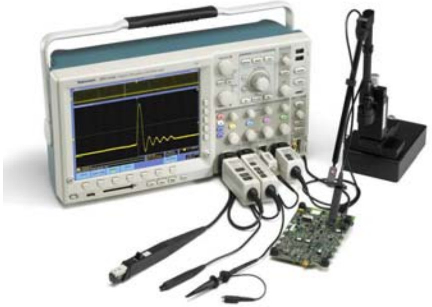
The Probe: Measurement Accuracy Begins at the Tip



Choosing the Right Probe

Probes provide a physical and electrical connection between the oscilloscope and the test point on your device. With an ideal probe, the signal at the oscilloscope input would exactly match the signal at the test point. Performance terms and considerations for choosing a probe include:

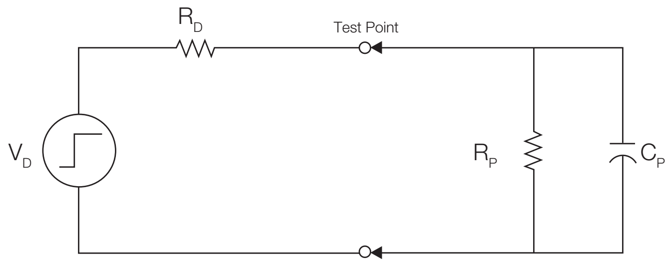
- Attenuation
  – The ratio of the probe's input signal amplitude to the output signal amplitude..
- Bandwidth
  – The bandwidth of both the oscilloscope and probe should be at least five times that of the circuit being tested to ensure a sine wave amplitude error of not more than 3%.
- Rise Time
  – The rise time of the measurement system should be less than one fifth of the rise- or fall-time of the measured signal to ensure an error of no more than 3%.

$$t_{r,\, meas.sys.} = \sqrt{t^2_{r,\, oscilloscope} + t^2_{r,\, probe}}$$

- Linear Phase
  – Bandwidth limitations affect the shape of signals by delaying different frequency components by different amounts of time.

Impact of Probe Loading

Probe loading is a measure of how the probe affects the device-under-test (DUT). The probe can be modeled as a resistor, capacitor and inductor, as seen below.



Simplified circuit diagram using Thevenin equivalent of the DUT

- Input Resistance
  – At DC, the reactive impedance of the probe's input capacitance is infinite and adds no loading on the DUT.

$$V_{Meas} = V_D \frac{R_P}{R_P + R_D}$$

- Input Capacitance
  – As the signal frequency increases, the probe's capacitance has the dominant effect on probe loading. Probe capacitance increases the rise and fall times on fast transition waveforms and decreasesthe amplitude of high frequency details in waveforms.

$$t_r = 2.2(R_D C_P)$$

- Probe Inductance
  – The probe inductance interacts with the probe capacitance to cause ringing at a certain frequency that is determined by the L and C values.

Tip: To minimize probe loading, use a higher impedance probe (higher R_p, lower C_p) or measure the signal at a test point where the impedance is lower.

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Passive Voltage Probe

Most common probe type and are useful for a wide range of applications.

- Advantages:
  - Relatively Inexpensive
  - Mechanically Rugged
  - Wide Dynamic Range
  - High Input Resistance
- Disadvantages:
  - High Input Capacitance

Active Voltage Probe

Good for measuring high frequency signals or high impedance circuits.

- Advantages:
  - Low Input Capacitance
  - Wide Bandwidth
  - High Input Resistance
  - Better Signal Fidelity
- Disadvantages:
  - Higher Cost
  - Limited Dynamic Range
  - Mechanically Less Rugged

Differential Probe

Provides a large common mode rejection ratio (CMRR) and minimal skew between inputs for measuring differential signals.

- Advantages:
  - Wide Bandwidth
  - Large Common Mode Rejection Ratio
  - Minimal Skew Between Inputs
  - Small Input Capacitance
- Disadvantages:
  - Higher Cost
  - Limited Dynamic Range
  - Mechanically Less Rugged

Current Probe

Used to make current measurements. Some current probes can only detect AC current. To measure DC current, an AC/DC current probe is required.

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