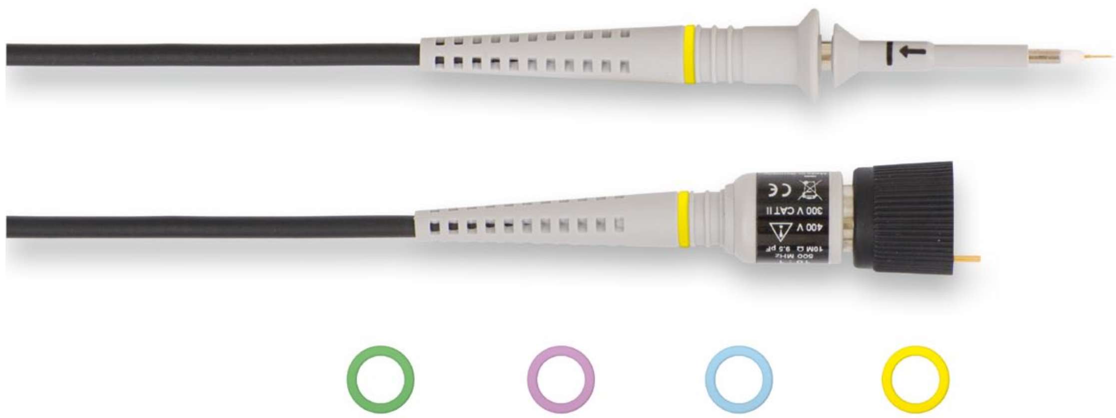
HAMEG Accessories

Minimizing measurement errors by properly using the right probes



When using an oscilloscope, the most ubiquitous measurement instrument in electronics design, quite frequently the importance of the correct connection to the signal is underestimated. There is no question that e.g. the high data rate of 5 GBit/s of USB 3.0 requires the use of special probes and methods of connection. The majority of design engineers, however, encounter much more moderate signal frequencies. Why worry about signal integrity problems, methods of contacting probes or special probes when the processor clock rate is about 30 MHz?

Just looking at the clock rate good passive probes with a bandwidth of 350 MHz should be fully adequate. By contacting a signal with a probe the circuit will be loaded, and the signal will be affected. It is hence a fact that the signal as seen on the scope will never be exactly identical to the signal as it exists in the circuit. Consequently, it is the goal to minimize any effect of the probe on the circuit in test so the display will represent the original as truly as possible. In order to arrive at this goal, all influences on the circuit by ground connections, inductive and capacitive loads must be taken into account.

The vast majority of signal distortions is due to non-optimum ground connections. The basic rule runs:

Use the shortest possible ground connection!

But what is actually the background of this general and often quoted rule?

The probe represents a resonance circuit consisting of an input capacity and an inductance. Passive probes usually specify an input capacitance of 10...13 pF which can hardly be changed. The inductance will be mainly determined by the ground connection, i.e. the shorter the ground connection, the smaller the inductance. Reducing the inductance will increase the resonance frequency with the goal of shifting it into a range far above the interesting frequency range.

The example shown here uses a real signal at the output of a FPGA. The following figure shows the whole signal at the top and a portion with the slope heavily zoomed below. The signal repetition rate is just 2.23 KHz, by looking at that one would not expect an influence on the signal. Because the signal is an output of a modern FPGA, and thanks to the high bandwidth and the deep memory of the oscilloscope used, the slope can be measured, its rise time is 3.2 ns. See Fig. 1.

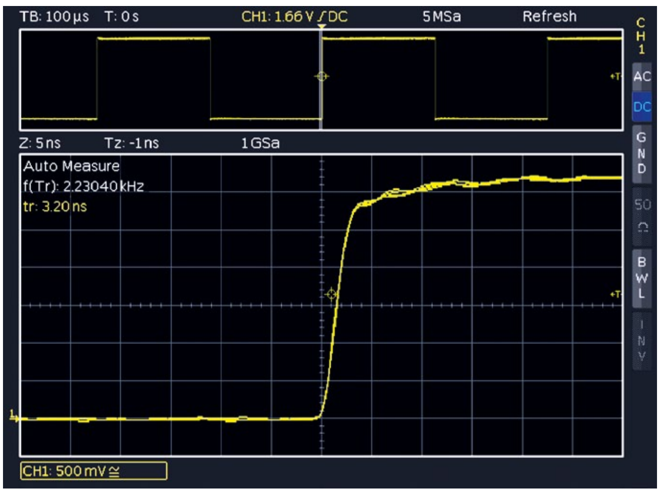


Fig. 1: A typical fast rise time signal

Fig. 2 shows the bandwidth of a signal vs. its rise time and allows to determine the bandwidth by measuring the rise time. The curve depicts the equation: bandwidth = 0.35/rise time which is valid for most forms of signal transitions.

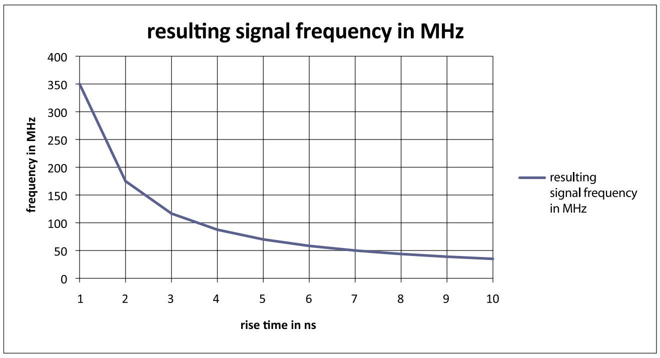


Fig. 2: Bandwidth vs. rise time of a signal

In this example, the signal hence has a bandwidth of 120 MHz. If this signal is measured using a passive probe and if the ground connection is varied, differing results will be obtained. In order to ease the comparison the following figure shows all measurements performed one after the other on the same screen shot.

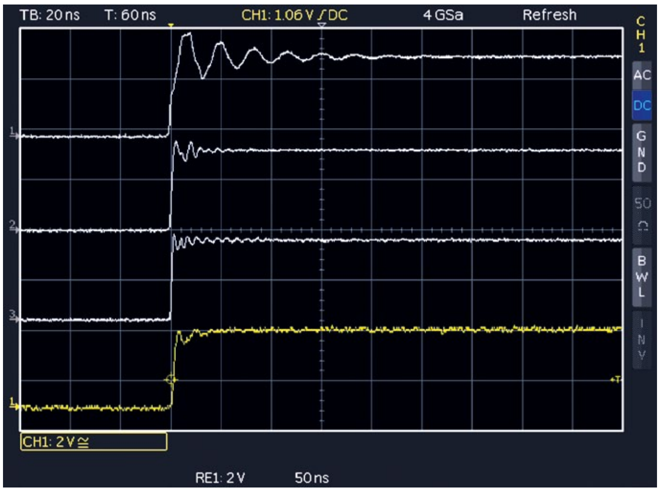


Fig. 3: Signal display using various ground connections

The top curve was taken without any ground connection to the probe (i.e. the measuring object and the scope were connected only via the chassis). The 2nd curve shows the same signal with a 20 cm ground cable, the 3rd with a 10 cm ground cable. For the lowest curve a 2 cm wire to the next ground connection available was used. It is obvious that the shorter ground connections generate less resonance and thus achieve more realistic measurement results.

Apart from the ground connection effects the influences of the probe bandwidth and the load on the circuit by its capacitance have to be considered. If, e.g., the circuit under test contains low current CMOS technology, the capacitive load of a passive probe must be observed with special care. Such a capacitance of 13 pF will be a considerable load for this technology with a comparatively small output drive capability; it will cause markedly increased signal delay and rise and fall times. In the last years, modern semiconductor technologies actually strengthened this trend. If the influence of the passive probe's capacitance is too high, the use of an active probe is recommended. The following figure shows 3 curves. The white reference curve as taken with an active probe with an input capacitance of 0.9 pF and the shortest possible ground connection. The yellow curve on channel 1 was taken with the same active probe while this measurment point was additionally loaded with a passive probe, the output of which is shown on channel 2 (blue curve).

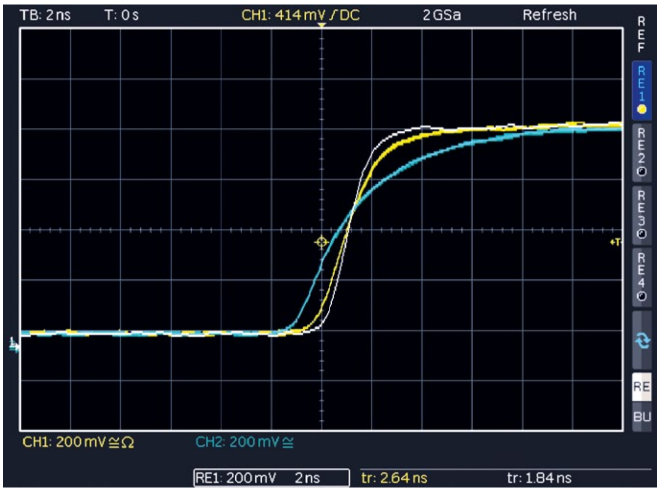


Fig. 4: Influences on a signal by probes

The white curve represents the real signal best with the shortest rise time. The influence on the signal by the passive probe is clearly visible by the difference between the white and yellow curves. The change of rise time from 1.84 ns to 2.64 ns amounts to 43 % and is thus considerable; with some circuits this may cause malfunctions. Looking now at the blue curve, it will be quite obvious that not only was the signal within the circuit affected but also the display on the scope does not reflect the reality. Summing the effects of the probe up the following ground rule can be formulated:

An active probe will yield results which come closest to the true signal at the test point (lowest signal deteriorations). This holds the more true the faster the signal and the more sensitive the semiconductor technology used is to capacitive loads.

As shown in this article, a passive probe will cause various problems for the user who desires correct results. The shortest possible ground connection is a must for good measurement results. Many probes like the HZ355 will come with special ground springs which make short ground connections possible. Many times just a short wire will help. It was also shown that today even standard circuits sport rise times of 1...2 ns. These signals will be strongly affected if a passive probe is used, hence an active probe with an input capacitance of ‹ 1 pF and with an appropriate bandwidth (greater than the scope's) should be used.

Today, active probes with such properties (e.g. HZO30) are available which yield very good results with 0.9 pF and 1 MOhm input resistance. These are available with a BNC connector and an external power supply for less than 700 € and can be used with any oscilloscope.