User's Manual

Model 701923
PBD2000 Differential Probe

YOKOGAWA

Yokogawa Test & Measurement Corporation

IM 701923-01E
5th Edition

Thank you for purchasing the PBD2000 Differential Probe (Model 701923).
This user's manual contains useful information about the functions and operating procedures of the PBD2000 Differential Probe and lists the handling precautions of the instrument. To ensure correct use, please read this manual thoroughly before beginning operation.
After reading this manual, keep it in a convenient location for quick reference in the event a question arises during operation.

List of Manuals

The following manuals are provided for the PBD2000 Differential Probe (Model 701923).

Manual Title	Manual No.	Notes
Model 701923 PBD2000 Differential Probe User's Manual	IM 701923-01E	This manual.
Model 701923 PBD2000 Differential Probe	IM 701923-92	Document for China
Model 701923 PBD2000 Differential Probe	IM 701923-93Z2	Document for Korea

The "E" and "Z2" in the manual numbers are the language codes.

Contact information of Yokogawa offices worldwide is provided on the following sheet.

Document No.	Description
PIM113-01Z2	List of worldwide contacts

Revisions

1st Edition: November 2005
2nd Edition: June 2008
3rd Edition: April 2009
4th Edition: November 2015
5th Edition: October 2017

5th Edition: October 2017 (YMI)

Checking the Contents of the Package

If any of the contents are incorrect, missing, or appear to be abnormal, please contact your Yokogawa dealer or representative.

PBD2000 Differential Probe: 1

Various kinds of attachments (see page 2)

- Straight and angle pins: 8 each
- Spring-type straight and angle pins: 4 each
- Microclips (red and black): 1 each
- Lead wires (red and black): 1 each
- L-pins: 2

Manuals: 1 set

Carrying case: 1

Optional Accessories (Sold Separately)

Standard accessory kit

701915

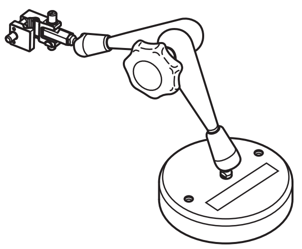
Composition

- Straight and angle pins: 20 each
- Spring-type straight and angle pins: 4 each
- Microclips (red and black): 1 each
- Lead wires (red and black): 1 each
- L-pins: 2
- Case: 1

Probe stand

701919

External view



Safety Precautions

To ensure safe and correct operation of the instrument, you must take the safety precautions given on the next page. The instrument may not function if used in a manner not described in this manual. YOKOGAWA bears no responsibility for, nor implies any warranty against damages occurring as a result of failure to take these precautions.

The following safety symbols and words are used in this manual.

⚠ Warning: Handle with care. Refer to the user's manual. This symbol appears on dangerous locations on the instrument which require special instructions for proper handling or use. The same symbol appears in the corresponding place in the manual to identify those instructions.)

Precautions

For safe use of the instrument, and for best results, please heed the following warnings and cautions.

⚠ **WARNING**

- Take care to avoid electric shock when connecting the probe to the circuit under test.
- Never disconnect the probe from the measuring instrument while the probe is connected to the circuit under test.
- Never use the probe with wet hands, or when the probe itself is wet. Electric shock can result.
- Before connecting the probe input terminal to the item under test, check that the measuring instrument is properly grounded, and that the probe output connector is connected to the input connector of the oscilloscope.
- Ground the measuring instrument.
  Always connect the main instrument's protective grounding.
- Maintain non-destructive input voltages.
  Do not apply a voltage exceeding ±25 V (DC+ACpeak) between input and ground.
- Do not use the probe in humid locations
  To avoid electric shock, never use the probe in areas of high humidity.
- Do not use the probe near flammable gases.
  To avoid injury and fire, do not use the probe near flammable or explosive gasses or vapors.
- Avoid exposed circuits.
  To prevent injury, when the power is ON, do not touch any exposed contact points or components.

CAUTION

- The probe head has undergone a precision assembly process. Take sufficient care when handling the probe as sudden changes in ambient temperature and physical shocks can damage it.
- Do not inadvertently twist or pull the cable. The wires inside the cable can break, causing malfunction.
- Avoid vibration, shock, and static electricity during shipping and handling. Take extra care not to drop the probe.
- Avoid storing or using the probe in direct sunlight, or in areas with high temperature, humidity, or condensation. Deformation and deterioration of insulation can occur resulting in failure to retain product specifications.
- Inspect the probe before use to ensure that damage has not occurred during shipping and storing. If damage is found, contact your nearest Yokogawa dealer or sales representative.
- This probe is not water or dust resistant. Do not use the probe in areas with a lot of dust, or near water.

See below for operating environmental limitations.

CAUTION

This product is a Class A (for industrial environments) product. Operation of this product in a residential area may cause radio interference in which case the user will be required to correct the interference.

Sales in Each Country or Region

Waste Electrical and Electronic Equipment

Waste Electrical and Electronic Equipment (WEEE), Directive
(This directive is valid only in the EU.)
This product complies with the WEEE directive marking requirement. This marking 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, this product is classified as a “Monitoring and control instruments” product.

When disposing products in the EU, contact your local Yokogawa Europe B.V. office.
Do not dispose in domestic household waste.

Authorized Representative in the EEA

Yokogawa Europe B.V. is the authorized representative of Yokogawa Test & Measurement Corporation for this product in the EEA. To contact Yokogawa Europe B.V., see the separate list of worldwide contacts, PIM 113-01Z2.

The following safety markings are used in this manual.

Improper handling or use can lead to injury to the user or damage to the instrument. This symbol appears on the instrument to indicate that the user must refer to the user's manual for special instructions. The same symbol appears in the corresponding place in the user's manual to identify those instructions. In the manual, the symbol is used in conjunction with the word "WARNING" or "CAUTION."

WARNING Calls attention to actions or conditions that could cause serious injury or death to the user, and precautions that can be taken to prevent such occurrences.

CAUTION Calls attentions to actions or conditions that could cause light injury to the user or damage to the instrument or the user's data, and precautions that can be taken to prevent such occurrences.

Note Calls attention to information that is important for proper operation of the instrument.

Contents

Product Overview

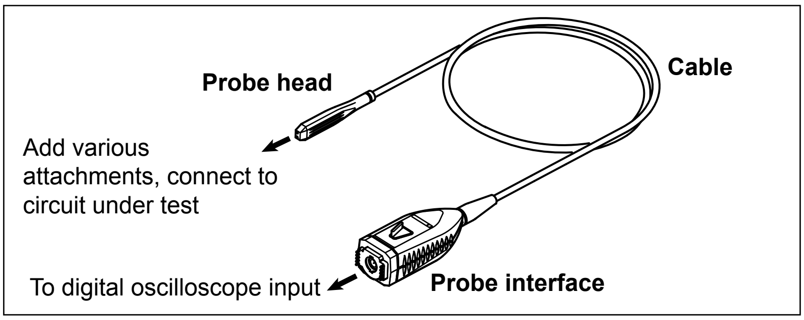
The PBD2000 Differential Probe is a 2-GHz bandwidth, differential-input, active probe that is used in combination with a digital oscilloscope* that has a YOKOGAWA probe interface (hereafter referred as digital oscilloscope with a probe interface).
To use the probe, you simply connect it to a BNC input terminal on a digital oscilloscope with a probe interface.

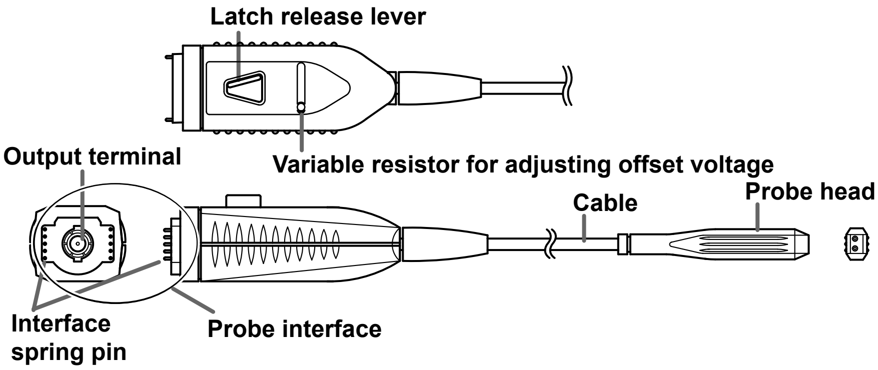
* For information about digital oscilloscopes with a probe interface, contact your nearest YOKOGAWA dealer.

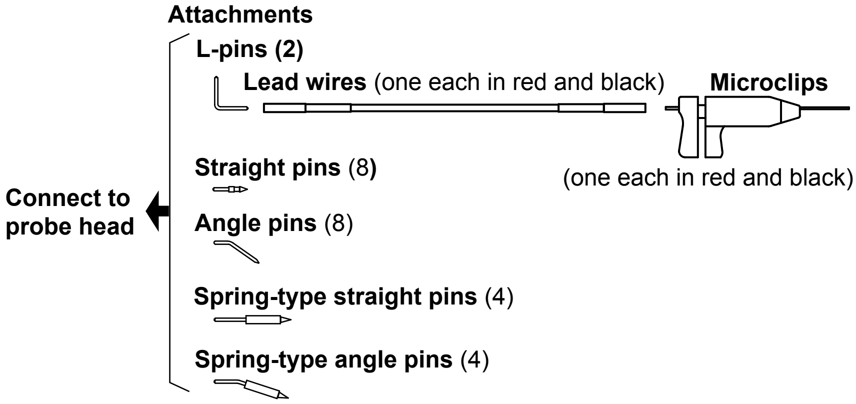
Features

- Allows direct observation of differential signals
- Common mode rejection capability
- Wide frequency bandwidth from DC to 2 GHz
- Able to receive power from a digital oscilloscope with a probe interface
- Allows a digital oscilloscope with a probe interface to automatically detect the probe
- Connects to various attachments that are used to touch the circuit under test
- Compact and lightweight

Component Names







The quantity in parentheses is the number of the various attachments that come with a single probe.

Probe interface
Connects to a digital oscilloscope input.

Interface spring pins
When the probe output terminal is connected, these pins touch the pad on the oscilloscope interface board. The probe's power is supplied through these interface pins. The interface pins are also used to supply a offset voltage and used by the DL9000 to automatically detect the probe.

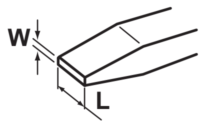
Cable
Connects the probe interface and the probe head.

Probe head
Connects to the circuit under test through various attachments.

Latch release lever
Releases the lock connecting the probe output terminal to the oscilloscope input.

Attachments
The probe's input terminals. You can select the probe head attachment that you want to use on the circuit under measurement.

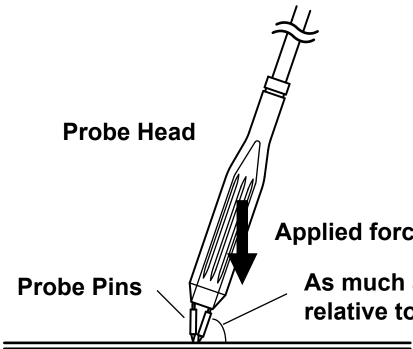
Output termina The output terminal is a BNC connector. It connects to an oscilloscope input BNC connector.	
Variable resistor for adjusting offset voltage You can adjust the offset voltage using an appropriate driver as described below. Adjustment driver Use an adjustment driver that fits into the adjustment groove. Using a driver with a large grip or a driver with a small head can damage the adjustment turn stop or groove. Recommended adjustment driver bit dimensions Head thickness (W): 0.2 to 0.35 mm; head width (L): 1.3 to 1.5 mm; head shape: flat or Philips	



Usage Precautions

CAUTION

- When touching the circuit under test with the probe pins, take care not to apply excessive force to the probe head. Damage can result if a force of 5 N or more is applied.



- Use a soft cloth to wipe away dirt, and be careful not to damage the probe. Do not immerse the probe in liquid or use abrasive cleaners on the probe. Do not use any volatile solvents such as benzine.

- Do not bring the probe near transformers, circuits with large currents, wireless devices, or other objects emitting large electric or magnetic fields. Doing so may produce inaccurate measurement results.
- As much as possible, keep the probe pins vertical relative to the circuit under test.
- It is recommended to use the probe stand (model 701919). It can prevent excessive force from being applied to the probe head.

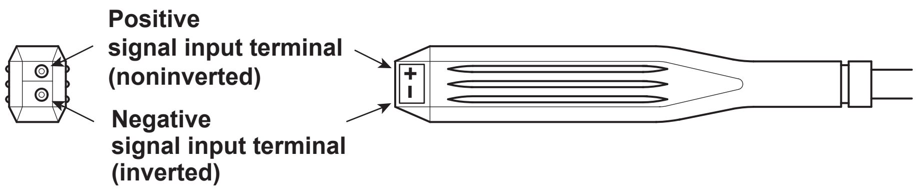
Operating Procedures

Preparation

1. Have the probe and a digital oscilloscope with a probe interface ready.
2. Insert the probe interface completely into the oscilloscope input, and confirm that the BNC connector and interface pin are securely fastened. You will hear the latch click when the connectors lock into place.
3. Attach any of the provided attachments to the probe head signal input terminals.

Attachment Handling

You can change the attachment according to the circuit under measurement. As shown below, there are holes for connecting an attachment to the probe head tip.

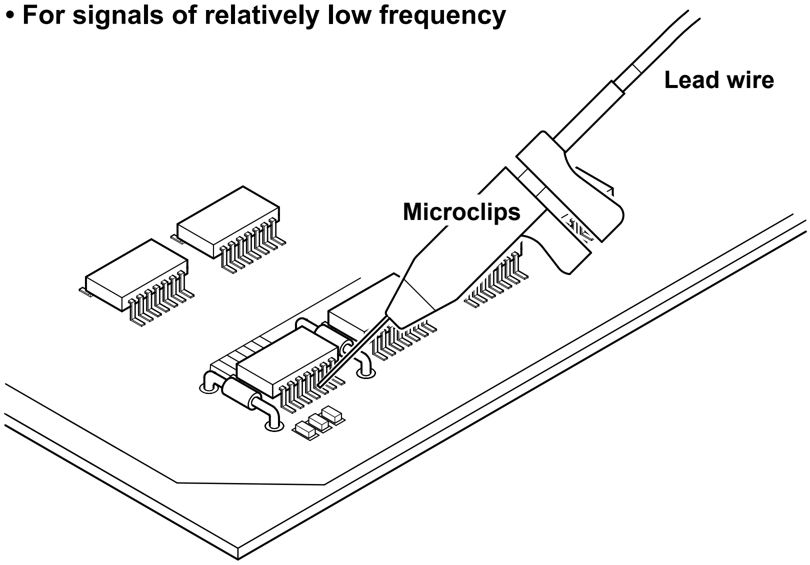


There are straight and angled attachment pins. Select the attachment that is appropriate for the circuit under test.

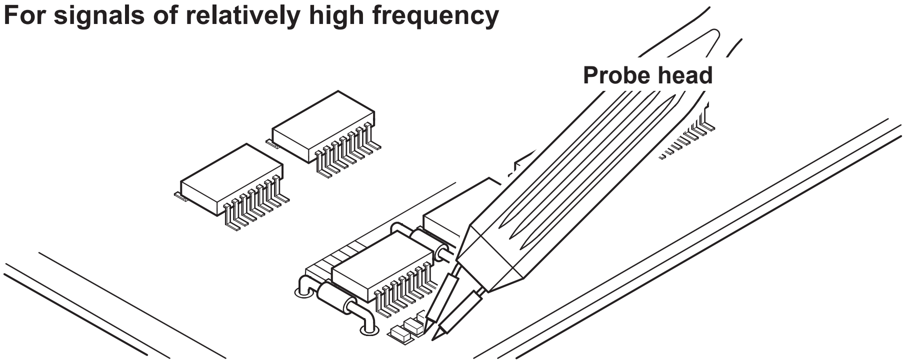
Because the probe input is high impedance, the inductance from the probe head to the circuit under test has a large effect on the measured results of high frequency signal components. When measuring signals that include frequency components of 100 MHz or higher, we recommend that you use the shortest attachments possible for both the positive and negative input terminals.

Example

• For signals of relatively low frequency



• For signals of relatively high frequency



Select an attachment according to the circuit to be tested (straight pin, angle pin, spring-type straight pin, or spring-type angle pin).

Warm-up and Offset Adjustment

Warm-up

Immediately after connecting the probe, the heat emitted by the probe itself causes the offset voltage to drift. Warm up the probe for at least 30 minutes after applying power to stabilize the probe.

Offset Adjustment

You can turn the offset voltage adjustment variable resistor on the probe interface by using an appropriate adjustment driver (see page 3 for details) to adjust the residual offset voltage that remains even after warm-up.

CAUTION

Do not turn the variable resistor with excessive force when adjusting the offset voltage. Doing so may break the variable resistor.

Note

- The offset voltage drifts depending on the ambient temperature. Pay attention to changes in the ambient temperature when making continuous measurements.
- Only use the offset voltage adjustment variable resistor to adjust the residual offset voltage. If you deliberately change the offset voltage for some other purpose, the probe may no longer meet the specifications.

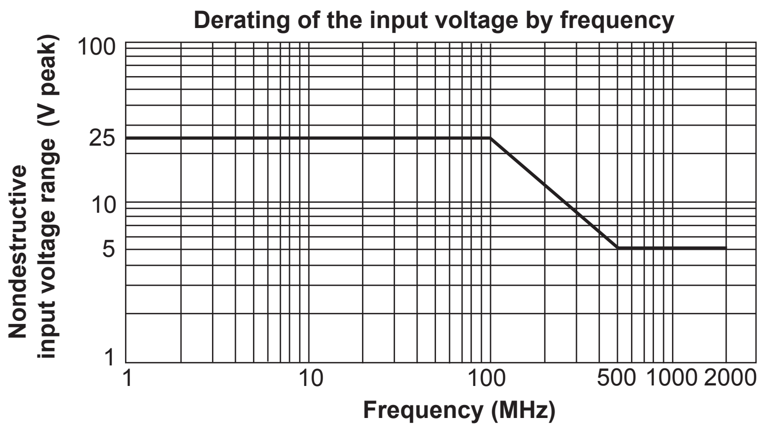
Product Specifications

Electrical Specifications

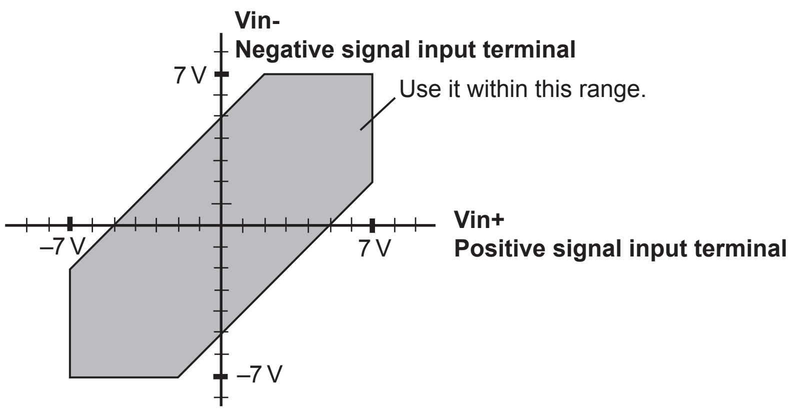
(The electrical specifications are based on standard operating environment after 30-minute warm-up.)

Frequency bandwidth	DC to 2 GHz (–3 dB or higher)
Attenuation ratio and DC voltage accuracy [1]	10:1, within ±2% of the differential input voltage (into 50-Ω load, excluding oscilloscope errors)
Input capacitance	Approx. 1.1 pF (relative to ground, typical value [4])
Input resistance	Within 50 kΩ ± 2% (relative to ground)
Output impedance	Approx. 50 Ω (typical value [4])
Maximum operating input voltage range	±7 V
Maximum differential input voltage range	±5 V
Maximum non-destructive voltage [2]	±25 V (DC+ACpeak)
Rise time	175 ps or less (excluding characteristics of the oscilloscope, typical value [4])
Residual noise	500 μVrms or less (at the probe output, typical value [4])
Residual offset [3]	Within ±10 mV (after adjustment)
Common mode rejection ratio	DC to 10 MHz: –35 dB or less 10 MHz to 100 MHz: –20 dB or less 100 MHz to 1 GHz: –12 dB or less

1 Excludes residual offset voltage.
2 Nondestructive maximum input voltage. This is not the probe's dynamic range.
3 When 0 V is applied to both positive and negative input terminals.
4 Typical values represent typical or average values. They are not strictly warranted.



Input voltage range



General Specifications

Supply voltage range Interface		Standard supply voltage ± 5V, within ±5% (Power is supplied to the probe through a dedicated terminal. Connect the probe to a digital oscilloscope with a compatible terminal.)
Storage altitude		3000 m or less
Operating altitude		2000 m or less
Standard operating environment		
	Temperature range	23 ± 5°C
	Humidity range [5]	55 ± 10%RH
Operating environment		
	Temperature range	5 to 40°C
	Humidity range [5]	20 to 80%RH
Storage environment		
	Temperature range	–20 to 60°C
	Humidity range [5]	20 to 80%RH
Calibration period		1 year
Warm-up time		At least 30 minutes
Total length		Approx. 1.2 m
Weight		Approx. 80 g

5 No condensation.

Standards Compliance

EMC	Emission	Complying standard	EN61326-1 Class A EN55011 Class A, Group1 EMC standards of Australia and New Zealand EN55011 Class A, Group1
	Immunity	Complying standard	EN61326-1 Table 2 (for use in industrial locations)
		Influence in immunity test environment	|Noise increase| ≤ 2 V [6]

6 Test conditions

Frequency bandwidth limit 20 MHz, using a DL9000 series digital oscilloscope with the input impedance set to 50 Ω, and both plus and minus probe tip inputs connected (terminated) to 50 Ω.

Appendix—Probing

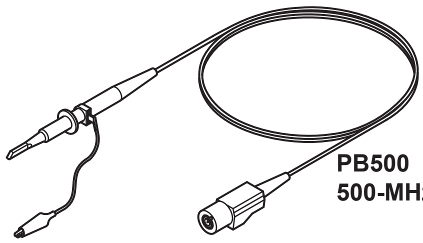
The speed of devices and electronic circuits that are incorporated into a variety of products, as exemplified by digital home electronics, is increasing, and oscilloscopes and probes used to observe their signal waveforms are also faster and have wider bandwidths.
When the speed of the measured signal increases, there are cases when correct measurements cannot be taken due to problems that have never occurred before, especially in probing. This chapter explains issues that need to be considered when probing high-speed signals.

Voltage Probe Types

A Voltage probes is a type of voltage sensor. The ideal probe should be selected according to the signal's voltage, output impedance, frequency components, and other factors. The input impedance (resistance and capacitance) and frequency can differ greatly depending on the type of probe. So, it is essential to understand the characteristics of the available probes to obtain highly reliable measurements. Below are three examples of probes generally used for measurements on high-frequency circuits.

Passive Probes

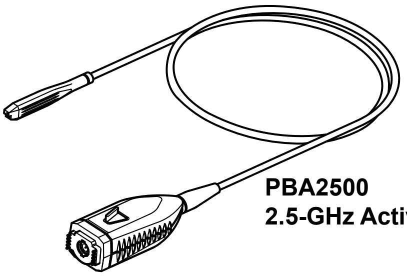
Passive probes with a 10:1 attenuation ratio are the most widely used due to their low cost, ruggedness, high withstand voltage, and high input impedance at DC and low frequencies.
Yokogawa's standard 10:1 passive probes are easy-to-use for general applications. Their input impedance is 10 MΩ and approximately 14 pF in parallel, and the withstand voltage is 600 V. However, the 14 pF input capacitance might cause problems when high frequencies are measured.



PB500
500-MHz Passive Probe

Active Probes and FET Probes

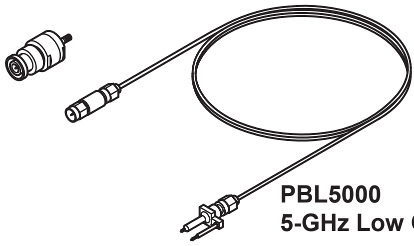
Active and FET probes are those most often used to measure high frequency signals.
Unlike passive probes, an impedance-converting buffer amplifier is situated near the tip of the probe which enables them to handle higher frequencies with around 1-pF input capacitance. They are very effective in terms of reliability and their ability to reproduce high frequency signal waveforms. They require a power supply and must be handled with more care than a passive probe, because the with-stand voltage is lower.



PBA2500
2.5-GHz Active Probe

Low Capacitance Probes (Low Impedance Probe)

These probes are not so well known, but they have been used with measuring instruments having 50 Ω inputs for a relatively long time.
The probe head has a special built-in 450-Ω or 950-Ω resistor, designed for high frequency, and uses a 50-Ω coaxial cable. It is still very popular to this day, because the input capacitance is extremely small.
This probe is ideal for high quality measurement of clock edges or other high speed digital signal waveforms as the input capacitance is half, or even a small fraction, of that of the active probe. However, because the input resistance is 500 Ω or 1 kΩ, it can have an affect on the DC bias or output amplitude if the impedance of the signal source being measured is high.

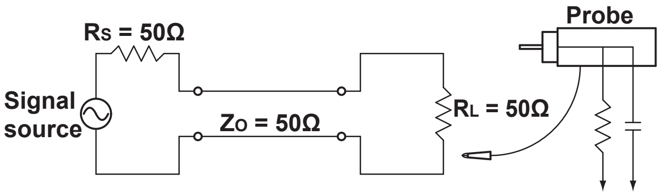


PBL5000
5-GHz Low Capacitance Probe

Problems with Probing High-Speed Signals

Loading Effect

When a probe is connected to the circuit under test, the input impedance of the probe itself has certain effects on the circuit. This is called the *loading effect*.
There can be cases where there are notable low pass filter effects caused by the signal source impedance and the probe’s load capacitance, particularly when observing frequency components of 100 MHz or more.
Let us take an example of a 50-Ω circuit shown below. In this example, the equivalent signal source impedance appears as 25 Ω (2 x 50 Ω in parallel) when observing the signal waveform at the load (terminal). The cutoff frequency at the probe's input point is $fc=1/2\pi RC$, if the probe input capacitance is added. When using a 14-pF input capacitance passive probe, fc equals 455 MHz, but when a 0.9-pF input capacitance active probe is used, fc equals 7 GHz.
We recommend that you use an active or FET probe with a smaller input capacitance, because even more pronounced loading effects will emerge when measuring a circuit with a high-output impedance.



Resonance due to Inductance

Pins or wires of some sort are used to connect the probe to the circuit under test. Inductance occurs when these pins or wires reach certain lengths, which results in resonance with the probe’s input capacitance. This will not obscure observation of the waveform if these resonant frequencies are outside of the oscilloscope's frequency bandwidth. However, overshooting or ringing, which was not originally present, will be introduced into the signal waveform being observed if the inductance or capacitance is large.
The resonant frequency is surprisingly low when the resonant frequencies of three different types of probes are compared as in Figure 1 with a given connected inductance of 10 nH (a length of up to 1 to 2 cm). You must be aware that effects of this inductance can be found not only on the probe input, but also in the ground connection.

	PB500 Passive Probe	**PBA2500 Active Probe**	**PBL5000 Low Capacitance Probe**
Input impedance	Approx. 14 pF	Approx. 0.9 pF	Approx. 0.25 pF or 0.4 pF
Resonant frequency (When L = 10 nH)	425 MHz	1.68 GHz	3.18 GHz

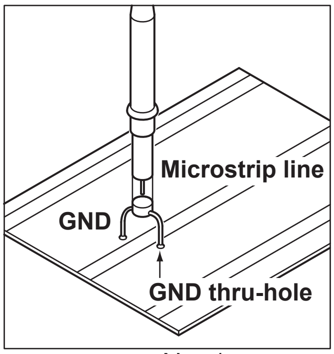
Changes in Cable Characteristics

A coaxial cable is used to transfer signals from the probe tip to the oscilloscope. Cables that can offer the right balance of both flexibility and high frequency performance are selected after considering the ways in which the cables will actually be handled. Even so, if a cable is bent sharply, the dielectric can break, altering the characteristic impedance and subsequently weakening the cable's throughput and reflectivity. This in turn will affect the high frequency components of the observed waveform.
This is one of the causes of poor repeatability in the observation of high frequency waveforms. The repeatability can be increased by bending the cables as little as possible in a uniform manner.

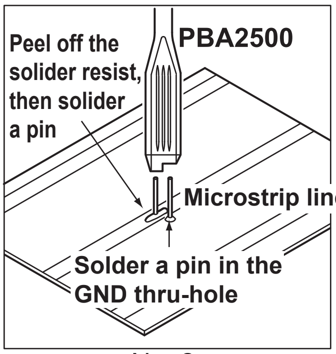
Getting the Best Performance Out of Your Probe

When using probes, inductance-based resonance is the biggest problem during waveform measurement, and it is most important to suppress it.
Make the probe's input pins and ground lead as short as possible when the goal is to easily check signals (browsing). When highly reliable waveform observation is called for, prepare a thru-hole PCB for connecting the probe and directly connect the probe's signal input pins onto the PCB trace or to another fitting (No. 1 and No. 2). Connect the probe to a prepared copper wire or plate that is as thick as possible to reduce inductance in the ground.
If it is not possible to connect a short wire, you can insert a 50 to 100-Ω resistor to dampen the resonance (No. 3). In this case, the measurable frequency bandwidth is reduced by the resistance, but you can approximate the original waveform more closely by suppressing the resonance effects of overshooting and ringing.
Also, try securing the cable to the workbench with tape so that the bends in the cable do not change (see the next page), because high frequency signal components are, as stated above, affected by cable bending. This may improve the repeatability of the observed waveform.

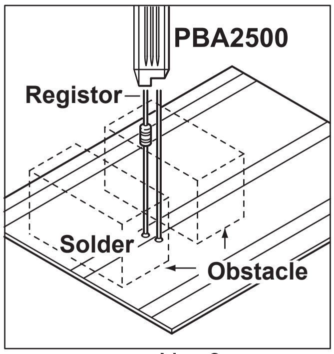
Probing Methods



No. 1



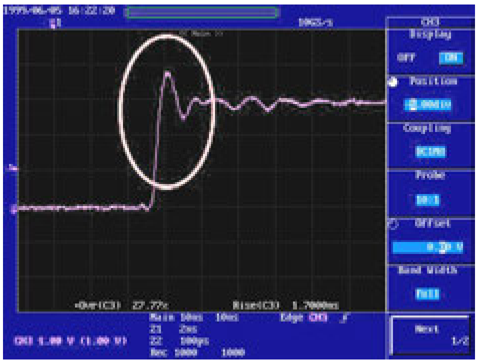
No. 2



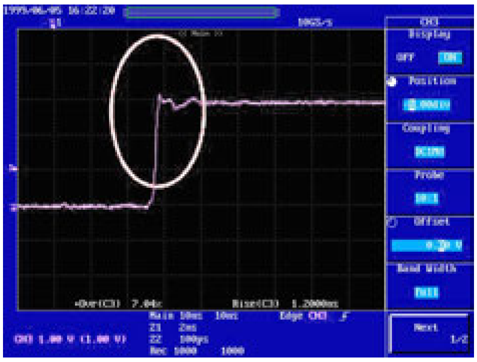
No. 3

Ringing Comparison

When inductance is large and ringing can be seen



When inductance is reduced and ringing is suppressed



Probe Cable Bending