White Paper

PTPv2 Holds Data Acquisition and Testing to a Tight Schedule

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Over the last few decades, many different timing mechanisms have been used to synchronize the operation of data acquisition and test & measurement devices. However, for synchronizing the operation of distributed systems, using the established Ethernet infrastructure is essential because it offers high flexibility and ease of use at a relatively low cost. Ethernet is the *de facto* worldwide standard for machine-to-machine or human-to-machine communications. Even mobile devices like smartphones and vehicles can be linked to Ethernet-based networks through mobile telecom networks. The IEEE1588:2008 Precision Time Protocol (PTPv2) was developed to support highly accurate time synchronization in distributed data acquisition and test & measurement applications.

In test & measurement applications, highly accurate time-stamped signal inputs representing the same physical process captured at the same moment play an important role in qualifying and analyzing measurement data in real time or during post-processing mode.

Absolute Time vs. Relative Time

Absolute time accuracy is needed when measurement data needs to be mapped to a specific real-world event or when two or more data acquisition systems are not on the same network. An example in which absolute time might be relevant would be when it's essential to monitor the load influence of a train crossing a bridge and identify the train to support further actions such as issuing an overload warning. The absolute time is explicitly available when it is represented by a clock.

Most test & measurement applications or processes can use a relative system time, particularly when a test is reproducible and what matters most is the relative timing of the signals to each other. Sometimes, time accuracy can be confused with reaction, latency or real time. Real time refers to deterministic behavior—a "decision" or "response" that needs to be done within a specific time frame and is used mainly in control or automation tasks (sensor -> control algorithm -> reaction/actuator).

Time latency must be taken into account when designing control algorithms or when a response is needed within a given maximum time. Real-time control applications normally require fixed and very low time latency from sensor to controller. For non-deterministic protocols like Ethernet TCP/IP, CANbus or any PC-based activity, time latency is variable. Time latency also plays a role when data is streamed to a real-time controller for monitoring purposes in case the time stamp sent with the data value is not or cannot be considered.

Hardware- vs. Software-based Time Stamping

PTPv2 is based on Ethernet. Unlike Network Time Protocol (NTP), PTPv2 is embedded in the physical layer, which allows for true hardware-based time stamping for precise time synchronization of all participants in an Ethernet network. The main difference between hardware- and software-based time stamping is the synchronization accuracy achievable. With software-based time stamping (used in NTP, for example), slave synchronization accuracies down to 100 microseconds are possible in small networks but are more typically on the order of 1 millisecond. In contrast, with hardware time stamping, it is possible to achieve time synchronization accuracy down to 100 nanoseconds. However, to obtain this level of accuracy, the network topology such as switches and slave hardware must support hardware time stamping.

How PTPv2 works

PTPv2 is a relative time sync mechanism. One participant is selected to work as the master clock, which delivers time sync messages to all slaves. The sync process starts with a time sync telegram to the network. All participants (slaves) calculate the time difference (delay) between their local time and the given master clock and adapt step by step to a time difference less than 2µs.

PTPv2 Applications

PTPv2 offers some major advantages over other synchronization methods for a wide range of data acquisition applications:

- PTPv2 supports time synchronization between different device types from different vendors via a standardized protocol.
- It allows for large distances between data acquisition modules.
- It supports synchronization of different product lines from the same manufacturer with each other. For example, HBM's QuantumX, SomatXR and GENESIS High Speed systems offer PTPv2 synchronization and can work together to enable data acquisition in both distributed applications in harsh environments and in lab settings with hundreds of channels and high speeds.
- It ensures high time accuracy (in the sub-microsecond range) between all participants when working with high data rates.
- It provides for simple, administration-free setup, including automatic master selection, high robustness, and a continuous time scale with no "jumping" time stamps and no rollover.
- When necessary, it supports absolute timing. A Grandmaster Clock based on GPS can be integrated to serve as an absolute time source when one or more data acquisition systems are not in the same network but the resulting data needs to be analyzed quickly.

A variety of applications highlight the advantages that PTPv2 time synchronization offers. For example, it allows data gathered from widely distributed data acquisition modules **(Figure 1)** to be used to study complex interactions, such as braking dynamics and structural stability of large ground transportation vehicles, such as trains and construction equipment.

Operators of today's complex electrical power grids use time-tagged measurements of voltage and current throughout the power grid to monitor and control grid performance. PTPv2 synchronization allows operators to monitor the relationships between voltage and current due to reactive loads, compare the phase at two voltages that might be connected together to divert power from one part of the grid to another, or monitor the harmonic content of the signal. Often, important data is aggregated from multiple data acquisition locations, which must be synchronized so that the data can be directly compared in time.

Systems that support PTPv2 are also well suited for monitoring of the stability of large engineered structures such as bridges, towers, or wind turbines using GPS-based absolute time signals.

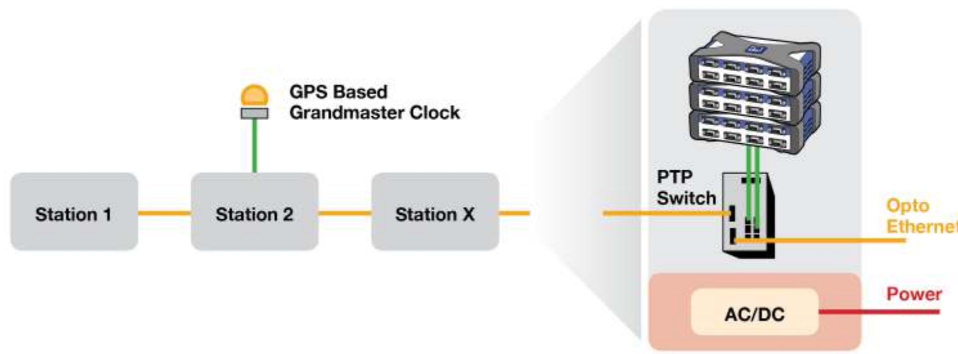

Figure 1. *A widely distributed topology based on the modular QuantumX data acquisition system, which is capable of acquiring signals from any type of analog sensor. They are widely used in mobile applications because their universal inputs provide maximum interference suppression for the acquisition of strain, force, displacement, acceleration, rotational speed, pressure, temperature, voltage and current.*

PTPv2 is also invaluable for synchronizing data produced by distributed data acquisition modules during ground-based testing of the structural reliability of new aircraft components. It also supports synchronizing data acquired under the control of a flight simulator using so-called "iron birds" or systems integration test benches. By using an iron bird as a testbed, data from various measurement sensors is synchronized and recorded for later analysis. An iron bird can be "flown" like a standard aircraft from a simulated flight deck, with a computer generating the aerodynamic model and environmental conditions like air density, air temperature, airspeed and Mach number. Aeronautics engineers use these engineering tools to incorporate, improve and validate vital aircraft systems, including electrical and hydraulic generation and flight controls. Iron birds allow these engineers to confirm the characteristics of all system components during early development stages and discover any incompatibilities that may require redesign or modifications. Engineers study electrical switching with variable interruptions and times to assess their impact on the computers and other components; the complete system assembly is also tested to gauge the effects of electromagnetic interference.

PTPv2 is equally suitable for hybrid applications **(Figure 2)** that combine high speed acquisition with high channel counts, such as for dynamometer testing of new electric or gas/electric hybrid vehicles. For example, one automotive industry customer has used HBM's GENESIS high-speed data acquisition system to acquire voltage and current data in sync with the modular mid-speed QuantumX system used to acquire dozens of channels of mechanical and thermal sensor data. GENESIS systems are widely used for high-speed data acquisition and transient recording because they can be configured with from 4 to 4,320 channels with sampling rates from 20 kS/s to 100 MS/s per channel. They support continuous direct-to-disk streaming at up to 200 MB/s. "Copper bird" testing of an aircraft's electrical grid is another example of the use of a hybrid architecture that depends on PTPv2 synchronization.

Hybrid systems are widely used in on-board vehicle testing or monitoring applications that employ high-speed cameras in combination with wheel force transducers, other data sources, and analog or digital vehicle bus data. For these applications, the ability to combine high acquisition speed and high channel counts is essential.

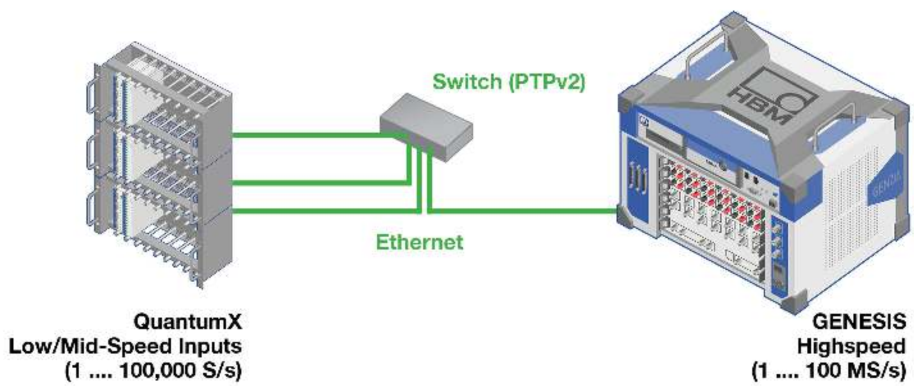

Figure 2. *A hybrid data acquisition system that combines the high speed of a GENESIS system with the high channel count capability of a QuantumX system.*

Conclusion

To learn more about how PTPv2 can help you synchronize your test & measurement and data acquisition applications more effectively, download a free IEEE1588:2008 Precision Time Protocol in Data Acquisition and Testing Tech Note, available from HBM, Inc.

About HBM, Inc.

For more than 65 years, the name HBM has stood for reliability, precision and innovation all over the world. HBM offers products and services for an extensive range of measurement applications in many industries. Users worldwide rely on the perfectly matched components of the measurement chain that guarantees maximum accuracy of measurement results and enables optimization of the complete product life cycle, from the development through the testing stages, as well as in manufacturing and production. Their product range covers sensors, transducers, gauges, amplifiers and data acquisition systems as well as software for structural durability investigations, tests and analysis. The potential fields of application can be found in every branch of engineering in both virtual and physical test and measurement.

HBM has 27 subsidiaries and sales offices in Europe, America and Asia. HBM also has representatives in another 40 countries around the world. In addition to headquarters in Darmstadt, Germany, other HBM production facilities are located in Marlborough, Massachusetts, and Suzhou, China.