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// WHITEPAPER

CSI-2, FPD-Link III, GMSL-2: Choosing the right vision technology for drones

Advanced camera technology for drones

In no other industry the reliability and security of machine vision systems do play a more pivotal role than in the sensitive landscape of defense technology. Operational capabilities and mission success highly depend on the quality and stability of the technologies used.

Cameras for defense vehicles such as unmanned ground vehicles (UGVs), autonomous underwater vehicles (AUVs), and unmanned aerial vehicles (UAVs) are subject to space constraints and rough use. They not only have to be small, light, and power efficient, but they must also operate reliably under harsh conditions.

This whitepaper will give an overview of typical drones technology. By comparing cameras with CSI-2, FPD-Link III and GMSL2 interfaces that meet their unique needs, this paper aims to inform and guide stakeholders in the development and implementation of effective drone-based solutions. This includes a deep explanation of the similarities and difference of FPD-Link and GMSL.

Drone-based applications

Drone Navigation

In GPS/GNSS-denied environments, AI-based navigating plays a crucial role in ensuring precise and reliable drone operation. Low-latency cameras, integrated into multi-sensor fusion systems, support navigation by complementing Inertial Measurement Units (IMU) and Inertial Navigation Systems (INS). By leveraging low-latency, high-resolution image processing, AI-driven systems can detect and respond to obstacles in real time, enabling safe and efficient navigation in complex environments.

Disaster Response with Drones

An automated reconnaissance system delivers real-time aerial data and images to a ground-based platform. This enables disaster response teams to quickly and accurately assess the situation, identify affected areas, and prioritize their actions. Additionally, the system can support long-term environmental monitoring, providing valuable insights into the impact of disasters and the effectiveness of response efforts.

Collision Avoidance

Low-latency cameras featuring a multi-camera setup on board of Unmanned Aerial Vehicles (UAVs). By providing high-resolution camera streams, the system enables real-time surround view for situational awareness. This is particularly critical for aviation, where UAVs operate in complex environments with potential obstacles. Advanced collision avoidance technology enhances safety by detecting and mitigating risks in low-altitude flights, ensuring secure navigation even in challenging conditions.

Unmanned Surface Vehicle (USV) for offshore mission

360° view for offshore maneuvering, generated by an advanced software, which stitches together the video feeds from multiple cameras to create a seamless and panoramic view of the surroundings.

Long Distance Detection on board of UGVs

Multi-camera setup on board of unmanned ground vehicles (UGVs) providing a comprehensive view of the surroundings, allowing military personnel to monitor and respond to potential threats from multiple angles.

Machine Vision Camera Technology

Machine Vision cameras play a crucial role in enabling drones to perceive and interact with their environment, facilitating applications such as aerial surveillance, object detection, mapping, and monitoring. However, the unique constraints of drone platforms pose significant challenges for machine vision camera systems. Each application has specific requirements and demands different technical solutions.

Small size and light weight are essential to minimize the overall payload and ensure efficient drone operation. Additionally, low power consumption is critical to prolong flight times and reduce the need for frequent recharging or battery replacement. Rugged hardware is also necessary to withstand the harsh environmental conditions and physical stresses associated with drone flights.

From a performance perspective, low-latency and high bandwidth are vital for real-time video processing and transmission, enabling drones to respond quickly to changing situations and transmit high-quality video feeds for remote monitoring and analysis.

Embedded Vision Technology

Many drone applications are designed with Computer Vision algorithms on an Embedded Vision system. Those systems benefit from small weight and size, low power consumption and stand out with minimal costs in hardware. The needed image data is often acquired by MIPI CSI-2 sensors and processed by highly effective SoCs. By leveraging the integrated image pipeline, the data can be transferred with low latency and high data rates into the system's memory, without any interaction of the CPU. Although successfully deployed in many systems, the maximum cable length of around o.sm for MIPI cables between camera and processor has restricted the adoption of CSI-2 cameras.

Because many systems require langer distance between processor and camera, FPD-Link III (Fiat Panel Display Link) and GMSL2 (Gigabit Multimedia Serial Link) have seen widespread adoption. Due to their high-speed data transmission capabilities, low latency, and robustness in harsh environments, they are now also transitioning into vision systems for drone-based applications. FPD-Link from Texas Instruments and GMSL from Analog Devices the primary suppliers of this technology. This is often referred to as "range extender" technology. Both represent physical layer standards, where data can be transmitted transparently to the user via coax or shielded twisted pair cables by using integrated SerDes technology.

FPD-Link III and GMSL2

FPD-Link (Flat Panel Display Link) and GMSL (Gigabit Multimedia Serial Link) from Texas Instruments and Analog Devices respectively, are both suitable for intralogistics and offer different benefits.

Alvium camera with FPD-Link or GMSL interface

FPD-Link III

FPD-Link III, an updated version of the Flat Panel Display Link protocol, is an industry-standard high-speed protocol developed by Texas Instruments. It uses LVDS (Low Voltage Differential Signaling) to transmit data at high speeds with low electromagnetic interference

Key features and benefits

- High-speed data transmission: Supports high-resolution 4k video transmission at high speed.
- Forward error correction: Enhances reliability and robustness in the face of signal degradation.
- Electromagnetic interference reduction techniques: Spread spectrum and low swing reduces electromagnetic interference (EMI).

GMSL2

GMSL2 is a high-speed communication protocol developed by Analog Devices. GMSL2 can transmit high-definition video, audio, and control data over a single cable.

Key features and benefits

- High-Speed Data Transmission: Capable of transmitting 4K and 8K video data.
- Long-Range Transmission: Supports long cable lengths, providing a practical advantage in large-scale drone design.
- Robustness to noise: Features robust error detection and correction mechanisms.

What is the difference in the performance of the interface?

Which one fits better to the requirements of an application?

Comparing Speed and Range

FPD-Link III and GMSL2 are designed to support high-speed data transmission, crucial for high-resolution vision applications. While both support 4K data transmission, GMSL2 stands out by even supporting 8K resolution, potentially offering a higher degree of precision in vision tasks.

- FPD-Link III 3,2 Gbit/s
- GMSL2 6,0 Gbit/s

In terms of range, GMSL2 can support longer cable lengths, providing an advantage in large-scale drone design.

- FPD-Link III 10 - 15 m
- GMSL2 15 - 20 m

Comparing Reliability and Noise Resistance

FPD-Link III and GMSL2 include mechanisms for error detection and correction, a key function for maintaining data integrity in defense applications. GMSL2 may give it an edge in the reliability.

Coaxial and STP cables

To connect an FPD-Link III or GMSL-2 camera to a system, either coaxial or STP (shielded twisted pair) cabling can be used. They provide power and a low speed control channel to the camera, as well as a highspeed downstream channel for the image data.

Both technologies come with rugged connectors that are not susceptible to vibrations and motions. Another advantage is that the connectors are also available as IP68 rated versions.

Possible cable lengths
Coaxial cable 10 - 15 m
STP cable 8 - 10 m


Coaxial cable


FAKRA Connector


STP cable


HSD Connector

Coax advantages over STP

- Cables are lighter, less expensive
- Better signal integrity enable longer cables
- Stiffer cables for harsh applications
- Coaxial-based FAKRA connector is widely supported resulting in a broader availability of carrier boards, cables, and connectors.

STP advantages over Coax

- Thinner and more flexible cables
- Can be bent to small bend radii

- ☑ FPD-Link III and GMSL2 are potent technologies for high-speed data transmission in drone applications. The choice between these two depends on the specific needs of the defense application. Especially factors like the required data transmission, transmission pace, and the existing physical setup determine the most appropriate solution.
- ☑ Both GMSL and FPD-Link provide an interesting alternative to overcome the cable length limitation of MIPI CSI-2, by keeping its characteristics and supporting distances beyond 0.5 meters.
- ☑ GMSL2 stands out in integration robustness and electromagnetic interference reduction, cable lengths, and data transmission capacity, while FPD-Link III offers potential benefits in system simplicity.
- ☑ Cameras with STP cables are better suited for dynamic applications such as drone applications with gimbal cameras. Since STP cables usually have more wires available, those can naturally be used to supply the camera with power.
- ☑ Coaxial connections enable single-cable solutions supported by Power over Coax (PoC). Coax cameras are the ideal choice for harsh environments and rough conditions.

Alvium FP3 and Alvium GM2 cameras

Alvium FP3 cameras with FPD-Link III (Flat Panel Display Link) interface and Alvium GM2 Coax cameras with GMSL2 (Gigabit Multi-media Serial Link) have been designed to overcome the limitations of standard CSI-2 cameras.

Within the Alvium platform, Allied Vision is offering a large range of Alvium cameras with either FPD-Link III or GMSL2 interface. There are more than 30 high-quality image sensors to choose from.

The housed Alvuim FP3 and Alvium GM2 cameras come with integrated serializer and rugged connectors: Either coaxial-based FAKRA connectors for coax cables or HSD STP connectors for thin shielded twisted pair cables.

For applications with static cables, Alvium FP3/GM2 cameras are available as Coax models with a FAKRA connector, supporting up to 15 m with FAKRA coaxial cables. For applications with moving cables, Alvium FP3/GM2 STP cameras with an HSD connector and STP (Shielded Twisted Pair) cables are better suited. The thin STP cables permit a tighter bend radius, are more flexible, and support up to 10 m for FP3 and up to 8 m for GM2 models.

Alvium FP3 Coax/STP and Alvium GM2 Coax/STP cameras

The cameras are particularly suitable for use in demanding drone-based defense applications because they address important requirements:

- Full Electromagnetic compatibility (EMC) compliance
- Resistance against shock and vibration
- Fast and low overhead image transmission on embedded systems
- 2 GPIOs (General Purpose Input/Output) on the camera that can be used either via the cable or the separate I/O connector.
- Multi camera friendly
- Deserializer boards available
- Support for single-cable solutions
- Support by Vimba X SDK
- Support for GenICam for CSI-2
- Easy set-up thanks to one driver for various embedded boards

Software and driver

The cameras are tested on NVIDIA® Jetson systems running NVIDIA Jetpack™ 6.2 with our open-source driver. The Alvium CSI-2 camera driver supports Jetson Xavier™ NX, AGX Xavier, Orin™ Nano, Orin NX, AGX Orin systems on module (SoMs) as well as NXP i.MX 8M Plus, AMD Xilinx Zynq UltraScale+ SoCs and Kria SoMs.

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***Non-Disclosure Statement**

Due to the sensitive nature of our work with defense customers, we maintain strict confidentiality regarding customer identities and project specifics. In the following slides, you will find use cases accompanied by brief application descriptions that intentionally omit any military context. Additionally, while we highlight our vision technology, we do not disclose specific model specifications or requirements to protect proprietary information and ensure compliance with our confidentiality agreements.

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