PCI Express – A High-bandwidth Interface for Multi-camera Embedded Systems
• XIMEA quick intro
• Camera manufacturers eco space
• Challenges and requirements to integrate an imager (camera or sensor) into embedded imaging system
• Existing imager interfaces, pros/cons
• PCIe does it all
• Proof “PCIe does it all”: HW scalability and SW transparency
• Invite to visit Summit Technology Showcase with live demo
XIMEA quick intro
XIMEA quick intro

- Versatile camera manufacturer for more than 25 years
- Recognized as an innovator in Machine vision and Imaging markets
- Located in Germany, Slovakia and USA
- 50% standard and 50% custom/OEM products:
  - Sensor resolutions from VGA to 50 Mpix
  - Frame rates up to 3500 fps
  - API/SDK support for variety of operating systems and hosts
  - Multiple interfaces, short/medium/long distances
  - Extremely compact camera arrangements
  - Aggregation of data from multiple imagers into a single cable
Camera Manufacturer Ecospace
Camera Manufacturer Ecospace

Sensor

Camera

System
Camera Manufacturer’s Ultimate Goal

• acquire perfect images and seamlessly deliver it to the processor
• … respecting all prerequisites of a system
• … removing hassles and efforts of integrating a “bare sensor“
• … providing middleware in regards to HW and SW
• … extensive support
Challenges and requirements to integrate an imager into embedded imaging system

- Minimize Latency, Power and CPU overhead
- High bandwidth demands, multiple formats, multiple imagers, and growing …
- Synchronization between imagers, time stamping, metadata
- Minimize effort to integrate a (different) imager or processor, both HW and SW
- Modify or reuse existing setups for new applications
Existing Imager Interfaces
# Existing Camera and Sensor Interfaces

<table>
<thead>
<tr>
<th></th>
<th>LVDS</th>
<th>MIPI CSI-2</th>
<th>USB/GigE</th>
<th>PCIe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>subLVDS</td>
<td>C-PHY</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>mm to cm</td>
<td>mm to m</td>
<td>cm to hm</td>
<td>mm to hm</td>
</tr>
<tr>
<td><strong>BW per lane, Gb/s</strong></td>
<td>0.3 … 3</td>
<td>2.5</td>
<td>0.5 … 10</td>
<td>2.5 … 8</td>
</tr>
<tr>
<td><strong>Number of lanes</strong></td>
<td>1 … 64</td>
<td>1 … 4</td>
<td>1</td>
<td>1 … 16</td>
</tr>
<tr>
<td><strong>Aggregated BW, Gb/s</strong></td>
<td>0.3 … 200</td>
<td>2.5 … 10</td>
<td>0.5 … 10</td>
<td>2.5 … 128</td>
</tr>
</tbody>
</table>
LVDS/subLVDS

- Provided either directly from the sensor or from FPGA in the camera
- Usually not supported by hosts and SoC, thus requires FPGA glue logic on the host side
- Moves complexity from the camera to the host
- Variety of specifications, no standard
- Today’s sensors and FPGAs do not support bandwidth above 1.6 Gb/s
- Low cost
MIPI CSI-2, C-PHY

• Provided directly from the sensor
• Usually supported by SoC
• Deal with sensor settings on a register level
• Lowest cost
USB and GigE

• Versatile camera interface
• Convenient from the host perspective
• Industrial standards **USB3 Vision** and **GigE Vision**
• Several software API/SDKs exist to integrate cameras
• Requires massive SW stacks on the host side
• High latency and CPU overheads
• Power hungry
• Highest cost
• Minimizes latency and CPU overhead
• Seamlessly delivers image data directly to the host memory via Scatter/Gather DMA
• Supports distances from millimeters to hundreds of meters
• Aggregation of multiple imagers into one wire/fiber
• Thin to none SW stack

• Ultimate Camera Interface for Embedded Vision Systems
## Pros and Cons

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<tr>
<th></th>
<th>LVDS subLVDS</th>
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<th>USB/GigE</th>
<th>PCIe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Imager HW overhead</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Imager SW overhead</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Processor HW overhead</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Processor SW overhead</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Multiple imagers</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Latency</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Power</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>
xPlatform – XIMEA PCIe camera platform
xPlatform – XIMEA PCIe camera platform
xiX – XIMEA PCIe camera family

- Resolutions
  VGA … 50 Mpix

- Framerate
  up to 3500 fps @1 Mpix

- PCIe interface
  X1Gen2 … X8Gen3
  5 Gb/s … 64 Gb/s
xiX – XIMEA PCIe camera family

• Variety of form factors housed and board level
• Compact size and low power
Topology of PCIe embedded system
xiSwitch – PCIe Multi-camera aggregation

- Several cameras aggregated into one high bandwidth upstream up to 64 Gbit/s
- Maximum compactness and modularity
xiSwitch – examples

Downstream 8x 10 Gb/s
Upstream 1x 32 Gb/s

Downstream 27x 10 Gb/s
Upstream 1x 64 Gb/s

Downstream 2x 64 Gb/s
2x 32 Gb/s, 5x USB 3.0
Upstream 1x 64 Gb/s
xPlatform – example 360° rig

- 8x FullHD cameras IMX174 each streaming at 165 fps
- All aggregated into one x4G3 32 Gb/s fiber cable
- Up to 100 m cable length
xPlatform – embedded example NVIDIA TX1/TX2

- 2x FullHD cameras IMX174
- 2x 9 Mpix cameras IMX255
- All streaming directly to TX1/TX2 memory

Welcome to Summit Technology Showcase to see Live demo
xPlatform Resources

- xiX infographics

- xiX brochure

- xiSwitch infographics

- XIMEA Embedded vision home
  https://www.ximea.com/embedded-vision/systems
Thank you for your attention

Questions?