
**User's
Manual**

**Model 701923
PBD2000 Differential Probe**

Foreword

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.

Revisions

1st Edition: November 2005

The following safety markings are used in this manual. 5



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 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.

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 1-2)

- 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
- Driver: 1

User's manual (this manual): 1

Carrying case: 1

Optional Accessories (Sold Separately)

| Name | Model | Remarks |
|------------------------|--------|--|
| Standard accessory kit | 701915 | Set of attachments (the quantity of each attachment differs from the accessories). |

Safety Symbols and 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.)

Safety 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 item 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 nondestructive input voltages.
Do not apply a voltage exceeding [PM]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, remove all jewelry such as rings and wristwatches. 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.

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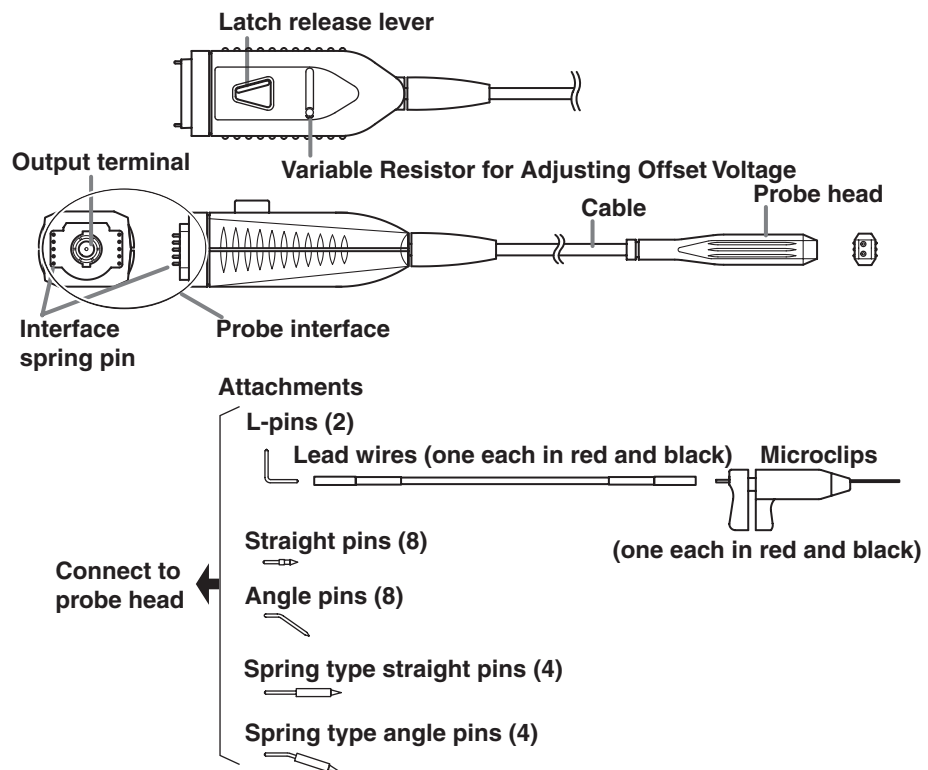
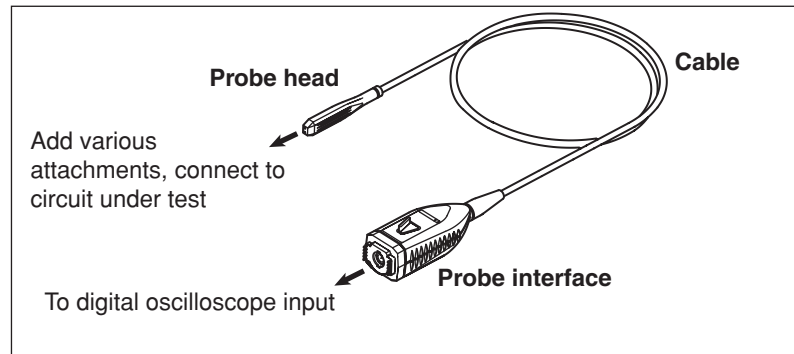
Product Overview

The PBD2000 Differential Probe is a 2 GHz bandwidth differential input probe that can be used in combination with DL9000 series digital oscilloscopes. The probe is simply connected to the BNC input terminal on the DL9000 series instrument. By touching the probe tip to the circuit under test, you can view voltage waveforms.

Features

- Allows direct observation of differential signals
- Common mode rejection capability
- Wide frequency bandwidth (DC to 2 GHz)
- Power can be supplied to the probe from the DL9000 series instrument.
- The probe is automatically recognized by the DL9000 series instrument.
- The attachment that touches the circuit under test can be changed
- Compact and lightweight

Names of Parts



The quantity in parentheses () is the number of the various attachments that belong to a single probe.

Probe interface

The point of connection to the input of the digital oscilloscope.

Interface spring pin

When the probe output terminal is connected, it touches the pad on the interface board of the oscilloscope. The probe's power is supplied through this interface component. The interface also supplies the offset voltage, and allows automatic recognition of the probe.

Cable

Links the probe interface and probe head.

Probe head

Contacts the circuit under test through various attachments.

Latch release lever

A lever that releases the lock connecting the probe output terminal to the oscilloscope input.

Attachments

The probe's input terminals. An attachment is selected according to the circuit to be tested, and attached to the probe head.

Output terminal

The output terminal is a BNC connector. It connects to the input of the oscilloscope (BNC connector).

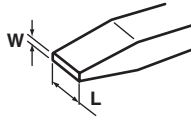
Variable resistor for adjusting offset voltage

You can adjust the offset voltage using an appropriate driver as described below.

Adjustment Driver

Use an adjustment driver that fits the adjustment groove. Using a driver with a large grip or a driver with a small head can result in damage to the adjustment turn stop or grooves.

Recommended Adjustment Driver Bit Dimensions



Head thickness (W): 0.2-0.35 mm, head length (L): 1.3-1.5 mm, head shape: minus or plus.

Usage Precautions

CAUTION

Use a soft cloth to wipe away dirt, and be careful not to damage the probe. Also, never dip the instrument in liquid, nor use any detergents or abrasives. 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 and/or magnetic fields. Inaccurate measurement may result.

Operating Procedures

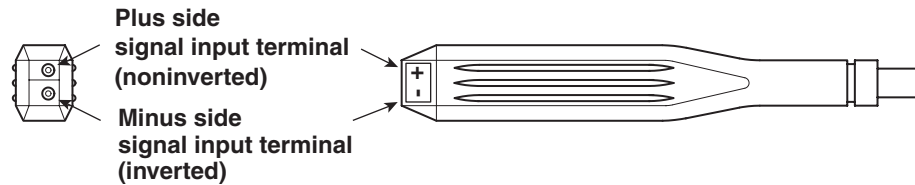
Preparing for Measurement

1. Set up the probe and DL9000 series digital oscilloscope.
2. Before measurement, insert the probe interface completely into the input of the oscilloscope and confirm that the BNC connector and interface pin are securely fastened. When inserting the interface, you will hear a click as the latch closes, indicating that the connection has been made.

Handling the Attachments

You can change attachments according to the circuit to be tested.

As in the figure below, there is a hole for attaching the attachments to the tip of the probe head.

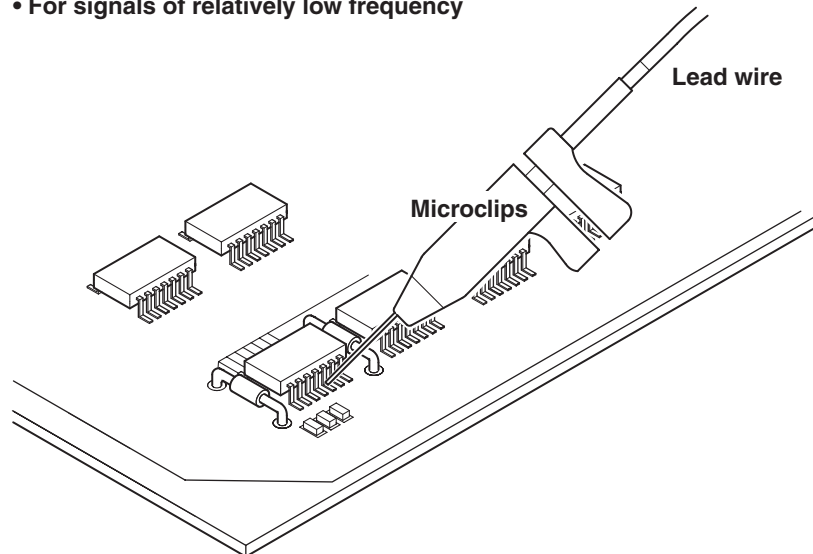


There are straight and angle pins. Select an attachment according to the circuit to be tested.

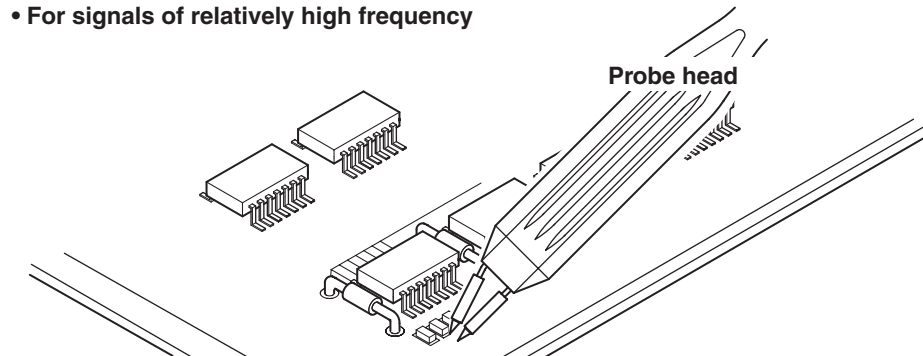
Since the impedance of the probe input is high, the inductance from the probe head to the circuit under test has a large effect on measured results of high frequency signal components. When measuring signals including frequency components of 100 MHz and higher in particular, we recommend that you use as short of an attachment as possible to connect the circuit under test to the probe head (both signal input terminal and ground terminal).

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, spring type angle pin).

Warm-up/offset adjustment

Warm-up

After connecting the probe, heat emitted from the probe itself causes the offset voltage to drift. The probe should nearly stabilize about thirty minutes after applying power. Allow a thirty minute warm-up after connecting the probe.

Offset adjustment

You can turn the offset voltage adjustment variable resistor on the probe interface with the appropriate adjustment driver (see page 3) to adjust the offset voltage remaining after warm-up (residual offset voltage).

CAUTION

When adjusting the offset voltage, do not force the offset voltage adjustment variable resistor. The offset voltage adjustment variable resistor may break.

Note

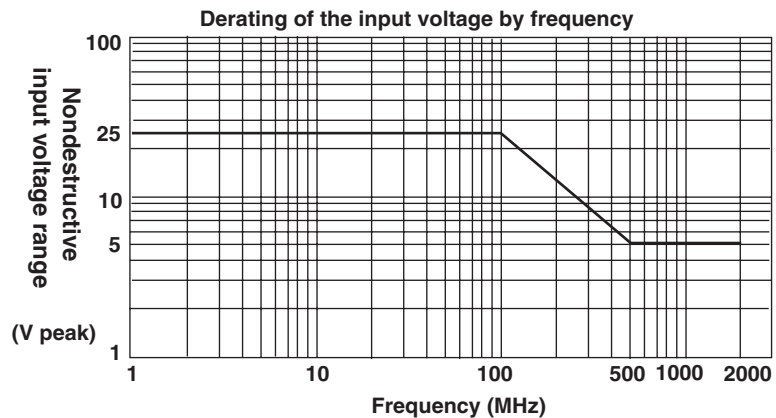
- The offset voltage drifts as a result of the ambient temperature. During continuous use, make sure the ambient temperature is stable.
 - Do not use the offset voltage adjustment variable resistor for any purpose other than adjusting the residual offset voltage. If you use it for purposes such as deliberately changing the offset value, the instrument will fail to meet its specifications.
-

Product Specifications

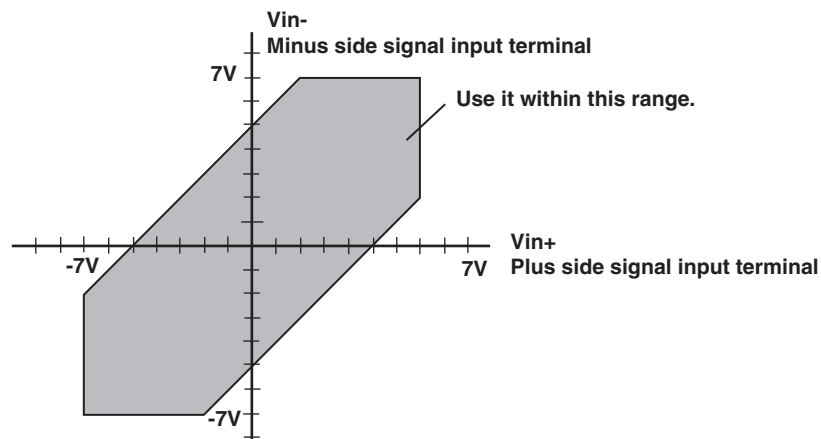
Electrical Specifications

(The electrical specifications are based on a standard operating conditions after a thirty-minute warm-up).

| | | |
|--|---|----------------|
| Frequency Bandwidth | DC to 2 GHz (-3 dB or more) | |
| Attenuation ratio and DC voltage accuracy ¹ | 10:1, within $\pm 2\%$ (including oscilloscope error at a 50 Ω load) | |
| Input capacitance | Approximately 1.1 pF (relative to ground, typical value ⁴) | |
| Input resistance: | Within $\pm 2\%$ of 50 k Ω (relative to ground) | |
| Output impedance | Approximately 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 (not including characteristics of the oscilloscope, typical value ⁴) | |
| Residual noise | 500 μ Vrms or less (in probe output, typical value ⁴) | |
| Residual offset ³ | Within ± 10 m (after adjustment) | |
| Common mode rejection ratio | DC-10 MHz: | -35 dB or less |
| | 10 MHz-100 MHz: | -20 dB or less |
| | 100 MHz-1 GHz: | -12 dB or less |



Input voltage range



General Specifications

| | | |
|--------------------------------|--|---|
| Power range | Standard power supply voltage of ± 5 V, within $\pm 5\%$ | |
| Interface | (The probe is supplied power from a dedicated terminal. Connect the probe to a DL series instrument having a matching dedicated terminal.) | |
| Storage altitude | 3,000 m or less | |
| Operating altitude | 2,000 m or less | |
| Standard operating environment | Temperature range | $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ |
| | Humidity range ^{*5} | $55\% \pm 10\% \text{RH}$ |
| Operating environment | Temperature range | 5°C 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 cycle | 1 year | |
| Warm-up time | 30 minutes or more | |
| Total length | Approximately 1.2 m. | |
| Weight | Approximately 80 g. | |

Standards Conformance

| | | |
|-----|----------|---|
| EMC | Emission | Conforms to EN61326 Class A |
| | Immunity | Conforms to EN61326 standards Effect of Immunity Environment noise increase: within ± 2 V ^{*6} |

*1 Excluding residual offset voltage

*2 Nondestructive maximum input voltage. This is not the dynamic range of the probe.

*3 When 0 V are input to both the plus and minus side signal input terminals.

*4 Typical value represents a typical or average value. It is not strictly guaranteed.

*5 No condensation

*6 Test conditions

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

Appendix (High Speed Waveform Measurement and Probing)

The speed of devices and electronic circuits incorporated into a variety of instruments, including digital home electronics, is increasing and the oscilloscopes and probes used to observe their signal waveforms are also faster and have wider bandwidths.

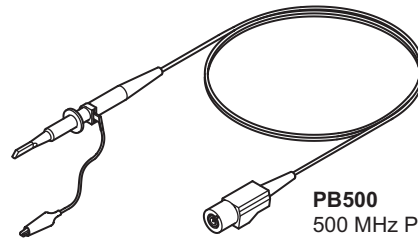
When the speed of the measured signal increases, there are cases when correct measurements cannot be taken due to problems that have never occurred before, especially in probing. In this article I offer some hints regarding the accurate probing of high speed signals.

Types of Voltage Probe

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. Individual probes have their own particular pros and cons, and since the input impedance (resistance and capacitance) and frequency can differ greatly depending on the type of probe, it is essential to understand the characteristics of the available probes in order to obtain highly reliable measurements. Below are three examples of probes generally used for measurements on high frequency circuits.

Passive Probes

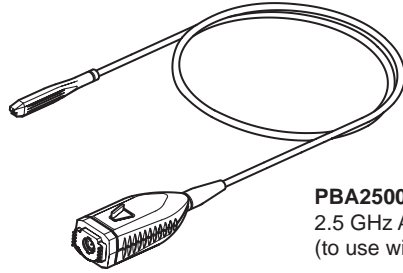
Passive probes with a 10:1 attenuation ratio are the most widely used due to their low cost, ruggedness, high withstand voltage, and high input impedance at DC and low frequencies. Yokogawa's standard 10:1 passive probes are easy-to-use for general applications. They have an input impedance of 10 M Ω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



PB500
500 MHz Passive Probe
(to use with DL9000 Series)

Active Probes / FET Probes

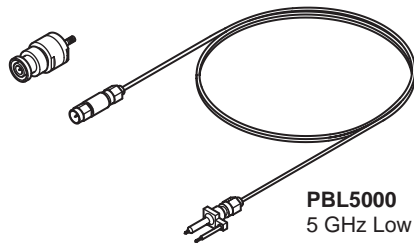
Active and FET probes are those most often used to measure high frequency signals. Unlike passive probes, an impedance converting buffer amplifier is situated near the tip of the probe which enables them to handle higher frequencies with around 1 pF input capacitance. They require a power supply and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



PBA2500
2.5 GHz Active Probe
(to use with DL9000 Series)

Low Capacitance Probes (Resistance)

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 since the input capacitance is extremely small. As the input resistance is 500 Ω or 1 k Ω it can have an affect on the DC bias or output amplitude if the impedance of the signal source being measured is high. However, 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.



PBL5000
5 GHz Low Capacitance Probe

Problems with Probing High Speed Signals

The Loading Effect

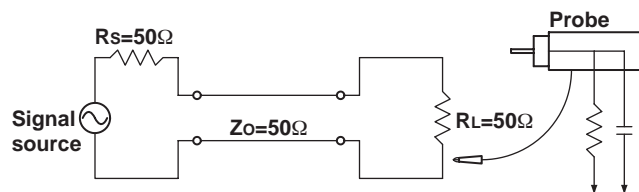
When a probe is connected to the circuit under test, the input impedance of the probe itself has certain effects on the circuit. This is called the loading effect. For example, when measuring a feedback circuit, the phase of the circuit changes due to the impedance of the connected probe, thus changing the operation of the circuit. For oscillating circuits, the frequency of oscillation can change or the oscillation can stop altogether. Special care must be taken when selecting a probe for measuring circuits that are sensitive to capacitance.

Observational Bandwidth Limits due to Probe Input Capacitance

There can be cases where there are notable low pass filter effects related to 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 (see below). In this example, the equivalent signal source impedance can be seen as 25 Ω (2 x 50 Ω in parallel) when observing the signal waveform at the load (terminal), and the cutoff frequency at the probe's input point is $f_c = 1/2 \pi RC$ if the probe input capacitance is added. When using a passive probe with an input capacitance of 14 pF, f_c equals 455 MHz, but when a 0.9 pF input capacitance active probe is used, f_c equals 7 GHz.

It is preferable to use an active or FET probe with a smaller input capacitance because even more pronounced loading effects emerge when measuring a circuit with a high output impedance.



Resonance due to Inductance

Pins or wires of one sort or another 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, but overshooting or ringing, which was not originally present, is introduced into the signal waveform being observed when 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 1-2 cm). The user 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 and the repeatability can be increased by bending the cables as little as possible. When bending is necessary, please do so in a uniform manner.

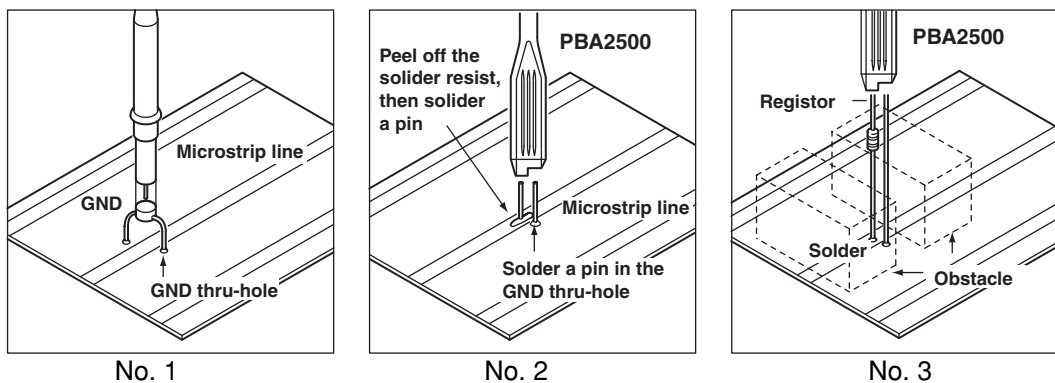
Getting the Best Performance Out of Your Probe

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 track 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 simply not possible to connect a short wire, you can insert a 50-100 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.

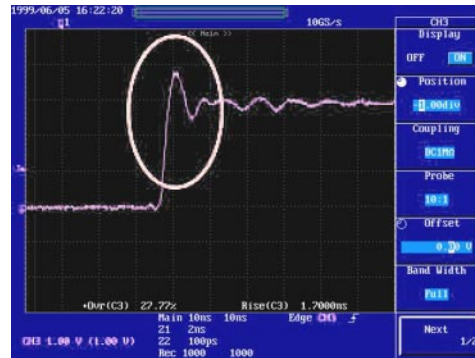
Also, try securing the cable to the workbench with tape so that the bends in the cable do not change (See the next page) since high frequency signal components are, as stated above, affected by cable bending. This may improve the repeatability of the observed waveform.

Ringing Comparison

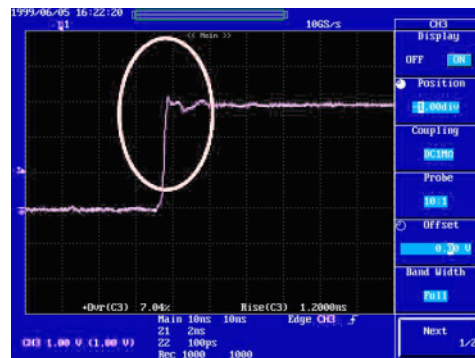


Ringing Comparison

When inductance is large and ringing can be seen.



When inductance is small and ringing is suppressed.



Probe Cable Bending

