Application Note: How to Measure Nanosecond Pulses

Related Products: All PicoLAS Short Pulse Drivers

Measuring pulses with durations below several µs is very critical.
This application note gives several hints and "how-to" information.

1. How to estimate the required bandwidth of the measurement set up

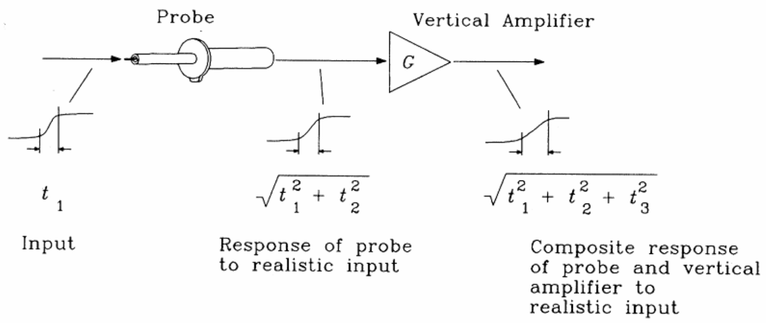
Each element in between the measuring point and the display impairs the signal's rise time. The total rise time thus results from the separate rise times:

$$T_{rise\_sum} = \sqrt{\left(T_1^2 + T_1^2 + ...T_n^2\right)}$$

This formula can only be exact, if the pulse responses of all elements are Gaussian. In all other cases, however, this formula provides a good estimate.
As the preamplifiers of an oscilloscope are not ideal, their amplification decreases above a certain frequency. The point at which the amplification has decreased by 3 dB is called the bandwidth F_{-3dB}.
Typically, the bandwidth F_{-3dB} is given for each element of a measurement system instead of the 10 – 90 % rise time. These two variables can be converted into each other by:

$$T_{10-90\%} = \frac{0.338}{F_{-3dB}}$$

This approximation is only valid if the frequency response of the probe head is Gaussian and a combination of several random poles of the filter, which need to lie close together.



Pictures courtesy of "High-Speed Digital Design, A Handbook of Black Magic" Howard Johnson, Martin Graham, ISBN 0-13-395724-1.

If you use a 200 MHz scope and a 100 MHz probe, you will get:

$$T_{r-scope} = \frac{0.338}{0.2\ \text{GHz}} = 1.69\ \text{ns}\ ,\ T_{r-probe} = \frac{0.338}{100\ \text{MHz}} = 3.38\ \text{ns}\ .$$

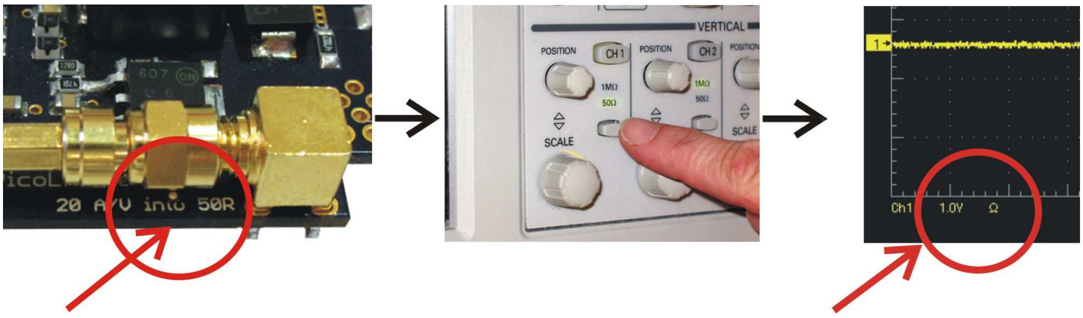
A signal with a slope of 2 ns is thus depicted with

$$T_{measured} = \sqrt{\left((1.69\ \text{ns})^2 + (3.38\text{ns})^2 + (2\ \text{ns})^2\right)} = 4.28\ \text{ns}\ \text{(!!).}$$

Using a 1 GHz scope and a 500 MHz probe for a 2 ns pulse rise you will read out 2.14 ns

2. Make sure that your scope is connected properly and the input is terminated

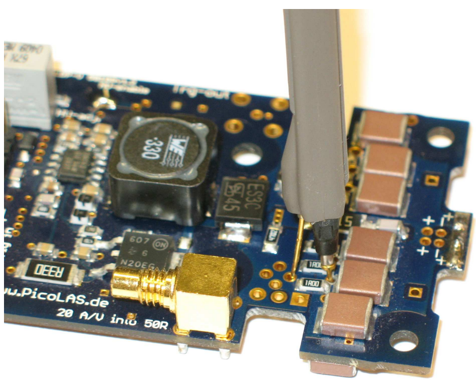
   To measure without probes but with coaxial connections it is strongly recommended to terminate the inputs correctly. Otherwise you will get overshoots, reflections and you will measure with 100% error.



3. Never measure with a grounded probe at the output of PicoLAS drivers

   Most of the PicoLAS products do have floating outputs or they have the switching element in the negative line. If you measure with a grounded probe this may destroy the driver and the probe. Even if not, the ground loop “Driver-Power-Supply-Grid-Scope-Probe-Driver” will cause excessive ringing on the measured signal. This kind of measurements can not be better than educated guesses. Use differential probes instead.

4. Measuring floating signals: Differential probes



   If you want to measure high-frequency floating signals we strongly recommend to use high quality differential probes e.g. Tektronix P7240. Beware: Some of them have an operating limit of only few volts. Don’t destroy them! The voltage across the output connectors is too high for most ultrafast probes!

5. Never measure using the ground clip

If the probe is grounded with its ground clip a parasitic inductance results. This inductance slows down the current rise in the probe.

Furthermore, unwanted magnetic interspersion through the spanned plane can occur as the example of a measurement on integrated electronic components shows. These interspersions are relatively easy to detect: if you short-out the probe with its own grounding clip and then bring it near the measurement point without changing the measuring conditions and without electrical contact, you will measure the interference voltage which the magnetic stray field couples into the ground loop. The coupling inductance results from:

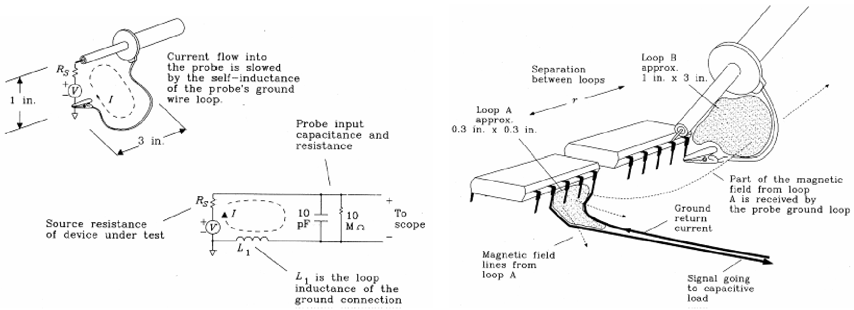
$$L_{coupling} \approx 12.9 \cdot \frac{A_{GND-loop} \cdot A_{Source-loop}}{r^3} \cdot \frac{\text{cm}^3}{\text{cm}^2 \cdot \text{cm}^2} \cdot \text{H}$$

With: $A_{GND-loop}$: area of the ground loop of the probe's grounding,

$A_{Source-loop}$: area of the loop of the source of interference

r : distance of the loops

$L_{coupling}$: coupling inductance between the two loops



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The induced voltage in the ground loop results from:

$$U_{noise} = L_{coupling} \cdot \frac{dI}{dt}$$

With: U_{noise} = induced interference voltage in the ground loop in V

$L_{coupling}$ = coupling inductance of the loops in H

$\frac{dI}{dt}$ = speed of the current's change in the loop of the source of interference in A/s

The only remedy is keeping the area of the ground loop as small as possible. Due to the signal slopes arising in this work, this rules out the use of the ground clip. Instead the exposed metal ground sheath, which reaches almost unto the probe's head, should be grounded directly at the measurement point, e.g. with a very short wire of the blade of a knife.

6. Measuring signals across grounded shunts

If there is a shunt resistor, which is grounded on one side, you can measure the voltage drop across it with a simple trick (picture on left side). Never use the ground clip of your probe.
Beware:
The measured voltage across the resistor contains not only the DC voltage, which you would like to know, but also the parasitic voltage U_{par}:

$$U_{par} = L_{par} \cdot \frac{dI}{dt}$$

Each shunt has a parasitic inductance L_{par}. With a high dI/dt oft the current through the shunt this causes an additional voltage overshoot at the rising edge of the pulse. One might misunderstand this as a current overshoot but not as a mistake with the measurement set up. So always use the corrected measurement outlets of the PicoLAS drivers.