents

1 General Information

The N7020A power-rail probe is designed for power integrity measurements such as Periodic and Random Disturbances (PARD), static and dynamic load response, and programmable power-rail response. The N7020A provides the following advantages:

- Low noise due to a low attenuation ratio (1.1:1) and 50Ω output. See Figure 1 on page 6 and Figure 2 on page 6.
- A large ±24V probe offset range. The offset allows small signals (≤1 mV), that exist on top of a DC supply, to be centered on an oscilloscope for maximum vertical sensitivity.
- Low DC loading due to a 50 kΩ input impedance at DC.
- Large ±850 mV active signal range in addition to the offset range

CAUTION

Before using the probe, refer to "Safety Information" on page 10. Handle the probe with care and refer to the safety notices in this manual. Avoid any mechanical shocks to this product in order to guarantee accurate performance and protection.

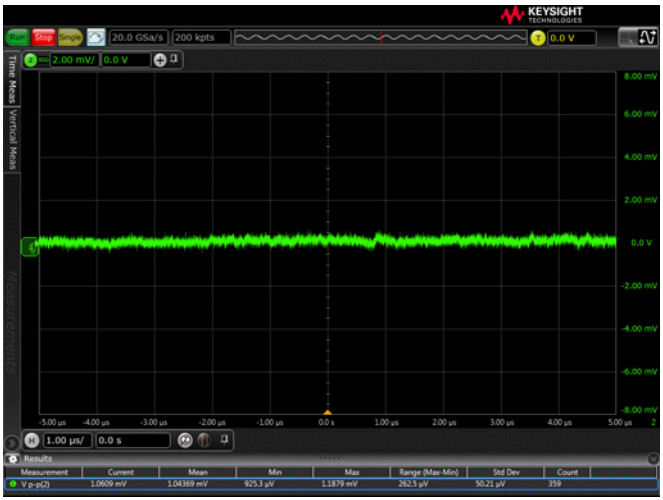


Figure 1 Example of Measured Mean Noise at 2 GHz BW: 1.04369 mV_{p-p}

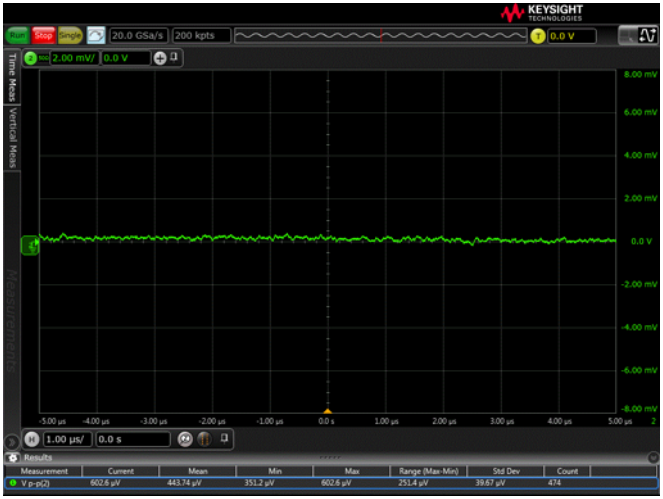


Figure 2 Example of Measured Mean Noise at 20 MHz BW: 443.74 μV_{p-p}

Oscilloscope Compatibility

The N7020A probe is compatible with the Keysight oscilloscopes shown in Table 1. Up to four probes can be connected to the oscilloscope at the same time. The table also lists the minimum required firmware version for the oscilloscope.

NOTE **The N7020A probe is designed for oscilloscopes with 50Ω AutoProbe-interface channel inputs. The AutoProbe interface provides the power to the probe.**

Table 1 Compatible Oscilloscopes and Support

Infiniium Oscilloscopes	Required Firmware Version	Adapter Required
S-Series	≥ 5.20	–
9000A	≥ 5.20	–

Is Your Oscilloscope Software Up-to-Date? Keysight periodically releases software updates to support your probe, fix known defects, and incorporate product enhancements. To download the latest firmware, go to www.keysight.com and search for your oscilloscope's topic. Click on the "Drivers, Firmware & Software" tab.

Supplied Accessories

The probe comes with the accessories shown in Figure 3. Use the SMA cables to connect the probe to the Device Under Test (DUT).

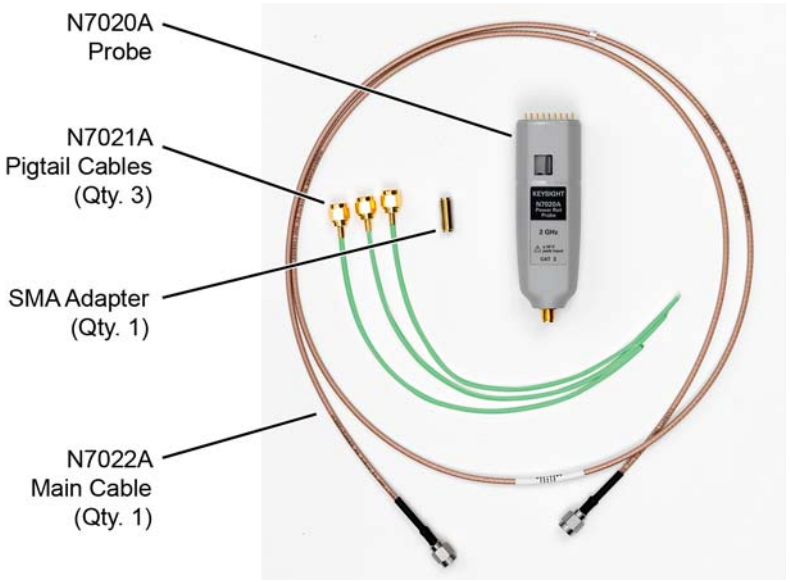


Figure 3 Probe with Accessories

To Clean the Probe

Disconnect the probe from the oscilloscope and clean the probe with a soft cloth dampened with a mild soap and water solution. Make sure that the probe is completely dry before reconnecting it to an oscilloscope. Avoid using abrasive cleaners and chemicals containing benzene or similar solvents.

Inspecting the Probe

- Inspect the shipping container for damage.

Keep the damaged shipping container or cushioning material until the contents of the shipment have been checked for completeness and the probe has been checked mechanically and electrically.

- Check the accessories.
- If the contents are incomplete or damaged, notify your Keysight Technologies Sales Office.
- Inspect the probe. If there is mechanical damage or defect, or if the probe does not operate properly or pass calibration tests, notify your Keysight Technologies Sales Office.

If the shipping container is damaged, or the cushioning materials show signs of stress, notify the carrier as well as your Keysight Technologies Sales Office. Keep the shipping materials for the carrier's inspection. The Keysight Technologies office will arrange for repair or replacement at Keysight Technologies' option without waiting for claim settlement.

WARNING **Must be Grounded. Before making connections to the input leads of this probe, ensure that the probe's output connector is attached to the channel input of the oscilloscope and the oscilloscope is properly grounded.**

CAUTION To protect against electrical shock, use only the accessories supplied with this probe or in the accessory kit.

Safety Information

This manual provides information and warnings essential for operating this probe in a safe manner and for maintaining it in safe operating condition. Before using this equipment and to ensure safe operation and to obtain maximum performance from the probe, carefully read and observe the following warnings, cautions, and notes.

This product has been designed and tested in accordance with accepted industry standards, and has been supplied in a safe condition. The documentation contains information and warnings that must be followed by the user to ensure safe operation and to maintain the product in a safe condition.

Note the external markings on the probe that are described in this document.

WARNING **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.**

WARNING **Use Only Grounded Instruments.**
Do not connect the probe's ground lead to a potential other than earth ground. Always make sure the probe and the oscilloscope are grounded properly.

WARNING **Connect and Disconnect Properly.**
Connect the probe to the oscilloscope and connect the ground lead to earth ground before connecting the probe to the circuit under test. Disconnect the probe input and the probe ground lead from the circuit under test before disconnecting the probe from the oscilloscope.

WARNING **Do Not Operate Without Covers. To avoid electrical shock or fire hazard, do not operate this probe with the covers removed.**

WARNING **Do Not Operate in Wet / Damp Conditions.**
To avoid electrical shock, do not operate this probe in wet or damp conditions.

WARNING **Do Not Operate in an Explosive Atmosphere.**
To avoid injury or fire hazard, do not operate this probe in an explosive atmosphere.

WARNING **Avoid Exposed Circuit. To avoid injury, remove jewelry such as rings, watches, and other metallic objects. Do not touch exposed connections and components when power is present.**

WARNING **For Indoor Use Only. Only use this probe indoors.**

WARNING **Do Not Operate With Suspected Failures. If you suspect there is damage to this probe, have it inspected by a qualified service personne.**

Concerning the Oscilloscope or Voltage Measuring Instrument to Which the Probe is Connected

WARNING **Whenever it is likely that the ground protection is impaired, you must make the instrument inoperative and secure it against any unintended operation.**

WARNING **If you energize the instrument by an auto transformer (for voltage reduction or mains isolation), the ground pin of the input connector terminal must be connected to the earth terminal of the power source.**

WARNING **Before turning on the instrument, you must connect the protective earth terminal of the instrument to the protective conductor of the (mains) power cord. The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. You must not negate the protective action by using an extension cord (power cable) without a protective conductor (grounding). Grounding one conductor of a two-conductor outlet is not sufficient protection.**

WARNING **Only fuses with the required rated current, voltage, and specified type (normal blow, time delay, etc.) should be used. Do not use repaired fuses or short-circuited fuse holders. To do so could cause a shock or fire hazard.**

WARNING **Capacitors inside the instrument may retain a charge even if the instrument is disconnected from its source of supply.**

Returning the Probe for Service

If the probe is found to be defective we recommend sending it to an authorized service center for all repair and calibration needs. Perform the following steps before shipping the probe back to Keysight Technologies for service.

1. Contact your nearest Keysight sales office for information on obtaining an RMA number and return address.
2. Write the following information on a tag and attach it to the malfunctioning equipment.
   - Name and address of owner
   - Product model number (for example, N7020A)
   - Product Serial Number (for example, MYXXXXXXXX)
   - Description of failure or service required.

NOTE Include probing and browsing heads if you feel the probe is not meeting performance specifications or a yearly calibration is requested.

3. Protect the probe by wrapping in plastic or heavy paper.
4. Pack the probe in the original carrying case or if not available use bubble wrap or packing peanuts.
5. Place securely in sealed shipping container and mark container as "FRAGILE".

NOTE If any correspondence is required, refer to the product by serial number and model number.

Contacting Keysight Technologies

For technical assistance, contact your local Keysight Call Center.

- In the Americas, call 1 (800) 829-4444
- In other regions, visit http://www.keysight.com/find/assist
- Before returning an instrument for service, you must first call the Call Center at 1 (800) 829-4444.

2 Using the N7020A

This chapter explains requirements for using the probe, how to connect the probe to the Device Under Test (DUT), and how to protect the oscilloscope and probe from damage due to ESD.

CAUTION Always wear an ESD wrist strap when working with active probes. Not doing so can result in damage to the probe and to the oscilloscope's input channel.

NOTE If the N7020A input is disconnected on an S-series oscilloscope at vertical settings at or below 20 mV/div with more than 200 mV of applied offset, the probe output may be indeterminate. Upon zeroing the offset, increasing the vertical setting, or connecting the probe input to a low impedance, the output will be correctly restored.

Requirements for Optimum Probe Performance

Low Source Impedance Required

The N7020A is designed explicitly for measuring voltage power supplies. In order to maintain a flat frequency response across the probe's bandwidth, the DUT must have extremely low source impedance, like that of a power rail. The N7020A has a non-flat input impedance that transitions from 50 kΩ at DC to 50Ω at 1 MHz and above. Therefore, if the DUT impedance is not low, it will divide with the probe's impedance unequally across frequency, causing a non-flat measurement. The recommended DUT impedance should be much less than 1 ohm. At 1 ohm, the DC-to-AC non-flatness is about 2%. Figure 4 shows the non-flatness for DUT impedances of 0Ω, 1Ω, 25Ω, and 50Ω.

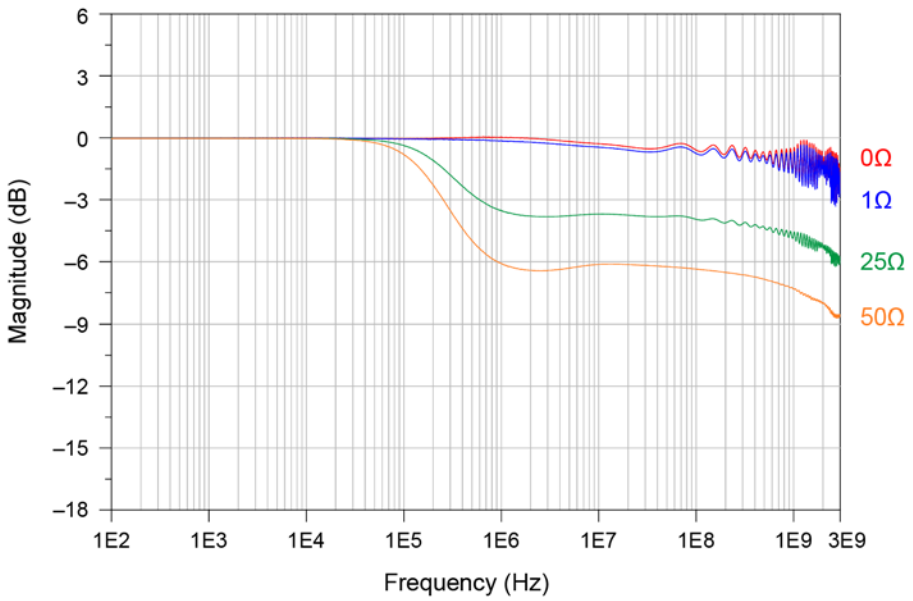


Figure 4 Frequency Response (Probe with N7022A Main Cable) Versus DUT Impedance

To the DC component of a supply voltage, the N7020A probe presents a high impedance and thus low loading (about 50 kΩ). To the ac component of the supply voltage, the probe presents a low 50Ω impedance. This probe's low input impedance, reduces noise on the probe's output to the oscilloscope thus increasing measurement range and accuracy.

The following graph shows the probe's input impedance versus frequency.

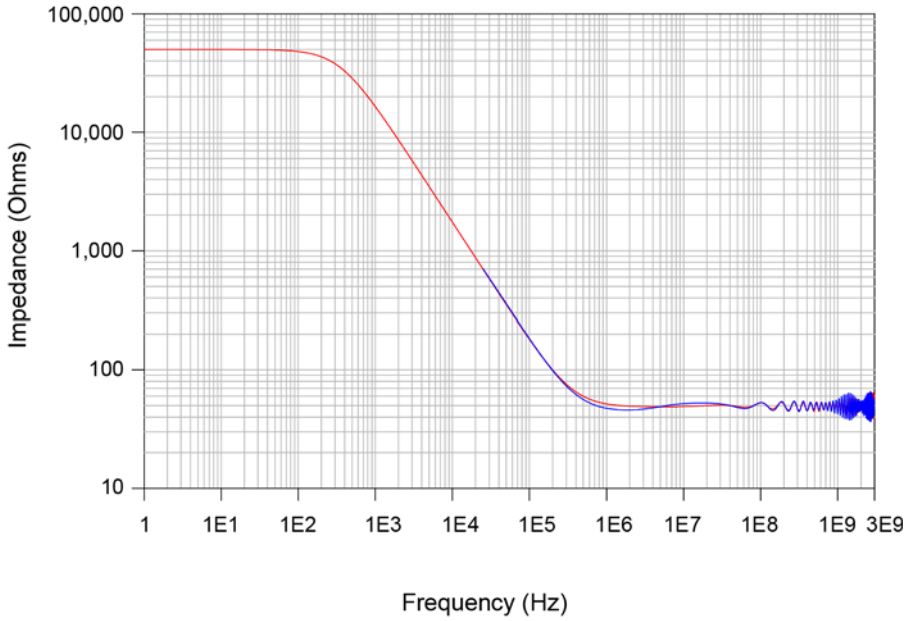


Figure 5 Input Impedance Versus Frequency, Z_{in} Measured, Z_{in} Modeled (N7020A with N7022A Main Cable)

Minimize Probe Ground Impedance for the Best Signal Fidelity

The N7020A is a single-ended probe that is designed for measuring small signals riding on large DC voltages. By using the oscilloscope's offset knob to offset the DC voltage, you can analyze a power rail using maximum vertical sensitivity. With no added noise other than a 10% increase to the oscilloscope channel's noise, due to 1.1:1 attenuation, the N7020A has very low input noise. For example, at maximum sensitivity on a 9000S oscilloscope, the input-referred AC_{rms} noise is 140 μV_{rms}.

To achieve the best signal fidelity, it is vital that the physical connection and ground impedance of the probe be minimized. Any unnecessary length in either the probe's signal or ground can cause capacitive coupling and inductive pick-up larger than the signal of interest. The N7020A provides two connection methods, both well-suited for high fidelity measurements:

- The N7022A main cable, connected directly to an SMA port on the DUT, provides the highest fidelity since the ground and signal are intimately mated with an SMA connector.
- The N7021A is a prepared coaxial-cable pigtail that allows the probe to be soldered to the DUT. It is recommended that the coaxial shield be soldered directly to ground, thus minimizing the ground impedance.

As with any single-ended probe there may be a concern of creating a ground loop by the connection of the DUT ground to the probe/scope ground. This generally does not cause a measurement issue as long as the DUT ground is not radically different than the scope ground. You can test this by connecting the probe's ground and signal contacts to the DUT ground. You should not see any significant signal on the oscilloscope's screen.

Common Types of Power Integrity Measurements

The following list some of the common types of power integrity measurements that you can perform using the N7020A probe:

- Static and dynamic load response.

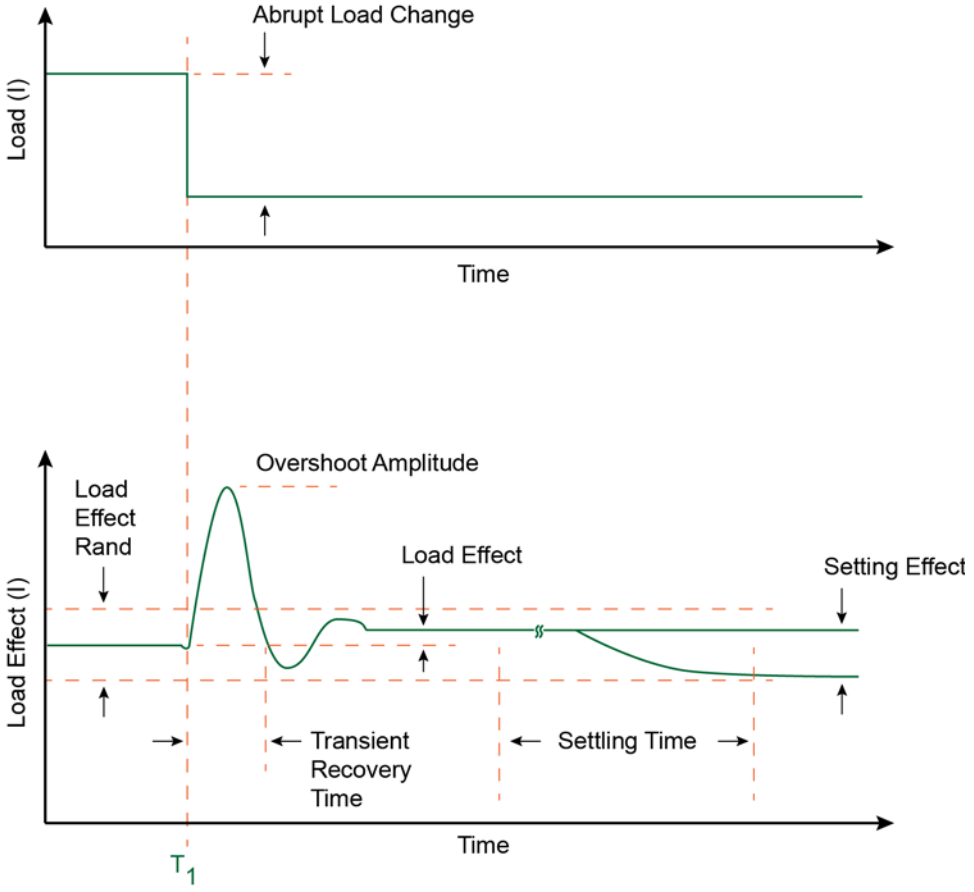


Figure 6 Example of Response to Changing Load

- Supply drift.
- Programmable power rail response.

- High frequency transients and noise.
- PARD (Periodic and Random Disturbances) such as noise, ripple, and switching transients on power rails.

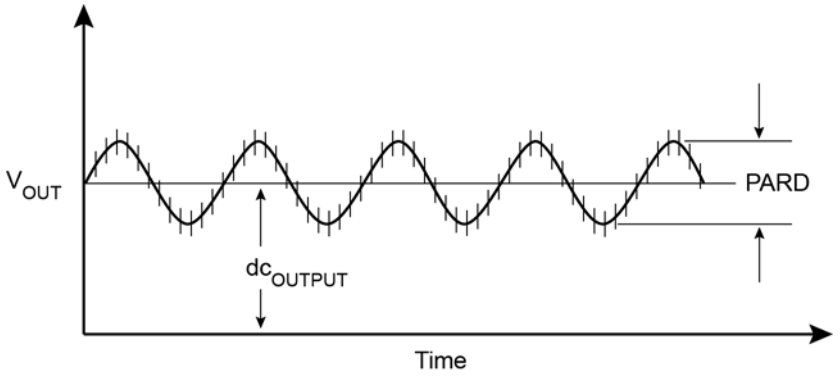


Figure 7 Example of PARD on DC Output

- Product electrical validation at extended temperatures.

Connecting to the DUT

Because supported Keysight oscilloscopes include S-parameter correction for the N7021A and N7022A cables, always use the following cables combinations for the most accurate measurements:

- N7020A probe with N7022A main cable
- N7020A probe with the N7022A main cable and N7021A pigtail cable. Use the supplied SMA adapter to connect the two cables.

The N7022A main cable allows you to probe DUTs that are located up to 1.2 meters from the probe. The N7021A pigtail cable is designed to be soldered onto the DUT. Figure 8 shows how to solder the end of the N7021A pigtail cable to a DUT. The typical probing point will often be across a bypass capacitor with the cable's outside conductor soldered to ground.

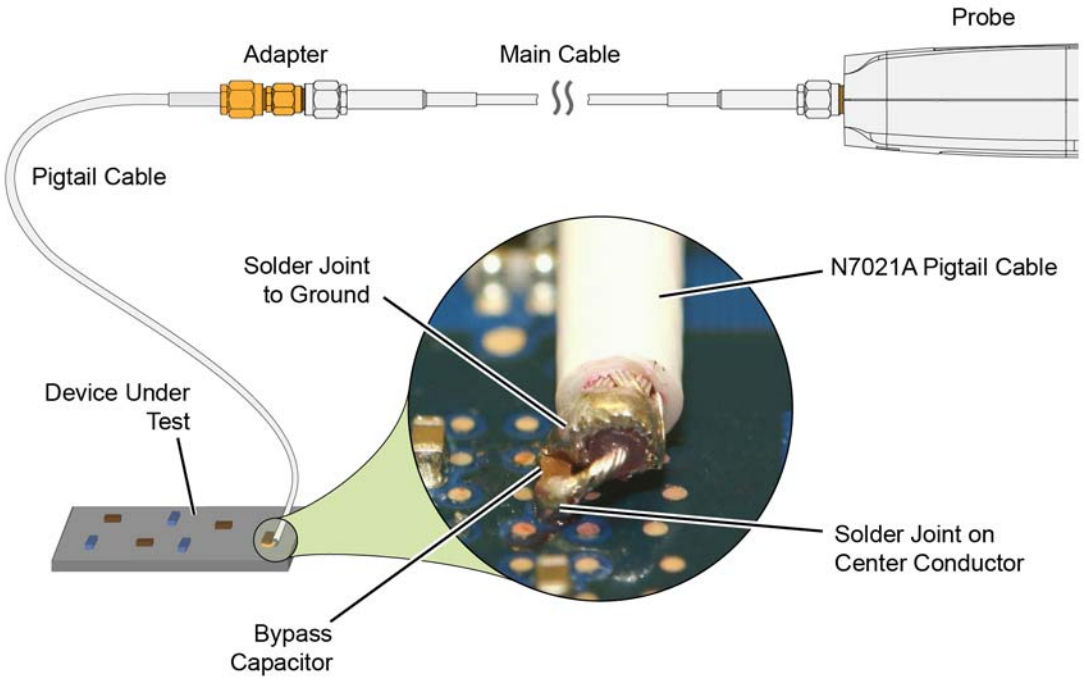


Figure 8 Soldering the Probing End of The N7021A Cable Across a Bypass Capacitor

CAUTION To avoid accidentally shorting the circuit via the cable's exposed ground, place a small strip of non-conductive tape onto the board before attaching the coax. To avoid undue stress to the solder joints, tape the cable to the DUT.

Avoiding Costly Repairs

When connecting or using the probe, use caution to avoid damaging the oscilloscope's channel input circuits due to electrostatic discharge (ESD).

CAUTION

When the probe is connected to the oscilloscope, the oscilloscope's channel input circuits can be damaged by electrostatic discharge (ESD). Avoid applying static discharges to the probe input. Prior to energizing and connecting any accessory cable to the probe, momentarily short the center and outer conductors of the cable together. Be sure that the instrument is properly earth-grounded to prevent buildup of static charge. Wear a wrist-strap or heel-strap.

Figure 9 on page 24 shows an example of a static-safe work station using two types of ESD protection:

- Conductive table-mat and wrist-strap combination.
- Conductive floor-mat and heel-strap combination.

Both types, when used together, provide a significant level of ESD protection. Of the two, only the table-mat and wrist-strap combination provides adequate ESD protection when used alone. To ensure user safety, the static-safe accessories must provide at least 1 MΩ of isolation from ground. Purchase acceptable ESD accessories from your local supplier.

WARNING

These techniques for a static-safe work station should not be used when working on circuitry with a voltage potential greater than 500 volts.

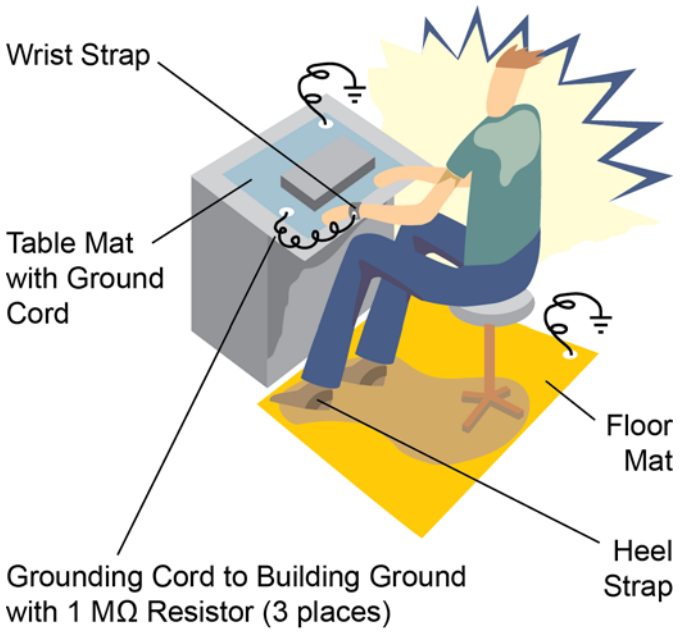


Figure 9 ESD Workstation

3 Calibrating

Always calibrate the probe before making any critical measurements. A probe calibration removes attenuation errors, offset errors, and timing delays that are introduced by the probe. This chapter contains basic calibration procedures for the supported Infiniium oscilloscopes. For additional information on the probe calibration refer to the oscilloscope's user documentation.

CAUTION **Always wear an ESD wrist strap when working with active probes. Not doing so can result in the probe becoming permanently damaged.**

The following calibrations are used:

- DC Attenuation/Offset Calibration
- Skew Calibration *(optional)*

DC Attenuation/Offset Calibration

1. Turn on the oscilloscope and connect the N7020A probe with the N7022A main cable attached to one of the oscilloscope's input channels.
2. Allow the oscilloscope and probe to warm up for 20 minutes.
3. If the oscilloscope needs calibration, perform a user calibration before the probe calibration. On the oscilloscope, click Utilities > Calibration.
4. Connect the output of the N7022A main cable to the oscilloscope's rear-panel AUX OUT BNC connector as shown in the following picture. You'll need a BNC (m) to SMA (f) adapter.

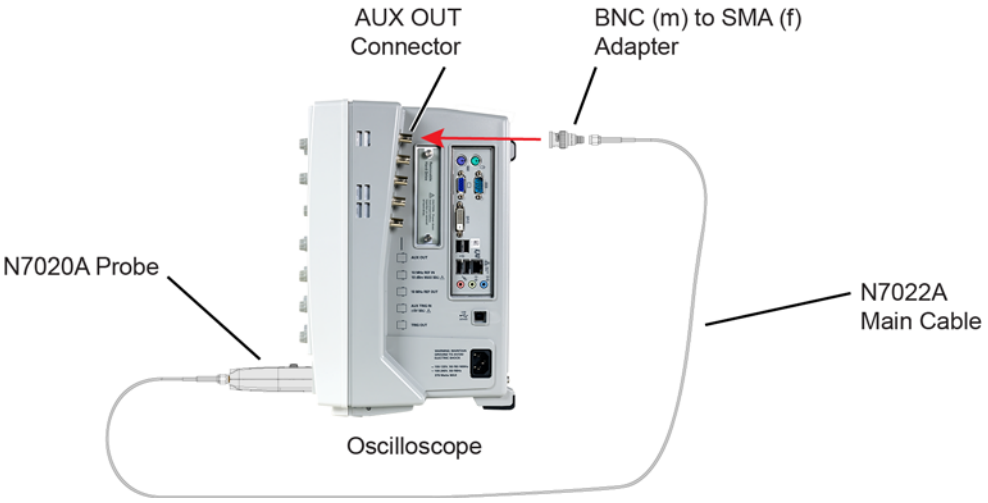


Figure 10 Calibration Setup

5. On the oscilloscope, click Setup > Probes.
6. In the Probe Calibration dialog box, select the tab representing the channel that has the probe attached.
7. In the dialog box, select the type of calibration. Click Start and follow the instructions shown on the oscilloscope.

Skew Calibration (Optional)

The optional skew calibration may be advised when multiple oscilloscope channels are used under the following conditions:

- The default delay applied by the oscilloscope to nominally deskew the probe is not accurate enough for a particular measurement situation, or
- Your test setup has strict timing considerations between channels.

When performing a the skew calibration, an E2655C Performance Verification (PV) and deskew fixture is used. An optional N2787A 3D Probe Positioner or equivalent can be used to hold the probe during the calibration.

NOTE

Before calibrating the probe, verify that the Infiniium oscilloscope has been calibrated recently and that the calibration Δ temperature is within ±5 °C. If this is not the case, calibrate the oscilloscope before calibrating the probe. This information is found in Infiniium Calibration dialog box.

The calibration procedure requires the following parts.

- BNC (male) to SMA (male) adapter
- Deskew fixture
- 50Ω SMA termination

Procedure

1. Connect a BNC (m) to SMA (f) adaptor to the E2655C deskew fixture on the connector closest to the yellow pincher.
2. Connect the 50Ω SMA terminator to the connector farthest from the yellow pincher.
3. Connect the BNC side of the deskew fixture to the oscilloscope's rear-panel AUX OUT.
4. Connect the probe to an oscilloscope channel. The test setup is shown in Figure 11 on page 28,

5 Gently hold the pigtail cable's center conductor to the deskew fixture's center conductor. And, hold the pigtail cable's outer conductor to the deskew fixture's ground plane.

CAUTION To avoid damaging the oscilloscope's AUX OUT connector, do not apply force to the PV fixture. Light probe contact is all that is needed for the calibration.

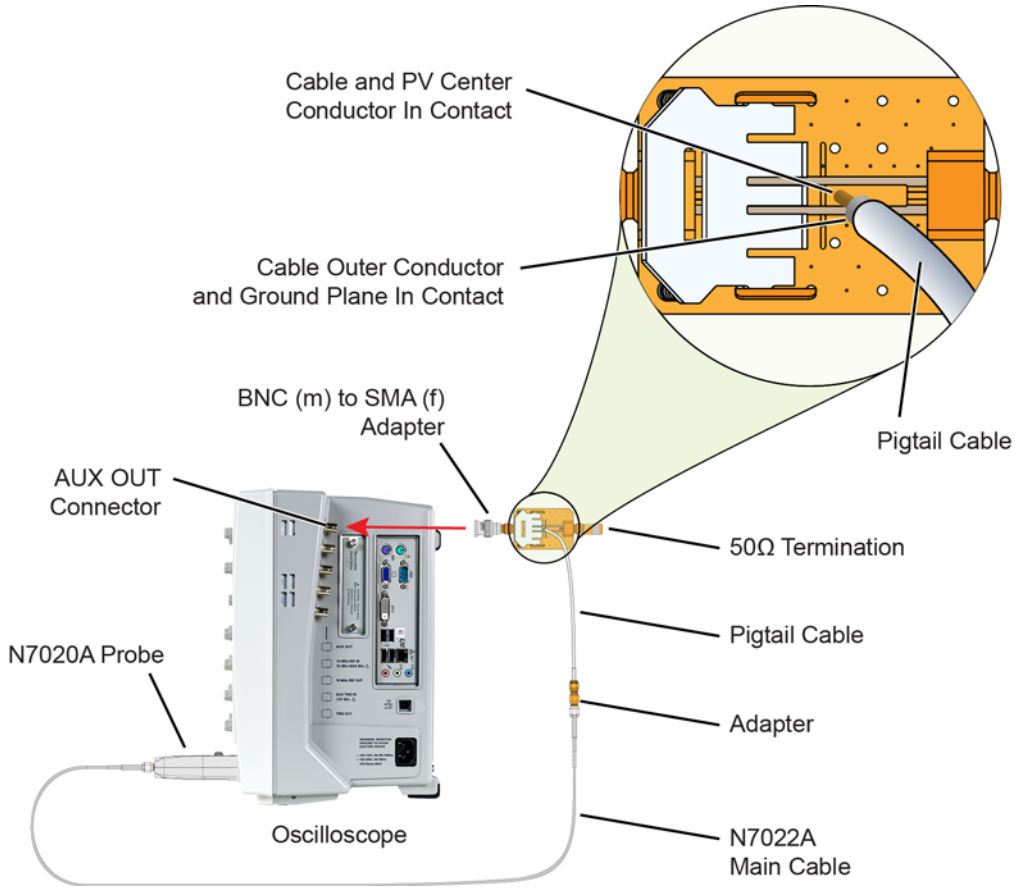


Figure 11 Deskew Setup

CAUTION NEVER solder a probe tip to the thick-film gold on the deskew fixture. The gold will immediately dissolve into the solder and disappear.

NOTE You use the N2787A 3D Probe Positioner to hold the pigtail cable in place on the deskew fixture.

NOTE You can check that the pigtail cable correctly contacts the fixture's center conductor and ground plane by pressing the front-panel autoscale button. A stable step should be shown on the screen. Pressing autoscale will close the Probe Calibration dialog box.

6 On the Infiniium oscilloscope in the Setup menu, select the channel connected to the probe.

7 In the Channel Setup dialog box select the Probes... button.

8 In the Probe Setup dialog box select the Calibrate Probe... button.

9 In the oscilloscope's Probe Cal dialog box select the Start Skew Calibration... button and follow the on-screen instructions for the skew calibration.

4 Specifications and Characteristics

The tables in this chapter list the specifications for the N7020A probe. Input Impedance ad DC is the only warranted specification. Connect the probe to a powered-on oscilloscope for at least 20 minutes before any testing to allow the probe to warm up. Ensure that the environmental conditions do not exceed the probe's specified limits.

Specifications and Characteristics

Table 2 N7020A Safety and Regulatory Information

Description
CEI/IEC 61010-031 CAT II
 This symbol indicates the Environmental Protection Use Period (EPUP) for the product's toxic substances for the China RoHS requirements.
 The CE mark is a registered trademark of the European Community. ISM GRP 1-A denotes the instrument is an Industrial Scientific and Medical Group 1 Class A product. ICES/NMB-001 indicates product compliance with the Canadian Interference-Causing Equipment Standard.
 This product complies with the WEEE Directive (2002/96/EC) marking requirements. The affixed label indicates that you must not discard this electrical/electronic product in domestic household waste. Product Category: With reference to the equipment types in the WEEE Directive Annex I, this product is classed as a "Monitoring and Control instrumentation" product. Do not dispose in domestic household. To return unwanted products, contact your local Keysight office, or refer to www.keysight.com for more information.

Table 3 Environmental Specifications

Description	Specification
Temperature	Operating: –10 °C to +55 °C Non-operating: –30 °C to +70 °C
Altitude	Operating: 3,000 m (9,842 feet) Non-operating: 15,300 m (50,196 feet)
Humidity	Operating: 25 – 85% room humidity Non-operating: 25 – 85% room humidity
Pollution Degree	Pollution Degree 2

Table 4 Electrical Characteristics and Specification

Item	Characteristics
Probe Bandwidth (–3 dB) *	2 GHz *(characteristic)*
Maximum Input Voltage (non-destructive)	±30V peak input
Attenuation Ratio	1.1:1 *(characteristic)*
Risetime (calculated, 10–90%)	175 ps *(characteristic)*
Offset Range	± 24V *(characteristic)*
Input Impedance †	50 kΩ ±2% (varies with frequency, see Figure 16 on page 39)
Active Signal Range	± 850 mV (about offset voltage) *(characteristic)*
Probe Noise (at 2 GHz)	35 µVrms *(characteristic)*
Output Termination	50Ω scope input *(characteristic)*
Probe Type	Single Ended *(characteristic)*

* Specified with N7020A and N7022A.
† Warranted specification.

Probe Dimensions

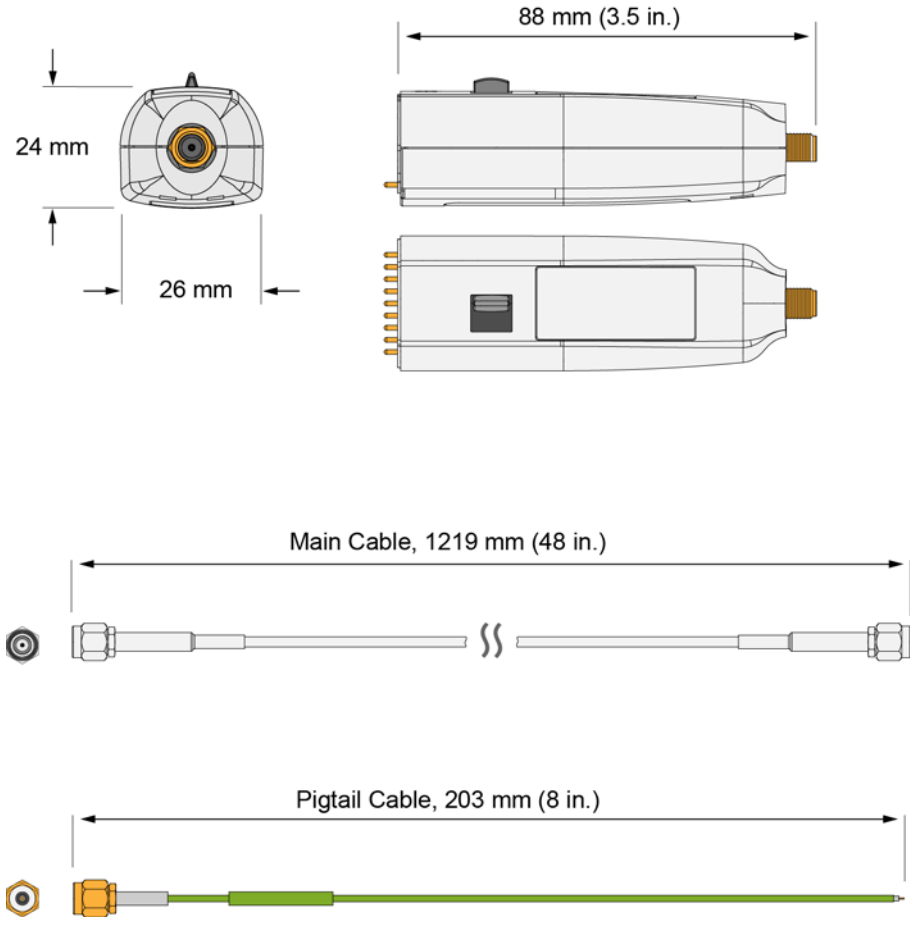


Figure 12 Probe and Accessory Cable Dimensions

5 Performance Plots

This chapter includes plots that show the probe's characteristic performance and an input impedance model of the probe. The performance characteristic plots in this chapter are for the N7020A probe with the N7022A main cable attached.

N7020A Performance Plots

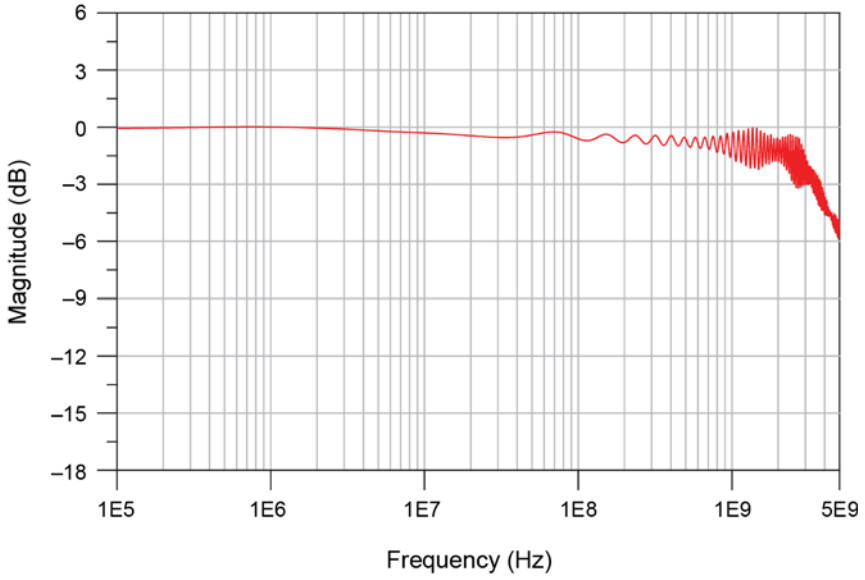


Figure 13 Normalized Frequency Response, V_{out}/V_{in}, 2.5 GHz BW (N7020A with N7022A Main Cable)

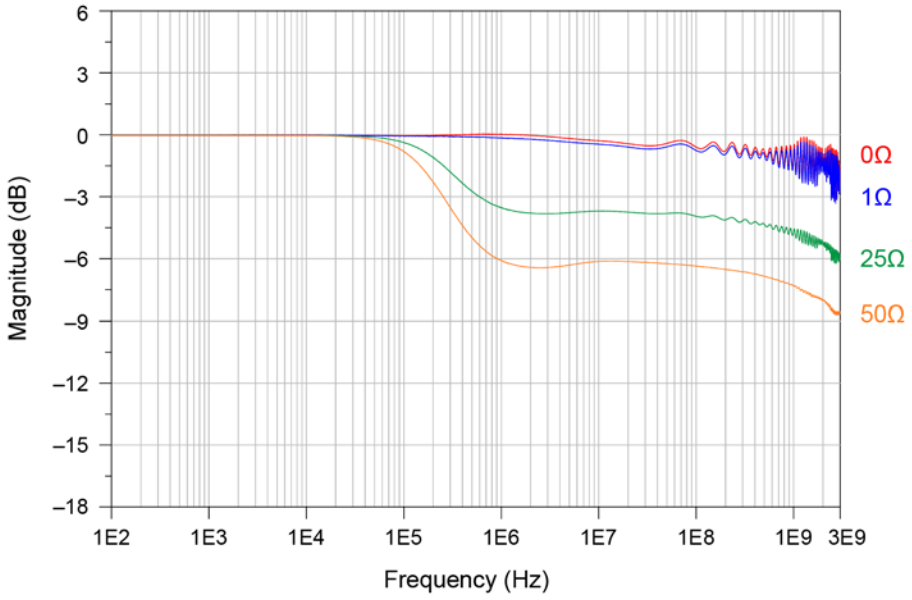
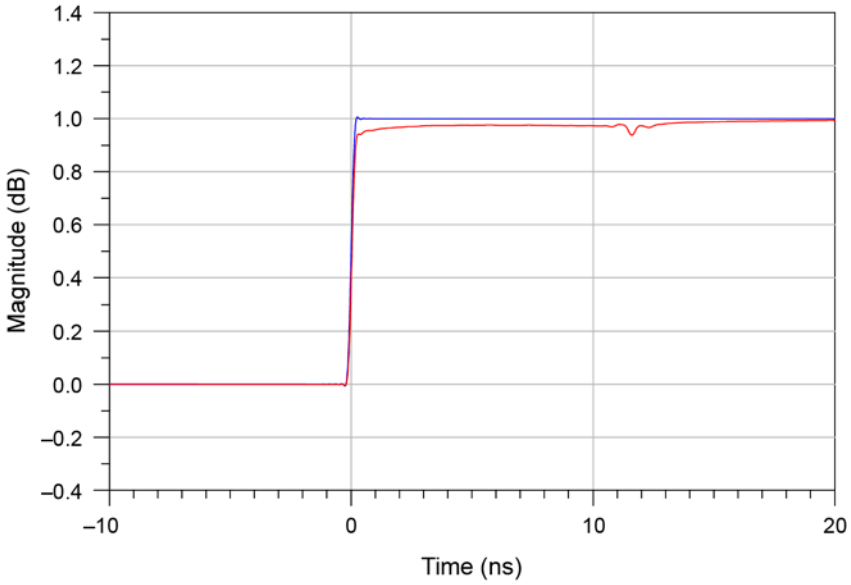


Figure 14 Frequency Response for Different DUT Impedances (N7020A with N7022A Main Cable)



Rise Time, Input Step (10/90%): . . . . . 250 ps
Rise Time, Input Step (20/80%): . . . . . 169 ps
Rise Time, N7020A with N7022A (10/90%): . . . . . 297 ps
Rise Time, N7020A with N7022A (20/80%): . . . . . 192 ps

Figure 15 Step Tracking (N7020A with N7022A Main Cable)

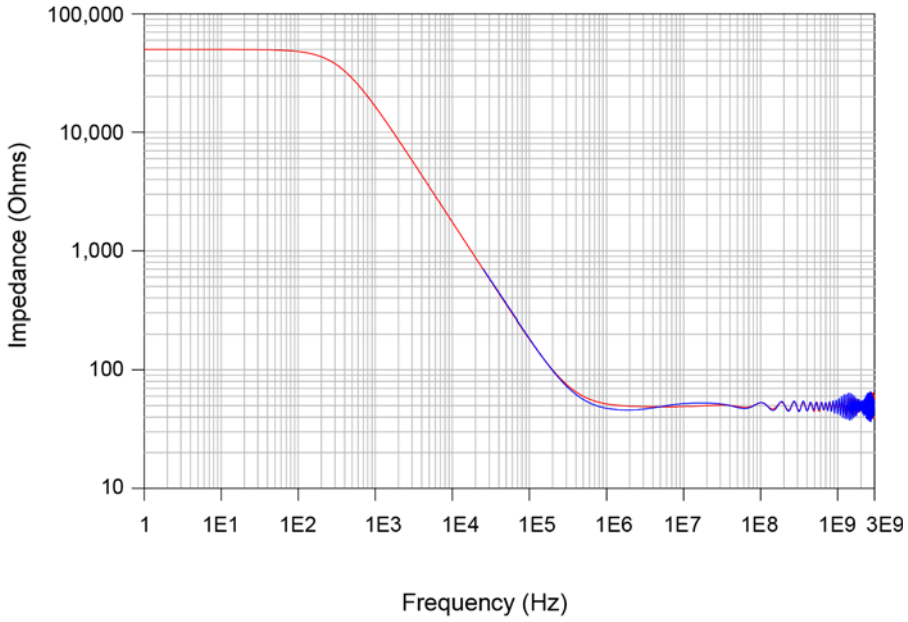


Figure 16 Input Impedance Versus Frequency, Z_{in} Measured, Z_{in} Modeled (N7020A with N7022A Main Cable)

N7020A Input Impedance Equivalent Model

The following Netlist is for the N7020A input impedance equivalent model shown in Figure 17 on page 41.

```
* source N7020A
.EXTERNAL INPUT Vin
.EXTERNAL OUTPUT Vout
R_R3 GND N01679 590
T_T8 N01635 GND N01646 GND Z0=51.7174 TD=177.789ps
T_T4 N01611 GND N01614 GND Z0=50.0323 TD=5.00049ns
T_T9 N01646 GND N01649 GND Z0=56.0807 TD=124.106ps
T_T10 N01649 GND N01652 GND Z0=52.0547 TD=194.457ps
T_T5 N01614 GND N01629 GND Z0=55.4861 TD=14.8781ps
T_T16 N01709 GND VOUT GND Z0=50.4332 TD=1.00771ns
T_T15 N01706 GND N01709 GND Z0=50.9109 TD=173.772ps
C_C1 N01652 N01667 9n
R_R2 N01667 N01670 3.9
T_T11 N01670 GND N01673 GND Z0=47.0657 TD=32.9877ps
T_T12 N01673 GND N01676 GND Z0=48.4028 TD=97.8628ps
T_T14 N01679 GND N01706 GND Z0=51.4414 TD=471.443ps
T_T6 N01629 GND N01632 GND Z0=52.1033 TD=38.7418ps
T_T13 N01676 GND N01679 GND Z0=48.0776 TD=53.1542ps
T_T1 Vin GND N01605 GND Z0=49.0683 TD=148.305ps
R_R4 GND VOUT 50
T_T2 N01605 GND N01608 GND Z0=49.4981 TD=107.256ps
T_T7 N01632 GND N01635 GND Z0=50.8744 TD=76.0454ps
T_T3 N01608 GND N01611 GND Z0=49.4457 TD=277.663ps
R_R1 GND N01635 50k
```

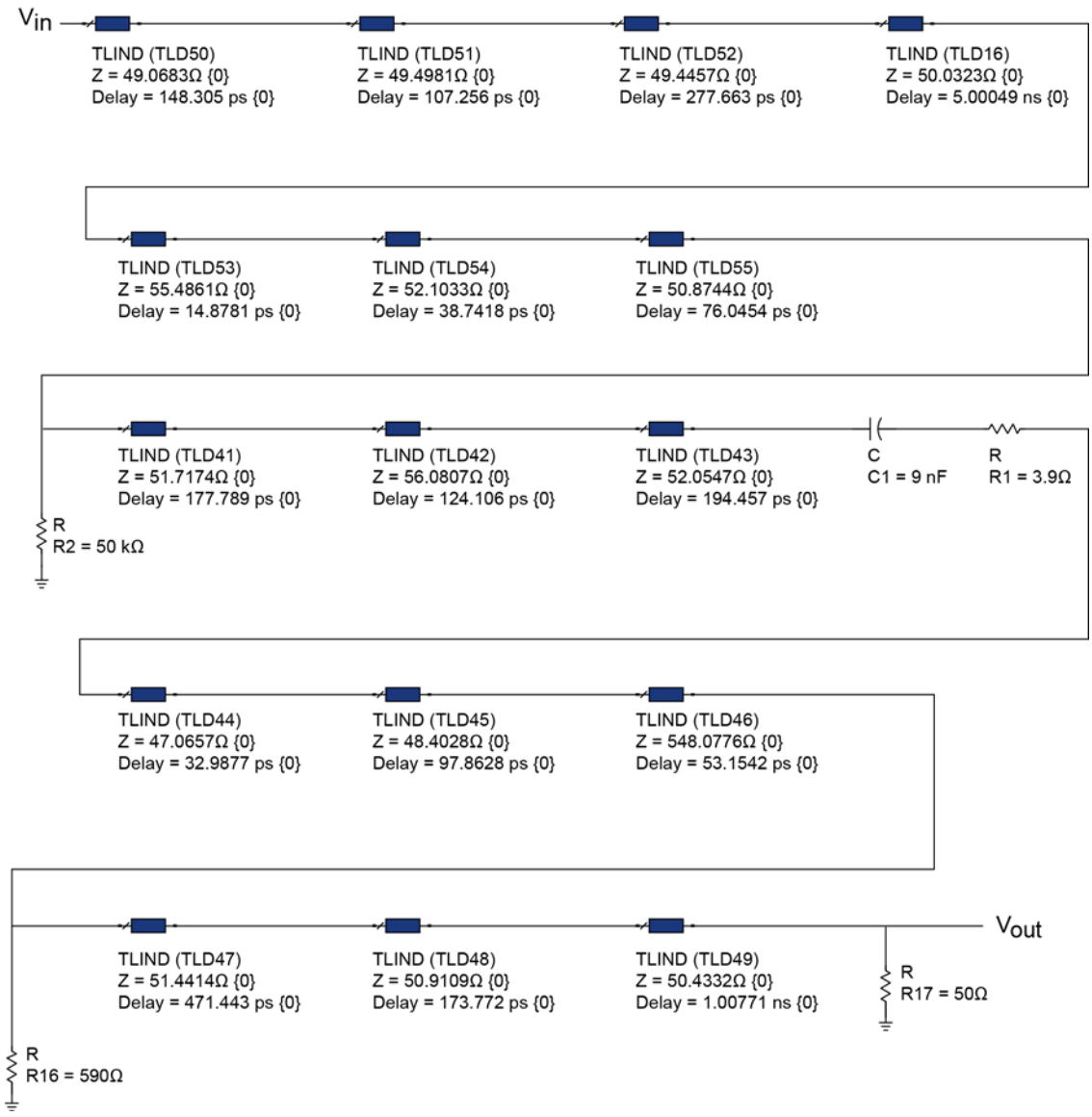


Figure 17 Input Impedance Equivalent Model

6 Performance Verification

This chapter tests that the probe meets its specified input resistance, which is 50 kΩ ±2%.

CAUTION Electrostatic discharge (ESD) can quickly and imperceptibly damage or destroy high performance probes, resulting in costly repairs. Always wear a wrist strap when handling probe components and ensure that cables are discharged before being connected.

NOTE Allow the probe to warm up for at least 20 minutes.

Table 5 Required Test Equipment

Test Equipment	Critical Specification	Model Number
Oscilloscope	Supported Oscilloscope	S-Series or 9000A series Infiniium Oscilloscope
Digital Multimeter	2 wire resistance accuracy > ± 0.01%	34401A or equivalent
Adapter	BNC (f) to SMA (m) (In E2655C Kit)	E2655-83201

Procedure

1. Connect the equipment as shown in Figure 18.
2. Power on the oscilloscope with the oscilloscope application maximized.
3. Power on the DMM and select the 2-wire Ohm display on the DMM.

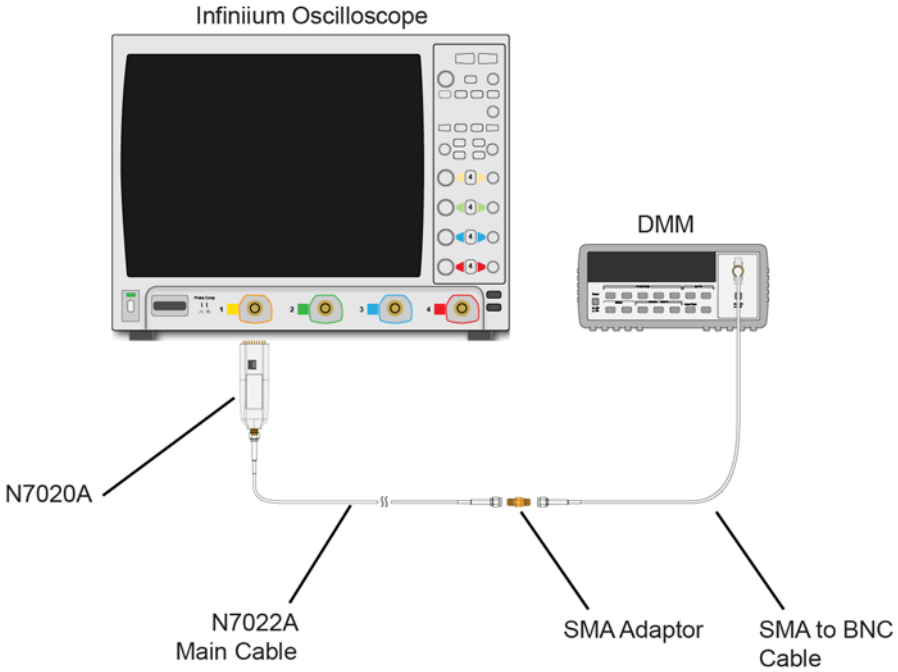


Figure 18 Test Setup

4. Read the DMM display for the input resistance.
5. Record the result in Table 6 on page 45. To pass this test the result should be between 49 kΩ and 51 kΩ.

Performance Test Record

Serial #:
Date:
Tested by:
Recommended Next Test Date:

Table 6 Input Impedance Test Results

Test Limits	Result	Pass/Fail
50 kΩ ± 2%		

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