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# Abstract

1 PPS signals are frequently used to physically measure the synchronization quality of timing nodes in general and specifically for PTP nodes. This application note describes the procedure for measuring and comparing 1 PPS (one pulse per second) signals from different sources or different vendors including syn1588® hardware like the syn1588® PCIe NIC.

# Introduction

Every 1 PPS signal of any product is generated internally accurately with the wrap of the seconds. But every 1 PPS signal experiences a delay to the output connector. This delay might be a simple asynchronous path delay inside the IC or FPGA or additionally some clocks due to pipelining and registering the of the 1 PPS signal (e.g. an output register etc.).

Additionally, one has to take into account that the 1 PPS signal is generated with the clock frequency of every hardware clock. This introduces an immanent jitter of +/- half of this hardware clock frequency. For the syn1588® hardware the hardware clock frequency is currently 125 MHz or 8 ns which gives a jitter of +/- 4 ns.

For Oregano Systems' syn1588® products the 1 PPS output path delay is fully compensated.

# Measuring 1 PPS

If one compares 1 PPS signals from different products or vendors one has to take the output delay and jitter into account when performing 1 PPS measurements.

For Oregano systems syn1588® hardware the 1 PPS signal is a 50 ohm signal. If you measure the signal using an oscilloscope

- without any other load one has to set the oscilloscope input to DC 50 ohm
- with another load add a 50 ohm feed-through termination to the T-connector where the oscillator cable connects to the 1 PPS signal.

When one is interested to squeeze out the exact nanoseconds other factors are of importance as well:

- cable length
- DC level
- rise time

Please use identical probes and cables with identical length when measuring 1 PPS signals. Typically, a cable length difference of 1 m introduces a delay of approx. 5 ns depending on the type of the cable (e.g. standard 50/75 ohm coax cable). Note, that a cable delay can be compensated in the input de-skew settings of the oscilloscope.

syn1588® products use 3.3 V 50 ohm signaling for the 1 PPS signals. Other products may use other voltage levels (e.g. 5 V TTL etc.).

syn1588® products use latest technologies. Thus, the 1 PPS signals own steep edges with a rise time less than 1 ns. This might differ from 1 PPS signals from other vendors. Use active probes for the measurement with a band width of at least 2 GHz (of course same is true for the oscilloscope's input channel).

The following figure shows an example of such a measurement.


**figure 1. 1 PPS measurement**

# Statistics vs. Single Measurement

In order to rate the quality of the synchronization we suggest not to use just a single measurement but to run several measurements and perform statistics:

- average
- min/max
- standard deviation

Using this method one can check whether a node is perfectly locked to a master or it jitters because of network load or network switch devices that are not IEEE1588 capable. Even if the average offset might be high due to different device structure the standard deviation can be very small flagging a good synchronization.

 

The following figure shows an example of such a measurement with statistics.


**figure 2. 1 PPS measurement with statistics**

# Interpreting Results

The recommended way to interpret the 1 PPS measurement results is to compare the offset to the master reported by the software (e.g. the syn1588® PTP Stack) against the measured average of the 1 PPS signals. The difference shall origin out of the different output delays of the 1 PPS signals.

For rating the quality of a synchronization one shall use the standard deviation. While the absolute measured offset of the 1 PPS signals might be quite “large” due to above mentioned delays, (compared to the actual offset) the standard deviation of the 1 PPS signals shall be very small. The expected value for the standard deviation is one clock period if a point-to-point network connection or a PTP aware network is used. If one uses standard Ethernet switches their delay variation contributes to the jitter and thus increases the standard variation.

 

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