WHITEPAPER

Latency for Situational Awareness and Driving Applications

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Introduction

Video transmission plays an important role in military ground vehicle local situational awareness (LSA) and driver vision enhancer (DVE) applications. Uncompressed low latency video provides crew members with access to real-time information to enhance decision-support capabilities and reduce cognitive burden while improving crew safety and vehicle operations.

SWaP: Size, weight, and power demands in vehicle retrofit and new design requires the use of small footprint, lower power computing and cabling.

COTS: Global military standards encourage the use of commercial off-the-shelf computing and networking technologies.

Useability: An end user-focused approach to design ensures systems are easy to use and reduce cognitive burden.

In a typical scenario, a crew commander and driver must navigate a heavy ground vehicle through unknown terrain. For DVE and LSA applications, data delays could cause sensory discomforts, such as motion sickness and confusion, resulting in hesitance, vehicle collision, or fatal inaccuracies as a crew navigates on-path obstacles and threats.

Supporting these applications in both new vehicle and retrofit design requires an open architecture, multi-vendor approach that networks multiple endpoints, including cameras and sensors, with displays and processors. System designers must also comply with global military standards, such as Def Stan 00-082 (VIVOE), STANAG 4697 (PLEVID), and MISB ST 1608, that include video performance requirements to help ensure future scalability and ease-of-use.

Military vetronics systems require high-quality, real-time low latency imaging data as a critical component to reduce cognitive burden and increase mission effectiveness. Latency performance data is a key metric to consider when determining how quickly a system can process, analyze, and display images. This document discusses Pleora's test bench set-up and results with regards to military vetronics and the Pleora RuggedCONNECT Smart Video Switcher.

Latency

Rather than defining latency figures that apply for select components of the system, or only in ideal situations, glass-to-glass measurements focus on understanding the end-to-end latency to provide an overall view of expected system performance. This metric is prudent and will be compared to latency performance benchmarks as set by military organizations and other studies that define the highest latency tolerated for military driving applications. The threshold mean for lag detection is 147.64 milliseconds (ms), and the median is 130 ms. (Moss, Muth, Tyrrell, & Stephens, 2010)

System latency, glass-to-glass latency – also called photon-to-photon or end-to-end, provides relevant performance data for end-users by measuring the time between a scene change in front of a camera and when that scene change is reflected on a display.

Several factors contribute to latency. There is a misconception that video over an Ethernet port using GigE Vision may be insufficient. This is easily overcome with minimal configuration changes to the network and protocol architecture and I/O mechanisms. While a system has an overall activity, from trigger event to output signal, the system itself consists of a number of internal events usually occurring serially. It is important to remember that in glass-to-glass applications, latency is impacted by camera choice, monitor refresh time, and data processing. Host computer and resource sharing -- including buses, memory, CPUs, operating systems, core imaging and graphics libraries -- will also have a substantial impact on latency.

In the context of this document, glass-to-glass latency will be referred to as 'latency' and is used to illustrate system latency as a measurement.

Reducing Latency

CPU usage required for software tasks is often an overlooked element in measurement testing, therefore it is pertinent that all CPU requirements are considered by the user when analysing latency performance. The host computing platform receiving images from networked imaging devices will have to share processing time between all of the services on that PC.

Latency can easily be introduced by devices and software that place a high processing overhead on the CPU. In addition, latency is impacted by variants in camera exposure and readout time. End-users must consider the implications of camera exposure when a free running analog camera is in use, as average processing time performance will differ based on the camera's frames per second (FPS).

Given that latency is a measurement of the time delay observed between the input to a system and its output, high-performance implementations can optimize packet handling processes on both the transmit and receive ends of a link to meet end-user latency needs. Point-to-point applications with a dedicated connection between an imaging source and computing port should be configured specifically for relatively low latency.

Glass-to-glass latency can be broken down into roughly the following major components, as illustrated in Figure 1.

Sensor:
- Exposure time
- Integration time
- Readout time

Camera Video Interface:
- Grab, packetize and transmit
- On Ethernet link

PC or FPGA Reception:

- De-encapsulate and reconstruct image
- Copy image to user application (PC ONLY)
- Colorspace conversion
- Write to display memory
- Transfer to monitor

Display:

- Monitor refresh

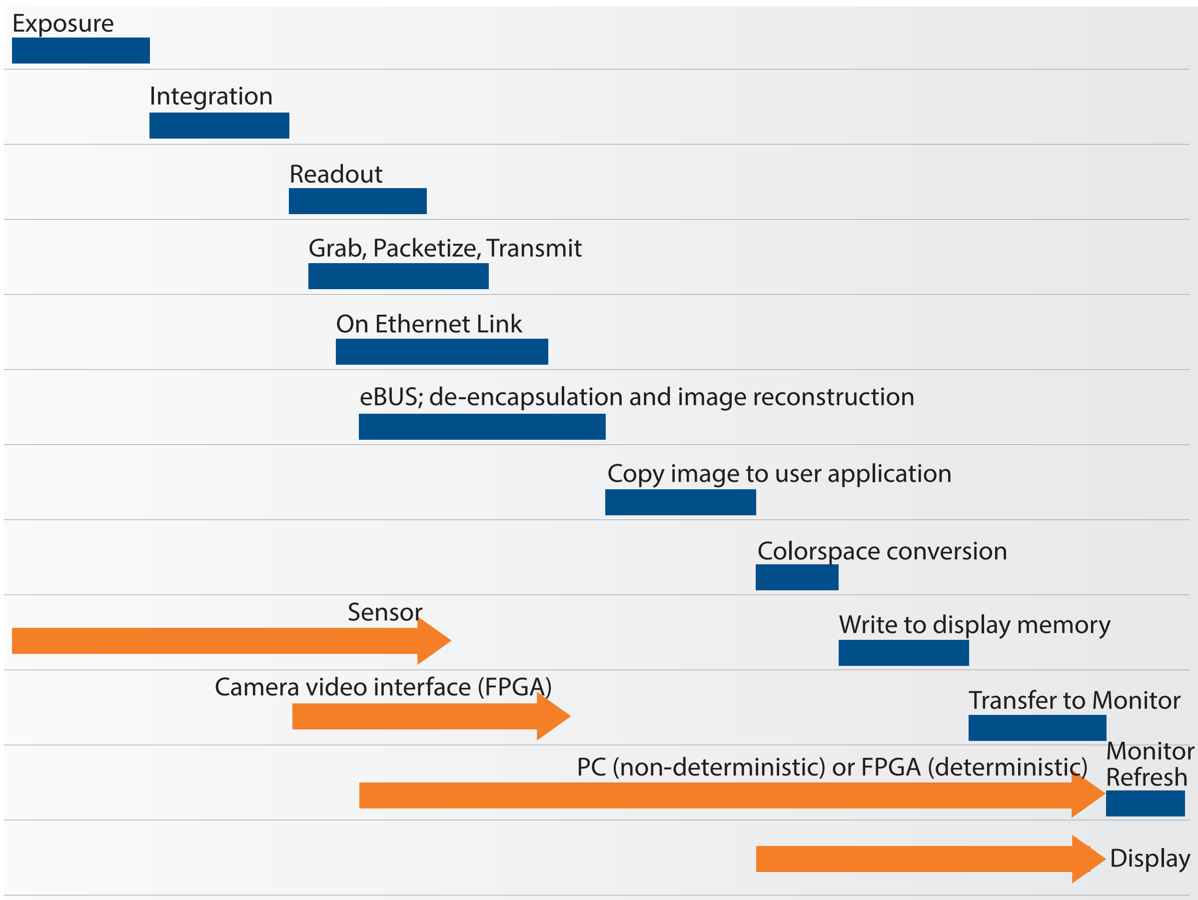

Diagram 1: Elements for potential glass-to-glass latency in a GigE Vision imaging system

In comparison, complex vision applications that rely on switches to interconnect multiple imaging sources and endpoints introduce various opportunities for delay. To help meet application requirements, Pleora's RuggedCONNECT Smart Video Switcher is designed with four video output modes for different levels of deployment flexibility and latency performance. This solution supports multiple sensor and display configurations, including basic sensor, display, or network-only processing units. System integrators can select the appropriate mode for their design needs, ultimately ensuring a glass-to-glass measured latency of less than 71 ms. This approach allows scalability to build larger scale video switching systems through Ethernet by combining multiple units in a system while providing flexible choices on how video is transmitted and displayed.

Test Bench Set-Up

To calculate the latency between the RuggedCONNECT device and a display, Pleora measured the difference in time from the triggering of an LED to the display of the light output on the monitor (Figure 2). Each measurement was conducted by connecting a photosensor circuit and a LED circuit to an oscilloscope. The photosensor circuit was placed in front of the monitor to capture the change in image displayed. The LED pulsed in front of the camera's lens, from this, pulses were measured on the oscilloscope to determine the latency from when the LED was pulsed in front of the camera until it was displayed on the monitor screen, then captured by the photosensor.

Figure 2 illustrates the following test set-up and sequence:

1. An LED is triggered by a pulse generator
2. An analog camera captures the light and the RuggedCONNECT receives the image.
3. The RuggedCONNECT outputs the image using one of the output modes (HD-SDI output, software-defined Video over Ethernet, or video signal passthrough).
4. The video is displayed on the monitor.
5. When the flash of the LED appears on the monitor, a photosensor is triggered.
6. An oscilloscope measures the difference in time from the generation of the original pulse to the capture of the light output.

The test was run for a four-hour period and the average latency measurements were obtained. The tests ensure that the measured results were reliable and repeatable. The pulse generator used during this test generates a square wave with a 1 Hz frequency. The oscilloscope used was model number DP7254. The camera used was a NTSC analog camera supporting 30 FPS.

It is important to remember that latency performance is imperative in any application where a human is taking action or making critical decisions based on what or when data or images are displayed. For example, real-time, low latency imaging is vital for military vetronics DVE and LSA applications.

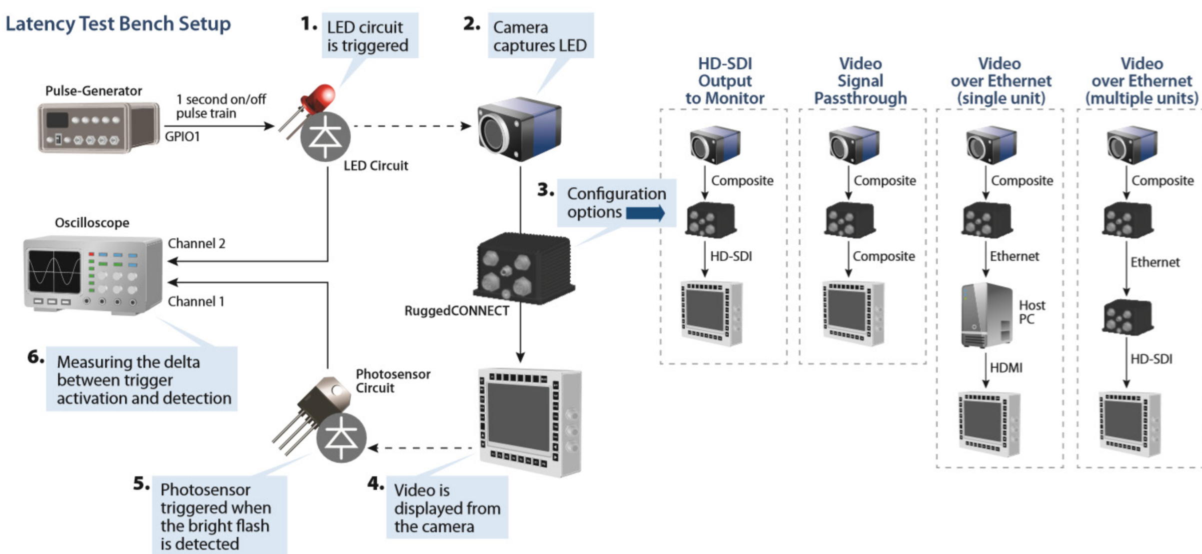

Diagram 2: Glass-to-glass latency test setup and sequence

The measured latency for all video output modes on Pleora's RuggedCONNECT was less than 71 ms; well below the performance requirements set by military organizations for driving applications. GigE Vision (video over Ethernet) adds very little latency to the overall video switching system (Figure 3). The video signal passthrough mode offers the lowest introduced latency between the camera and the display, ensuring proper response times and avoiding motion sickness for driving systems. This same architecture enables Pleora to add more interfaces, support a different mix of interfaces, additional network interfaces, and general communications ports, to enable a highly configurable architecture with redundant capabilities.

Configuration Options

The RuggedCONNECT supports the following output modes:
HD-SDI Output to Monitor. With this mode video is output using Pleora's optimized, low latency display drivers to the HD-SDI output port on the RuggedCONNECT. Video processing and AI can be used in this mode.

Video Signal Passthrough. This is the lowest latency mode on the RuggedCONNECT. With this mode the original signal is passed directly through the RuggedCONNECT with no video buffering or processing. This mode is ideal for driver and crew DVE and LSA applications, where ultra-low latency is required

Video over Ethernet (single unit). With this mode the RuggedCONNECT outputs video over an Ethernet port, using GigE Vision. Video processing and artificial intelligence (AI) can also be used in this mode.

Video over Ethernet (multiple units). With this mode there are 2 RuggedCONNECT devices outputting video over an Ethernet port, using GigE Vision. Video processing and AI can also be used in this mode.

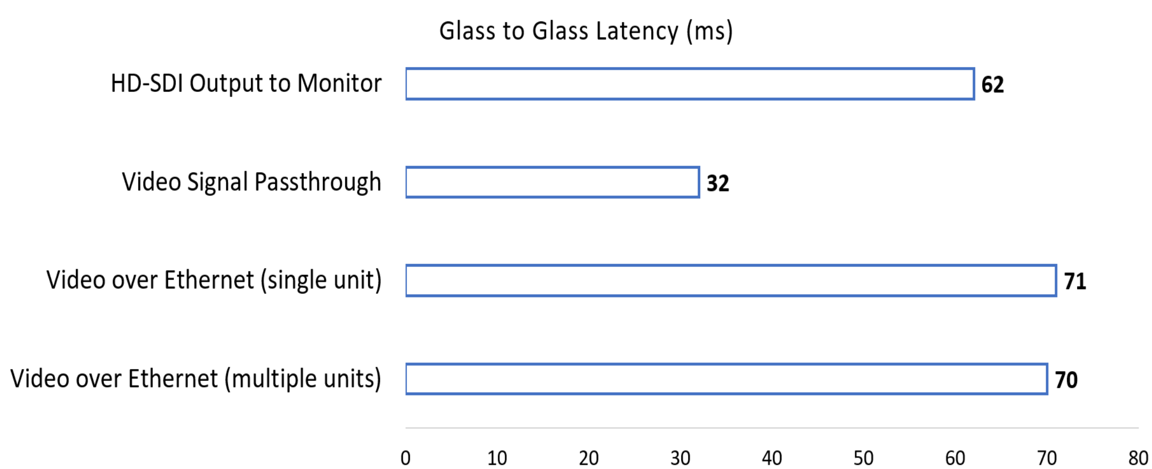

Diagram 3: Measured latency for all video output modes on Pleora's RuggedCONNECT

Conclusion

System latency is a critical aspect to many network-based vision applications, including military vetronics, factory automation, diagnostic imaging, and more. There is a misconception that system latency is insufficient while using GigE Vision over a network for some applications.

Based on the benchmarks for each of the configuration options, a summary is provided below for recommended use case.

Video signal passthrough: for drivers, where the lowest latency is required.

HD-SDI output to Monitor: for the crew commander and rest of crew, where cabling distance is not an issue.

Video over Ethernet (single): for the crew commander and rest of crew, where cabling distances and complexity is challenging.

Video over Ethernet (multiple): for more complex video switching systems where multiple inputs and outputs are required, affecting cabling and overall system complexity.

GigE Vision has already been proven and adopted as the de facto standard for cameras in challenging machine vision environments for low latency video analysis. Our results show that with the right configuration, optimizations and hardware, GigE Vision can be used reliably for mission critical applications in DVE and C4ISR.

The benchmarks in this paper prove that Pleora's RuggedCONNECT Smart Video Switcher meets latency benchmarks set by military organizations and other studies for military vetronics applications, while providing the flexiblity in choosing the right video transport outputs depending on the use case in a distributed, scalable video switching architecture.

Resources

Jason D. Moss, Eric R Muth, Richard A. Tyrrell, Benjamin R Stephens, (2010) Perceptual thresholds for display lag in a real visual environment are not affected by field of view or psychophysical technique, Department of Psychology, Clemson University

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