

Scope

This document applies to Prosilica GT cameras using a firmware version below 01.54.11026.

For higher firmware versions, please see

https://www.alliedvision.com/fileadmin/content/documents/products/cameras/various/appnote/GigE/PTP_IEEE1588_with_Prosilica_GT_GC_Manta.pdf.

Description

IEEE1588 Precision Time Protocol (PTP) manages clock synchronization of multiple devices across an Ethernet network. Once the clocks of devices such as cameras, PCs, and sensors are synchronized, future software based triggers can be synchronized within 2 μ s.

Background

PTP was designed to improve on existing clock synchronization methods such as Network Time Protocol (NTP) and Global Positioning System (GPS). NTP suffers from poor accuracy, often quoted to be several milliseconds using a fast Ethernet network. GPS provides nanosecond precision using atomic clock and satellite triangulation; however, it is an expensive component to incorporate into a camera.

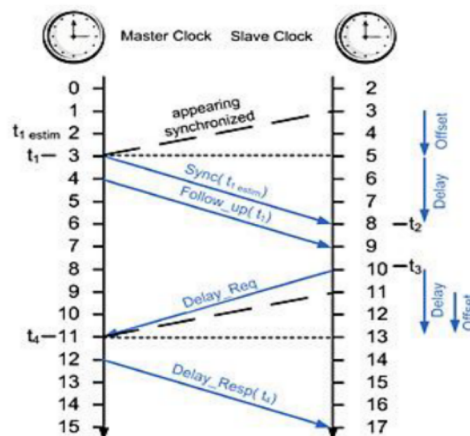
PTP provides microsecond precision without increasing component cost, providing better accuracy than NTP at a lower cost than GPS.

The GigE Vision 2.0 standard includes IEEE1588 to ensure compatibility amongst machine vision hardware and software vendors into the future.

How is PTP synchronization achieved?

Synchronization begins when the device configured as the Master PTP clock transmits a “Sync” telegram using multicast messaging. Devices configured as Slave PTP clocks calculate the time difference between their clock and the Master PTP clock and adjust accordingly.

Slave clock frequencies are constantly adjusted, through follow up and delay messages, to keep their clock value as close as possible to the master clock. While all Slave clocks are within 2 μ s of the master, PTP sync is achieved.



Network topology

Achieving PTP sync between multiple devices requires that all devices be on the same network/subnet. This restriction is due to the current inability of any network card hardware to forward PTP sync multicast packets between ports within the 2 μ s requirement.

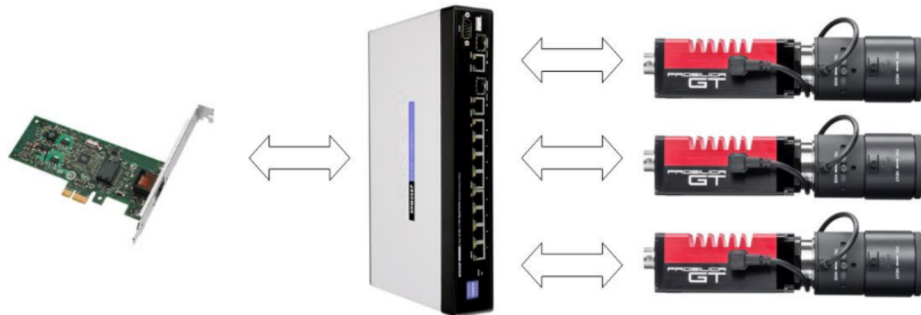


Figure 1: Multiple cameras on a switch

Therefore, all devices must be connected to a single port through a switch. Note that the total amount of bandwidth from all cameras must not exceed 125 MB on a single GigE connection, or packets will be dropped. Use StreamBytesPerSecond to reduce the bandwidth for each camera.

Users of Allied Vision cameras requiring full GigE bandwidth from multiple cameras are encouraged to use a switch with a 10 GigE uplink and 10 GigE NIC on the host.

Enabling PTP synchronization with Prosilica GT cameras

PTP is enabled with the camera PtpMode attribute. Once a device's PtpMode is changed to Master, Slave, or Auto, synchronization of devices on the network begins to occur provided there is at minimum one master.

PtpMode = Off

This camera's clock is not synchronized with any other device. This is the traditional functionality of a GigE camera. This is the factory preset PTP Mode on Allied Vision GigE cameras.

PtpMode = Master

This camera's clock is the master clock. All other PTP enabled slave devices synchronize their clock to this camera.

PtpMode = Slave

This camera's clock is altered to align with a Master device's clock.

PtpMode = Auto

This camera uses the IEEE1588 best master clock algorithm to determine which device is master, and which devices are slaves. It may be assigned as either.

Determining the status of PTP synchronization

All Allied Vision cameras' device clocks are represented by the TimeStampValue attribute.

TimeStampValue is divided into TimeStampValueHi and TimeStampValueLo.

The period of each TimeStampValueHi count is ~ 4.295 seconds, the period of every TimeStampValueLo count is 1 nanosecond. Note: the actual resolution of Allied Vision cameras is 100 nanoseconds.

Synchronization is complete on all devices when all TimeStampValues are equal to the Master TimeStampValue, and no device's PtpStatus = Syncing, or PtpStatus = Error. PtpStatus is a read only attribute.

PtpStatus = Off

The device PtpMode is set to off.

PtpStatus = Master

PTP synchronization achieved. This device is acting as the master clock in the PTP network.

PtpStatus = Slave

PTP synchronization achieved. This device is acting as a slave to another device's master clock.

PtpStatus = Syncing

PTP synchronization not yet achieved but synchronization between master and slave(s) has started.

PtpStatus = Error

PTP synchronization was previously achieved and has now failed.

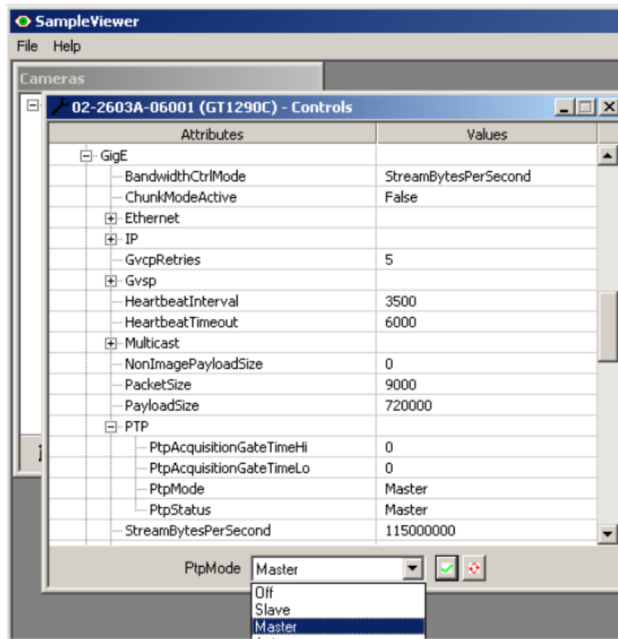


Figure 2: PtpMode attribute in AVT SampleViewer

PTP event callbacks

In addition to PtpStatus, Allied Vision PvAPI users can use event callbacks to determine when synch is achieved, and if synch is ever lost. This is superior to polling PtpStatus.

```

Press 'q' to quit or 't' to set PtpAcquisitionGateTime.
Cam[1]: 169.254.211.186 [GT1290C] opened
Cam[1]: PtpMode = Off.
Cam[1]: PtpStatus = Off
Cam[1]: PtpMode = Auto.
Cam[1]: Waiting for EventPtpSyncLocked
Cam[1]: PtpStatus = Syncing
Cam[2]: 169.254.22.193 [GT2750C] opened
Cam[2]: PtpMode = Off.
Cam[2]: PtpStatus = Off
Cam[2]: PtpMode = Auto.
Cam[2]: Waiting for EventPtpSyncLocked
Cam[2]: PtpStatus = Syncing
Cam[1]: PtpStatus = Syncing
Cam[2]: PtpStatus = Syncing
Cam[1]: PtpStatus = Syncing
Cam[2]: PtpStatus = Syncing
Cam[1]: PtpStatus = Syncing
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Cam[2]: PtpStatus = Syncing
Cam[1]: PtpStatus = Syncing
Cam[2]: PtpStatus = Syncing
Cam[1]: PtpStatus = Syncing
Cam[1]: ***EventPtpSyncLocked
Cam[2]: PtpStatus = Syncing
Cam[2]: ***EventPtpSyncLocked
Cam[1]: ***EventAcquisitionStart
Cam[1]: AcquisitionStart success
Cam[2]: ***EventAcquisitionStart
Cam[2]: AcquisitionStart success
Cam[1]: Frame: [1] TimestampHi: [25] TimestampLo: [2162209400]
Cam[2]: Frame: [2] TimestampHi: [25] TimestampLo: [2162209500]

```

Figure 3: Output of running the EventCallbackPTP sample code

PTP synch failure

In the event that a slave device clock drifts more than 2 μ s from the master, PtpStatus is set to Error and a EventPtpSyncLost callback is sent (if setup).

The device must manually be reset to PtpMode = Slave/Auto. This is an intentional design choice – it is important for any application relying on Ptp synch to know if synch is lost.

The cause of a Ptp synch failure may be related to a network hardware component’s inability to forward multicast synch packets successfully within the 2 μ s required time.

Executing a synchronized scheduled software trigger

Once all device clocks are synchronized, it is possible to issue a future simultaneous software trigger event to all Allied Vision cameras using the PtpAcquisitionGateTime attribute.

Follow the steps below to enable a synchronized scheduled trigger on multiple GT cameras:

1. Achieve clock synchronization. Set PtpMode = Master, Slave or Auto.
2. Set camera FrameRate, FrameStartTriggerMode, and AcquisitionMode as desired (some possible scenarios listed below).
3. Call AcquisitionStart() to start an acquisition stream.
4. Determine the current camera TimeStampValue using TimeStampValueLatch.
5. Set PtpAcquisitionGateTime to a value which sufficiently exceeds the current camera TimeStampValue.

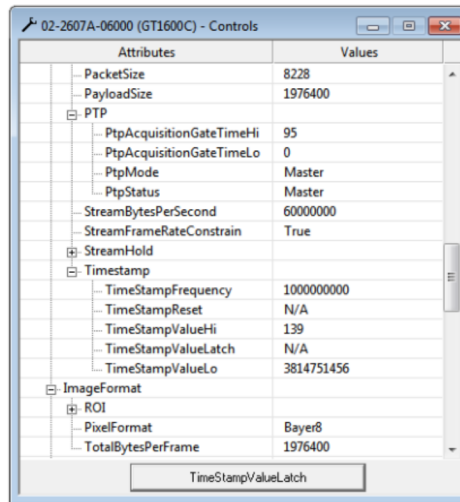


Figure 4: PTP attributes in the SampleViewer

Calculating values

- $PtpAcquisitionGateTime = Current\ TimeStampValue + \Delta$
- Δ = At minimum, the combined time required to set PtpAcquisitionGateTime on each camera. This time will vary depending on OS, host, network hardware, and system load.

Setting PtpAcquisitionGateTime will suspend all frame triggers in a camera's current AcquisitionStart() stream until $TimeStampValue \geq PtpAcquisitionGateTime$, at which point frame triggers will resume.

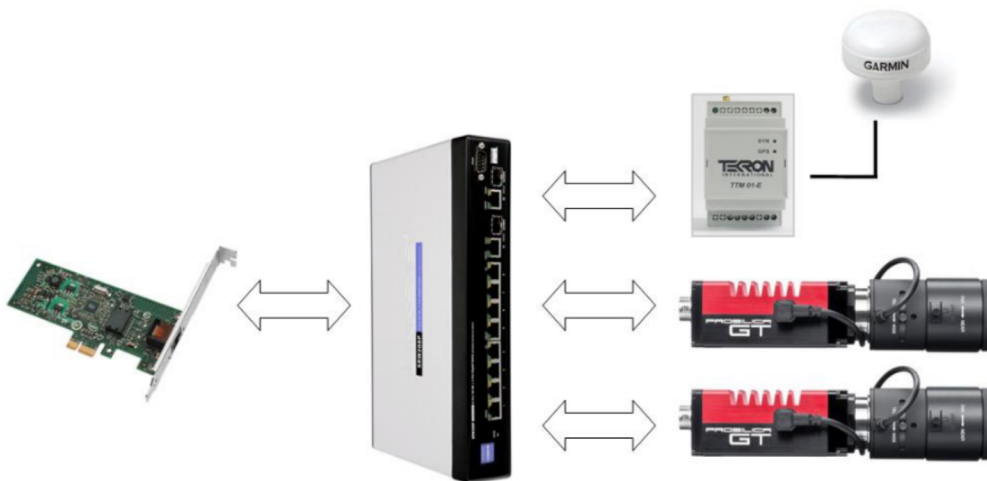
Typical use cases

Fixed frame rate Synchronization

- Synchronize camera clocks.
- Set FrameStartTriggerMode = FixedRate on all cameras.
- Set FrameRate to the same value on all cameras.
- Set PtpAcquisitionGateTime the same for all cameras and greater than existing TimeStampValue.

When the camera TimeStampValue increments to the PtpAcquisitionGateTime, all cameras will start imaging synchronously at the configured frame rate. Reading the TimeStampValue contained in the image header will verify this synchronization.

Precision timing by using GPS



Allied Vision cameras can be synchronized to a GPS timer, allowing “real world time” synchronization. Configure PtpMode on all of the cameras to Slave or Auto. In Auto, the IEEE1588 best master clock algorithm will elect the GPS clock as the master. Each camera will synchronize to the GPS master clock.

Validating the synchronization accuracy of PTP

Method 1

PvApi users can view the TimeStampValue associated with any given frame through the tPvFrame->TimestampLo

A total of 4 Allied Vision cameras were connected and set up in the following way.

All cameras were configured to FrameStartTriggerMode = FixedRate, FrameRate = 1 fps

PtpMode on one camera was set to Master, PtpMode on other three cameras set to Slave

The same PtpAcquisitionGateTime was uploaded to all the cameras using approach shown in Case 1

The Graph below shows a histogram of the calculated offset between the recorded Master camera frame TimeStampValue and the TimeStampValue of the Slave cameras' EventSynclnRise. The data presented is compiled from 69 hours of continuous operation. The maximum offset recorded was less than ± 1 us. This means that in this test, the timestamp of our three Slave cameras were synchronized to within 1 us of the Master camera.

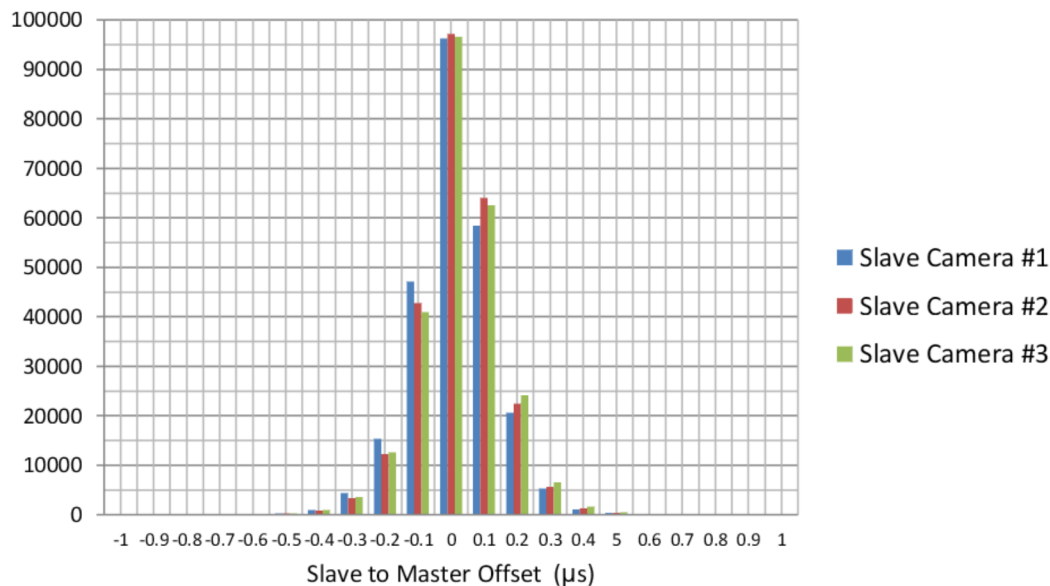


Figure 6: Histogram of Slave to Master Offset

Method 2

To measure PTP accuracy in a different way we can use an oscilloscope and probe output triggers from multiple cameras. Two cameras were connected and setup in the following way:

- All cameras were configured to FrameStartTriggerMode = FixedRate, FrameRate = 15 fps .
- PtpMode on one camera was set to Master, PtpMode on other camera set to Slave.
- The same PtpAcquisitionGateTime was uploaded to all cameras using approach shown in Case 1 .
- The SyncOut signals on both cameras were set to Strobe1, Strobe1ControlledDuration = On, Strobe1Duration = 10 us, Strobe1Mode = FrameTrigger.
- The SyncOut signals were monitored on an oscilloscope and viewed over a period of time.

The capture below shows the readout from the oscilloscope when monitoring the SyncOut signals from both cameras. In the image below, channel 1 is approximately 125 ns offset from channel 2. This shows that the TimeStampValue synchronization between the two cameras is approximately 125 ns apart.

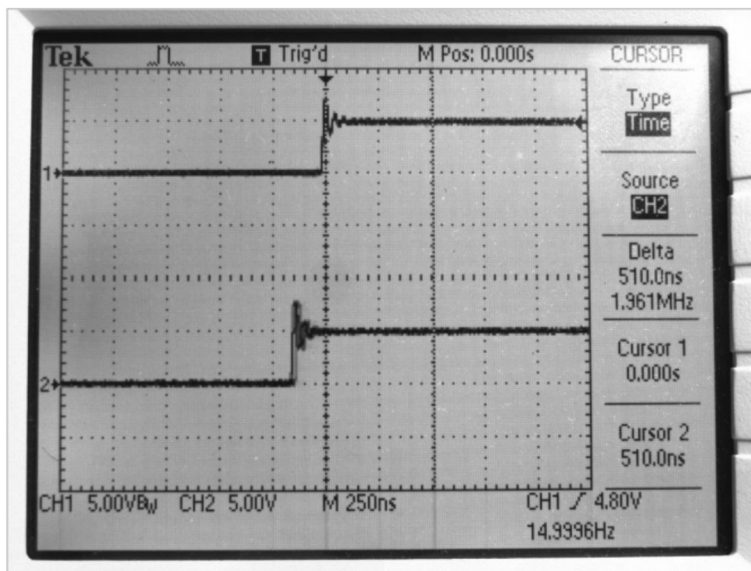


Figure 7: Scope Image of Oscilloscope showing trigger waveforms

Frequently asked questions

Question

Can I use a host driven, software-based PTP clock?

Answer

Allied Vision has tested the possibility of using a PC based, PTP software clock to synchronize cameras across multiple adapters. In the process we discovered that using a host driven master clock on a non real time operating system such as windows or linux generated very poor synchronization plagued by significant jitter between the timestamp of cameras. This approach may be sufficient for some applications but it does not generate the precise time synchronization we hope to achieve using PTP.

Question

How do I translate TimeStampValue to real world time?

Answer

Each TimeStampValueHi count is approximately 4.295 seconds, the period of every TimeStampValueLo count is 1 nanosecond, TimeStampValue frequency is 1 Ghz. You can use this to determine the value in seconds that the TimeStampValue represents. To associate this with real world time a GPS master clock needs to be used in the PTP network. Alternatively, you can reference the latest TimeStampValue to the PC clock however this will suffer from significant jitter.

References

Download Prosilica GT documentation, including the technical manual and features descriptions at <https://www.alliedvision.com/en/support/technical-documentation/prosilica-gt-documentation.html>.

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