An idealistic oscilloscope probe would simply provide an exact replica of the signal being probed. However, in the real world, the probe becomes a part of the circuit under test, because the probe or probing accessories attached to the DUT introduces probe loading to the circuit. Depending on the different loading effects, the non-ideal loading effects on DUT could impose limitations on the probe's bandwidth and frequency response flatness in the frequency domain and may cause unwanted side effects such as overshooting, ringing, and DC offset problems in the time domain.

**RCRC vs. RC input impedance characteristics**

One important factor you must keep in mind when choosing a high bandwidth probe is that the probe's loading characteristics may be somewhat different from that of a conventional probe. The conventional model of probe impedance looks like this red trace in the input impedance vs frequency chart (Fig 1). The example here is of the Keysight InfiniiMax 1169A 12 GHz differential probe. At frequencies as low as ~10 MHz, you see the input impedance is 50 kΩ driven by input R of the probe. It then intersects the 210 fF capacitance of the probe. That is what we call an RC input impedance profile. This is very traditional for any oscilloscope probes, including Keysight’s InfiniiMax I or II probes or almost any other probes you may deal with in your everyday use.

The high bandwidth differential probes like InfiniiMax III or III+ have a different input impedance characteristic. They have a 100 kΩ differential impedance at DC and at very low frequencies, which intersects with the 50nF capacitance of the probe, where it hits the mid-band impedance. Then over six decades of frequency, it maintains a 1 kΩ differential input impedance until it finally intersects the 32fF capacitance. Also shown in the magenta color is the input impedance plot of the Tek’s P75xx Trimode probe. Again, this has a 100 KΩ at DC, and it falls due to its 110pF mid-capacitance down to a 450 Ω loading, and then intersects with 65 fF capacitance. The crossover frequency of this probe is much higher and it levels out to the midband impedance at ~100MHz. We call this an RCRC profile for semantics here. This is very typical of the newer high frequency probe systems such as the Keysight InfiniiMax III/III+ or Tek P75xx probes.

Generally, RCRC probes do an excellent job of reproducing wave-shapes with fast edge speeds, but may produce effects when trying to measure absolute voltage levels, especially if the source impedance of the target signal is high or if there are long time constants in the signal being probed. Another clear benefit of using a RCRC probe over a RC probe is that the high frequency loading is much lower. If your signal has the frequency contents that are ~1 GHz or higher, using the RCRC probe such as Keysight InfiniiMax III/III+ probe may give you the better result.
What the probe input impedance does to your step

Below on Fig 2 is a simulated plot of three different probes measuring a step with a 20 psec risetime in the time domain. The black trace is the Vsource signal before the probe is attached. The red trace shows how the probe loading could affect the waveform when the InfiniiMax II 1169A probe with RC input impedance is connected. You can see that the edge has slowed down a bit with a rounded top, which is reducing the rise time and knocking the bandwidth down of your probe point.

The blue trace indicates the InfiniiMax III N2800A probe with RCRC profile, and the magenta indicates the Tek's P7520 20 GHz Trimode probe also with RCRC profile. The blue trace doesn't nearly have the rise time degradation, but it does have amplitude degradation. What happened is the midband loading of 1 kΩ or 500 Ω per each side of the probe has caused the amplitude to reduce by ~5%.

Note that the traces on the scope screen may not be the same as what the probe output shows on the scope screen, because each probe may have a different transfer function, and the way the probe is calibrated may be different. The point to note here is that the RC probe has a less impact on the signal amplitude due to lower input loading at midband ranges, but it may change the rise time of a fast step due to probe loading effect with higher capacitance (210 fF). The RCRC probe has broadband attenuation, but it preserves the wave shape very well due to high bandwidth and low loading at high frequency. For all these measurements, we assumed 25 Ω source impedance.
Examples – Selecting the right probe gives you right result

Note that the RCRC type probes may not provide expected results, such as when probing buses that transition to a “high Z” state, or when dealing with any signal source with high impedance.

A good example of a circumstance in which the RCRC probe shouldn’t be used is when dealing with the MIPI D-phy signal standard. The D-phy provides a flexible high-speed, differential and low-speed, low-power single-ended serial interface solution for interconnection between components within mobile and embedded devices. Depending on the application, the D-Phy can transition from 50 Ω HS (high speed) mode to high impedance LP (low power) mode to save power usage (Fig 3). In LP mode, the signaling is single-ended with 1.2 V swing operating at a max data rate of 10 Mb/sec. The impedance driving the high impedance bus is typically pulled up or pulled down with a high value resistor, and this interacts with the RCRC input impedance of the probe, which causes very long time constant effects and a noticeable change in signal amplitude (yellow trace in Fig 3). In this case, the 1 KΩ differential input impedance of the RCRC probe introduces probe loading effect, resulting in amplitude change, while the higher impedance RC probe does not. Therefore, it is generally not recommended to use an RCRC type probe for this type of bus. An RC type of probe with high input impedance across the wide bandwidth range, such as InfiniiMax I/II probe, is recommended for this application (blue trace in Fig 3). An RCRC probe would do a better job in measuring high speed signals with low source impedance, such as a 50 ohm transmission line.
Figure 3. The RCRC type probes may not provide expected results when probing buses that transition to a "high Z" state, such as this MIPI D-phy signal.

Yellow = Keysight N2832A InfiniiMax III+ 13 GHz probe (RCRC)
Blue = Keysight 1169A InfiniiMax II 12 GHz probe (RC)

Let’s look at another example – the eMMC (Embedded Multi-Media Controller). The eMMC is a memory card standard used for solid state storage. It puts the MMC components (flash memory plus controller) into a small BGA IC package for use with portable consumer products such as mobile and tablet devices.

Here in the eMMC circuitry, we are about to measure the Data Strobe line. The driver circuit is driving the eMMC circuit load pulled down to ground through a 10 kΩ resistor (Fig 4). The data rate of the signal is 400 Mbps, which is a slow speed signal for an RCRC probe. The source impedance is indeed very heavy for any probe to deal with. When the InfiniiMax III N2800A probe (with RCRC impedance profile) is used, notice that the idle state voltage gets loaded by the probe and the signal level is shifted. (Fig 5) However, when the InfiniiMax II 1169A (with RC impedance profile) is used, the idle state gets down close to zero voltage as was expected. (Fig 6) This is an example of how selecting the right probe is crucial to giving you the right measurement result.
Figure 4. The driver circuit is driving the eMMC circuit load pulled down to ground through a 10 kΩ resistor.

Figure 5. The eMMC data strobe line measured with an RCRC probe.

Figure 6. The eMMC data strobe line measured with an RC probe.
Conclusion

There is a common misconception that a higher priced, higher bandwidth probe could do a decent job across all bandwidths and could encompass probing capability where a lower bandwidth general purpose probe can do just as well. The reality is that there are different probes optimized for different jobs. High bandwidth probes are optimized for performing better in high bandwidth applications, but not quite as well for low bandwidth applications.

One should consider probe loading effect to ensure that the probe loading is tolerable. Most probe manufacturers provide input loading models so users can take a stab at understanding the probe loading characteristics before probe selection.

Generally, RCRC probes do an excellent job of reproducing wave-shapes with fast edge speeds, but may produce effects when trying to measure absolute voltage levels, especially if the source impedance of the target signal is high or if there are long time constants in the signal being probed. Another clear benefit of using a RCRC probe over a RC probe is that the high frequency loading is much lower. If your signal has frequency contents that are ~1 GHz or higher, using a RCRC probe such as the Keysight InfiniiMax III/III+ probe may give you the better result.

Additionally, the InfiniiMax III+ probes provide the InfiniiMode function that allows you to measure a differential signal, single-ended A or B signal, and common-mode component of a differential signal through a single probe connection. Traditionally, multiple components of a differential signal have been looked at using two oscilloscope channels and two separate probes, either single-ended or differential. However, achieving accurate measurements with two separate probes can be difficult for several reasons. InfiniiMax III+ probes with InfiniiMode attempt to solve many of the shortcomings of the double-probing approach. In any application where the individual components of a differential signal are of interest, InfiniiMax III+ probes offer better visibility of the makeup of the signal.

![Image](image_url)

Fig 7. The InfiniiMax III+ probe with InfiniiMode allows convenient measurements of differential, single-ended, and common mode signals with a single probe tip.
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