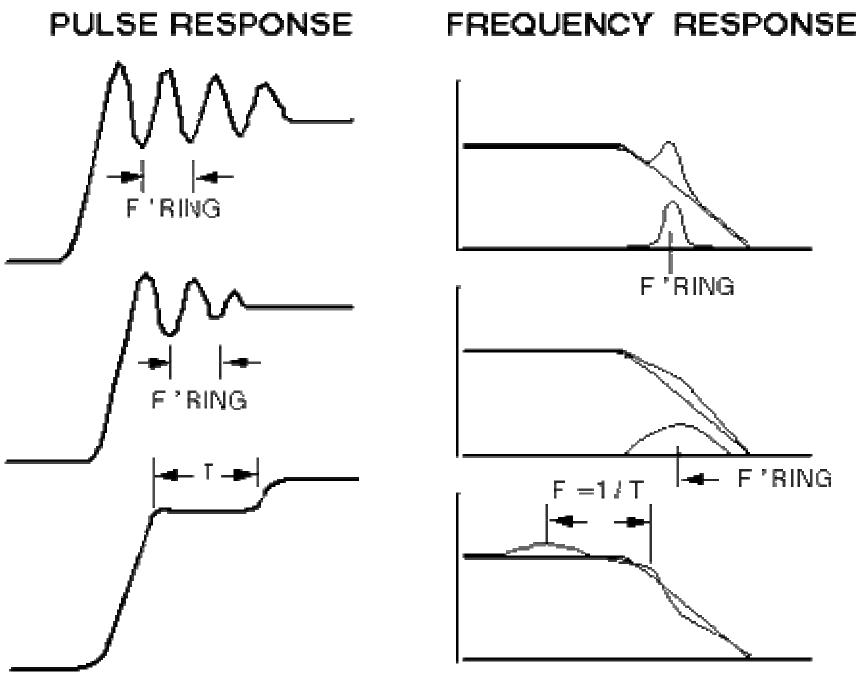
Tutorial sobre las Sondas

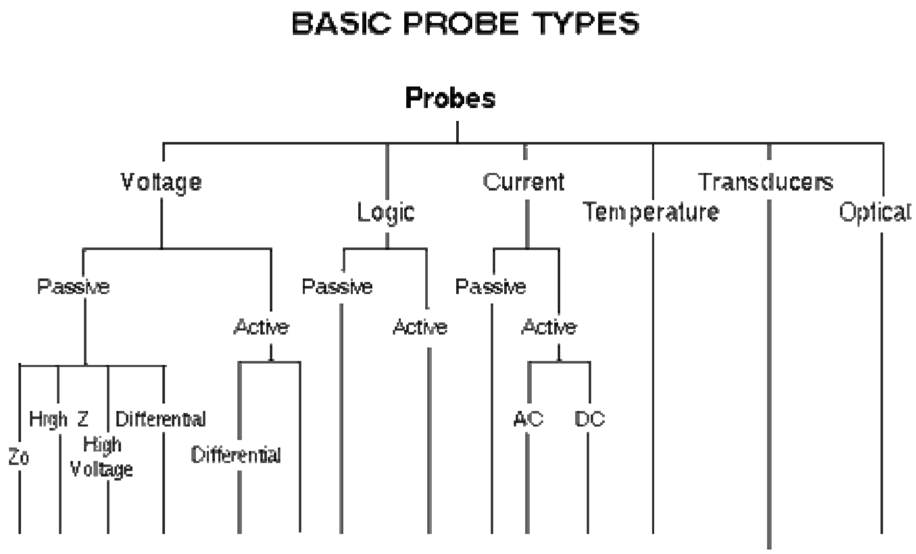
A probe can be any conductor used to establish a connection between the circuit under test and the measuring instrument. This conductor could be a piece of bare wire, a multimeter lead, or a piece of unterminated coaxial cable.

These "simple probes", however, do not fulfill the essential purpose of a probe; that is, "to extract minimal energy from the circuit under test and transfer it to a measuring instrument with maximum fidelity." The bare wire can load the input amplifier with its high capacitance and inductance or even cause a short circuit; multimeter leads are unshielded and are often susceptible to stray pickup, and the unterminated coax will severely capacitively load the circuit under test (100 pF per meter typically). Also, the unterminated coax is usually resonant at certain frequencies and does not allow faithful transfer of the signal to the test instrument due to reflections.

Tektronix has been designing and manufacturing instrument probes for more than 40 years, placing a constant effort on minimizing the reflections and other effects associated with unterminated coaxial probe cables and to reduce the effect of coaxial probe cables' capacitance in today's high-speed probing products.



This brief tutorial will quickly review the basic probe types and look at some of the more common issues around probe selection.



Types of Probes

Tektronix probe products include General Purpose Passive Voltage Probes, Active (FET) Voltage Probes, SMD Passive Voltage Probes, Active and Passive Current Probes, High Voltage Passive Probes, 50 Ohm Divider Passive Voltage Probes (Zo, low impedance/high frequency), and Differential Voltage Probes, to name a few.

General Purpose Passive

Attenuating Passive Voltage Probes are the most commonly used probes today. They provide a convenient and extremely rugged, yet inexpensive, way to acquire signals from your device under test. They maintain the accuracy of the oscilloscope to which they are connected over a wide dynamic range (+/-400 V). The 10X passive voltage probe presents a high impedance to the circuit under test at low frequencies (approximately 5 MHz and lower). Their main disadvantage is a decreasing impedance level with increasing frequency (i.e., high input capacitance).

Active FET Probes

FET probes include active components (field effect transistors or other active devices) rather than passive components. The FET input results in a higher input impedance without loss of signal, i.e., low input capacitance (typically <0.4 pF to <2 pF), and high input resistance values (typically >100 kilohm). Some FET probes include an offset control that allows a substantial increase in the active probe's linear dynamic range. Since FET probes have a 50 Ohm output impedance, they can drive a 50 Ohm cable. This capability allows the distance from the probe tip to the instrument to be increased within the practical limits of the probe amplifier system and the limitations of the coaxial cable.

High Voltage Passive

Several high voltage probes are available from Tektronix that provide 100X or 1000X compensated dividers. Because of the larger attenuation factors required for high voltage applications, the input capitance is reduced to approximately 3 pF.

Current Probes

Current probes provide a method to measure the current flowing in a circuit. Two types of current probes are available, the traditional AC only probes and the "Hall Effect" semiconductor type. AC only current probes use a transformer to convert current flux into AC signals and have a frequency response from a few hundred Hz to GHz. Combining a "Hall Effect" device with an AC transformer provides a frequency response from DC to 50 MHz. Because of its "non-invasive" nature, a current probe typically imposes less loading than other probes.

50 Ohm Divider Probes (Z0)

50 Ohm Divider Probes provide the lowest input capacitance (typically <1 pF for high frequency signals) and are used with high frequency, 50 Ohm input scopes. 50 Ohm Divider Probes provide the most consistent probe loading because they exhibit a frequency response that is essentially flat throughout their designed frequency range.

Differential Probes

Tektronix differential probes are available with high common mode rejection ratio (P5200/ADA 400A). The normal 10X probe has a typical accuracy of +1% and gives a differential measurement accuracy of two parts per 100. Using this 10X probe, the common mode rejection ratio of a scope and probe combination would be no better than 50:1. A matched pair (P6135A) of differential probes allows the user to adjust the probe's attenuation for compatibility with a variety of Tektronix amplifiers to provide common mode rejection ratios of 10,000:1 and higher. This attenuation adjustment includes probe compensation so the probes match at high frequency as well as low frequencies.

Probe Selection Criteria

Proper probe selection will extend and enhance an instrument's performance, while imprudent probe selection often reduces your system's performance. Thoughtful consideration of probe characteristics will help ensure that the performance of your instrument meets your application's requirements. While the major considerations for an appropriate probe are its loading and signal fidelity transfer, physical parameters such as probe size, cable length and device under test interconnect adapters are potentially more important to the success of your measurement.

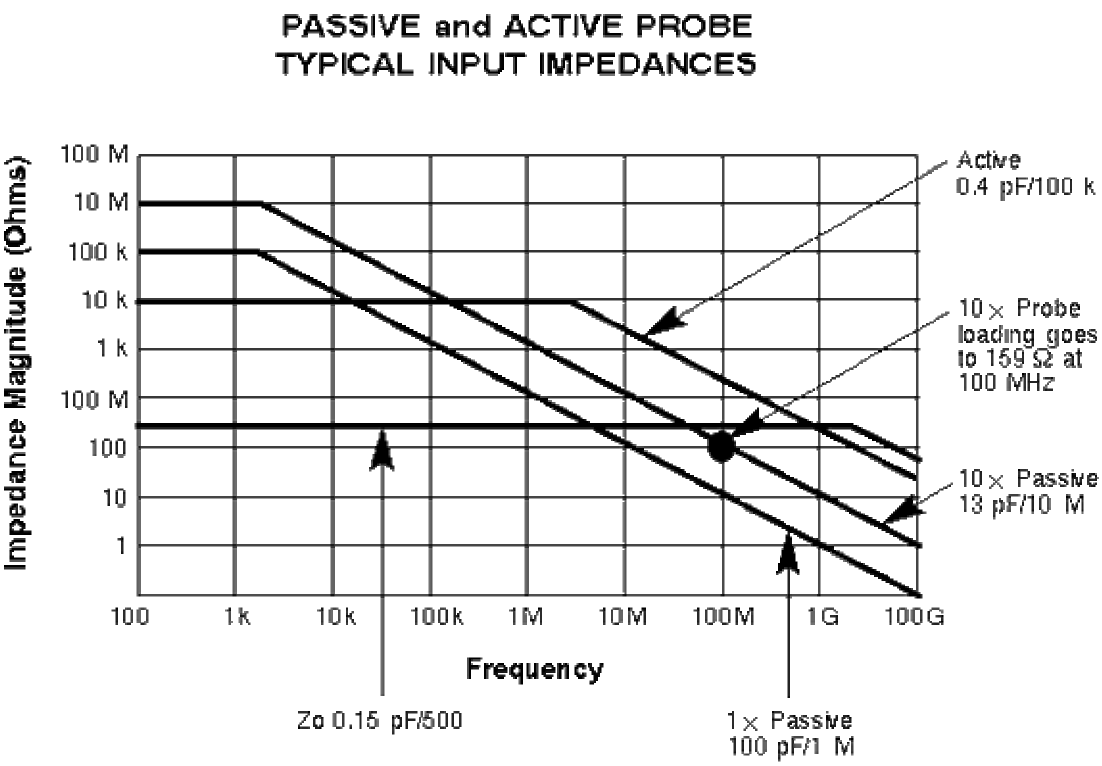
For a complete understanding and description of signal acquisition probing techniques, issues and applications, the following information is available by contacting your local Tektronix representative.

- "ABC's of Probes"
- Literature # 60W-6053-5 (Free)
- "Probing High Frequency Digital Circuitry"
- Literature # 60W-8412-0 (Free)
- "Active Probes: Their Unique Characteristics and Applications"
- Literature # 60W-6883 (Free)
- "The Effect of Probe Input Capacitance on Measurement Accuracy"
- Literature # 60W-8910-0 (Free)
- "Probe and Signal Concepts" Videotape and Workbook.
    - Order 068-0229-XX specify tape format:
      01 Beta
      02 Beta II
      03 Beta III
      04 VHS NTSC
      06 VHS PAL
      07 VHS SECAM
- "Differential Oscilloscope Measurements"
- Literature # 51W-10540-0

Criteria

Bandwidth/Rise Time

The bandwidth of a probe can be defined as the maximum -3 dB frequency a user can expect with a scope/probe system. In most probes, the bandwidth/rise time product is close to 0.35. In many cases the bandwidth is verified by pulse rise time to ensure minimum aberrations. To define these parameters accurately, the source impedance is specified as a terminated 50 Ohm system (i.e., 25 Ohm).



Probe Loading

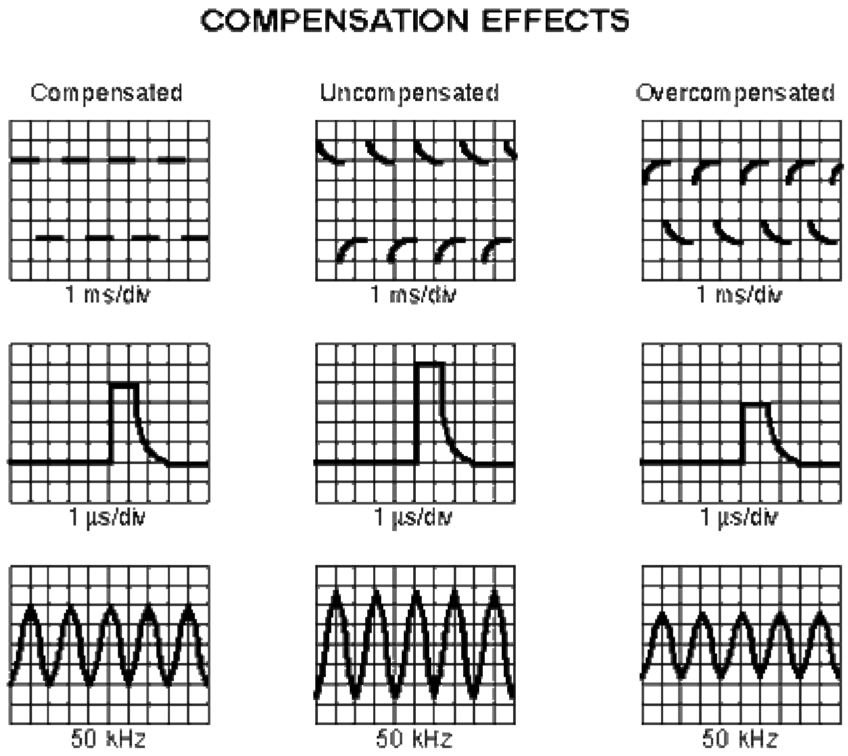
Input resistance and capacitance is used to describe the loading effect of a probe. At low frequencies (<1 MHz) the probe input resistance is the key factor for probe loading of the circuit under test. At higher frequencies the probe input capacitance is now the significant factor. The chart above shows various probes and changes in their impedance as frequency changes.

Aberrations

A high frequency probe that is specified without limiting aberrations can provide very misleading measurements. Existing aberrations can indicate a severely distorted bandwidth/roll-off characteristic.

Compensation Range

The range of a scope's input capacitance over which a specific probe will compensate to provide a flat frequency/attenuation ratio.



Attenuator Ratio

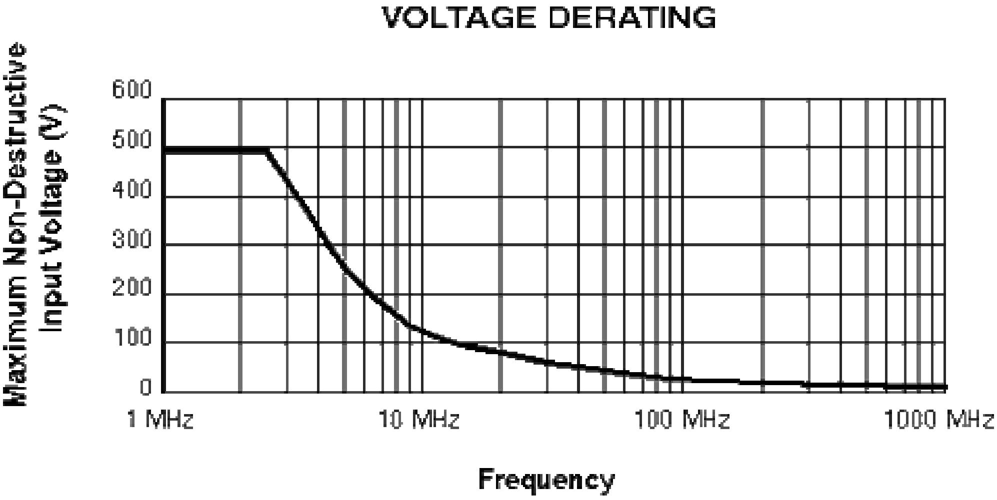
When correctly terminated, a probe should have a constant attenuation ratio. The attenuation ratio is the ratio of the output signal to the input signal. The attenuation should remain constant throughout a wide band of frequencies, decreasing by 3 dB as the frequency increases to the rated bandwidth.

Maximum Voltage

The maximum voltage (DC + peak AC) should be specified to ensure a usable, upper voltage range. At Tektronix, probes are tested in accordance with standard safety procedures.

Voltage Derating with Frequency

This specification is applicable for all high frequency probes. Either the termination elements or the resistive center conductor in the probe cable limits the maximum voltage that may be applied to a probe at a specific frequency. This derating applies at frequencies above 100 kHz.



Probe Length

Keep probe cable lengths as short as possible because extra length decreases the bandwidth and increases the loading capacitance of the probe. Longer probe cables also have greater propagation delays (typically 4 ns/meter in passive probes).

Probe Tip Accessories

A wide variety of adapters is available to mechanically connect the probe to the circuit under test. Since the probe tip conducts very little current, many materials that are normally considered to be good conductors have high resistance at lower current levels. Tektronix probe tips use an alloy coating to minimize current conduction problems.

Probe Coding

Probe coding provides the user with an indication of the actual probe tip sensitivity. This coding eliminates the need to divide by the attenuation ratio or remember which probe is being used. Most passive probes today provide readout capability that allows you to read your measurements directly from the oscilloscope screen.

Maximum Current (CW)

The maximum sine wave current that can be measured with a specified current probe without distortion.

Maximum Current (Pulse)

The maximum current pulse that can be measured with a specified current probe without distortion limited by Amp-Second (A-S) product.

Amp-Second Product

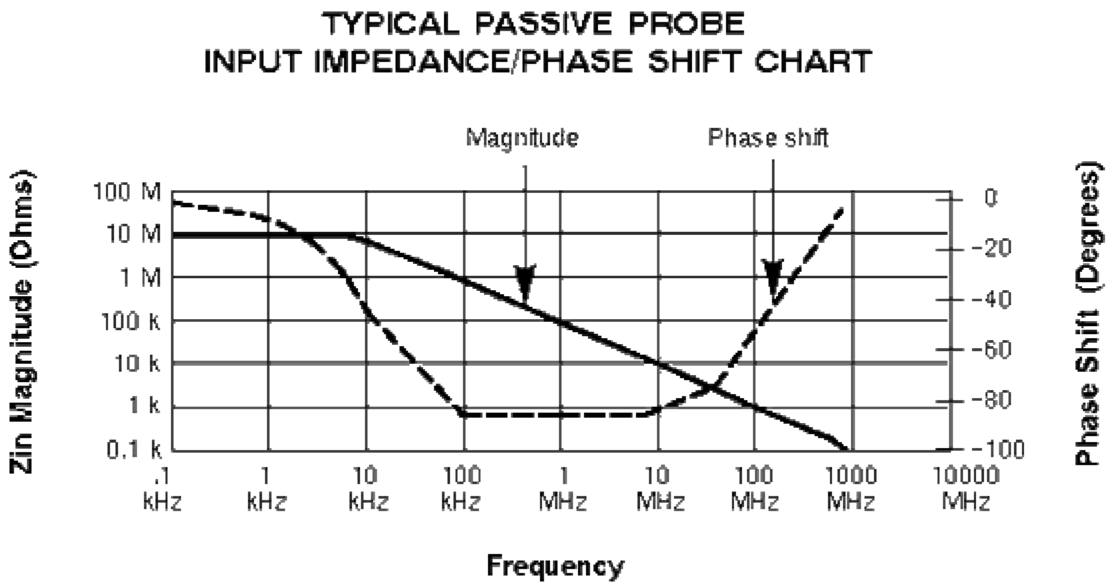
The maximum integral of the Pulse Current Waveform that may be measured without distortion.

Maximum DC Current

At levels lower than the RMS current specification, a DC level will saturate AC-only current probes causing distortion and insertion impedance changes. The impedance reflected into the circuit being measured is normally in the form of resistance and inductance.

Probing Considerations And Rules Of Thumb

A prime consideration in selecting the proper probe is the circuit loading effect of the oscilloscope/probe combination. The probe with the highest input impedance (lowest input capacitance and highest input resistance) will provide the least circuit loading. As circuit frequency increases and/or rise time decreases, the capacitive loading becomes most important. At DC and low frequencies the resistive loading is the most important.



Capacitive loading of voltage probes is the most important consideration when measuring fast rise time pulses. The time required to charge the input capacitance of the probe from the 10 to 90% level is

tr = 2.2 x Rsource x Cprobe

Probe only rise time is the rise time of the probe driven from a terminated 50 Ohm source. From this formula the rise time of the probe/oscilloscope system may be calculated for non passive probes that terminate in 50 Ohm.

tr2 system = tr2 probe + tr2 scope

Bandwidth (3 dB down) of the probe/oscilloscope system may be calculated, knowing the system rise time and using the formula

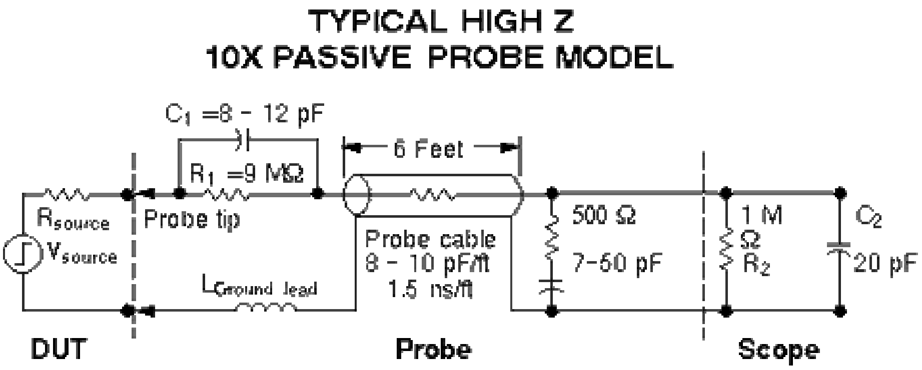
BW 9 0.35 / trise

As you can see, these formulas are all dependent upon the input capacitance of the probe/oscilloscope system. **Since input capacitance plays such an important role, carefully consider the value of the probe's input capacitance when selecting your probe.**

Probe attenuation ratio is also an important consideration. The oscilloscope must have enough gain to allow viewing of the attenuated signal when using probes with larger attenuation ratios.

When an attenuating probe is used with an oscilloscope, the input resistance and input capacitance of the oscilloscope are represented by R2C2, and the probe resistance and capacitance are represented by R1C1 (see the figure below).

R2C2 = R1C1 = Optimum Signal Transfer

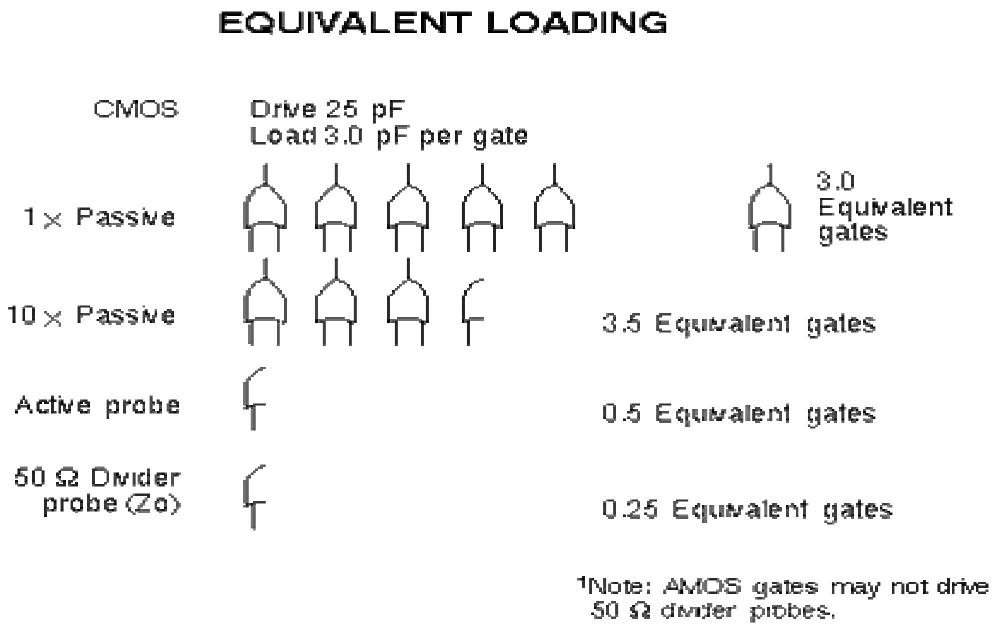


When the probe is first connected to the oscilloscope, compensate it by applying a low frequency square wave (1 to 10 kHz normally) to achieve the equalization of time constants. Improper compensation will result in either overshoot, roll-off or incorrect signal amplitudes (see Compensation Effects figure).

Consider the following factors in making your probe selection:

- **Match Probe to Scope Input Resistance and Input Capacitance:** Be sure the desired probe will match the input resistance and capacitance of the oscilloscope being used. Fifty ohm (50 Ohm) scope inputs will require 50 Ohm probes. One Megaohm (1 Megohm) scope inputs will require 1 Megohm probes. Also check for connector interface compatibility or choose the appropriate adapter required. 1 Megohm inputs may also be used with appropriate 50 Ohm adapters.

- **Match to Scope Bandwidth and Rise Times:** Select a probe with adequate rise time and bandwidth for the oscilloscope and application.
- **Probe Loading Effects:** Minimize probe loading effects by selecting low-impedance test points. Although the input impedance of a probe is made as high as possible, it still will always have some finite effect on the circuit under test. Usually cathodes, emitters and sources are preferred over plates, collectors or drains. Inputs to high-impedance dividers should be used rather than the midpoints.
- Be aware of the fact that the input impedance of a probe varies inversely with frequency. Example: A probe having a bandwidth of 50 MHz and an input resistance of 10 Megohm at DC would have an input resistance of approximately 1.5 kilohm at 50 MHz. Choose the probe with the lowest possible input capacitance and highest input resistance for best overall signal fidelity.



- **Time Delay Effects:** Time delay differences must be considered, particularly in phase and time coincidence measurements and in differential measurement applications. Always use two probes of the same model and cable length when making skew or time difference measurements.
- **Grounding Effects:** Grounding practices should always be kept in mind, particularly in high-impedance probe applications. Using as short a ground path as possible (preferably a coaxial adapter or short ground connector) will minimize the effect of series inductance to the probe input.